GREEN INFRASTRUCTURE IMPLEMENTATION AND EFFICIENCY

ENV.B.2/SER/2010/0059

FINAL REPORT

22 December 2011

Institute for European Environmental Policy

Together with:
Ecologic Institute, Germany
GHK, United Kingdom
Syzygy, Netherlands
TAU Consultora Ambiental, S.L, Spain
University of Antwerp, Belgium
VITO, Belgium

This report is submitted by:

Institute for European Environmental Policy (IEEP)

London office:
15 Queen Anne's Gate
London SW1H 9BU, UK
United Kingdom

Brussels Office:
Quai au Foin, 55
Hooikaai 55
1000 Brussels
Belgium

Contacts:

Graham Tucker (Project director)
Direct tel.: +44 (0)20 7340 2688
Fax: +44 (0)20 7799 2600
Email: gtucker@ieep.eu

Leonardo Mazza (Project coordinator)
Direct tel.: +32 (0) 2 738 74 77
Fax: +32 (0)2 732 40 04
Email: lmazza@ieep.eu

The Institute for European Environmental Policy (IEEP) is an independent institute with its own research programmes. Based in London and Brussels, the Institute's major focus is the development, implementation and evaluation of EU policies of environmental significance, including agriculture, biodiversity, climate and energy, fisheries, industrial policy, regional development and transport, water and waste.

Citation and disclaimer:

Recommended citation:
Mazza L., Bennett G., De Nocker L., Gantioler S., Losarcos L., Margerison C., Kaphengst T., McConville A., Rayment M., ten Brink P., Tucker G., van Diggelen R. 2011. ***Green Infrastructure Implementation and Efficiency***. Final report for the European Commission, DG Environment on Contract ENV.B.2/SER/2010/0059. Institute for European Environmental Policy, Brussels and London.

Contributing Authors:
Laura Baroni (IEEP), Samuela Bassi (IEEP), Marcelline Bonneau (GHK Consulting Ltd), Steven Broekx (VITO), Steph Charalambous (GHK), Eoghan Daly (GHK), McKenna Davis (Ecologic Institute), Sophie Herbert (Ecologic Institute), Aertsens Joris (VITO), Marianne Kettunen (IEEP), Bettina Kretschmer (IEEP), Inge Liekens (VITO), Indrani Lutchman (IEEP), Keti Medarova (IEEP), Stephanie Newman (IEEP), Mavourneen Pieterse (GHK), Jana Polakova (IEEP), Laura Romero Vaquero (TAU Consultora Ambiental), Sirini Withana (IEEP).

The authors would like to acknowledge the useful inputs and contributions from:
Evdokia Achilleos (DG ENV, EC), Viviane André (DG ENV, EC), Pedro Ivo Arriegas (Institute for the Conservation of Nature and Biodiversity, Portugal), Estelle Bailey (Montgomeryshire Wildlife Trust), Castell Carles (Barcelona Provincial Council), Irene Bouwma (Alterra), Christine Estreguil (JRC), Marco Fritz (DG ENV, EC), Rafael Hidalgo (Ministry of Environment, Rural and Marine of Spain), Ruta Landgrebe-Trinkunaite (Ecologic Institute), Alberto Leboreiro Amaro (Autonomous Community of Madrid), Sandra Naumann (Ecologic Insitute), Carlos Peña (Spanish Ministry of Environment and Rural and Marine Affairs), Selma Pena (Centro de Estudos de Arquitectura Paisagista "Prof.Caldeira Cabral"), Vaiva Ramanauskiene (Environmental Centre for Administration and Technology), Bocquet Renaud (Leefmilieu Brussel (BIM) - Bruxelles Environnement (IBGE)), Dominique Richard (ETC/BD), Monteiro Sou Rosário (National Commission of REN (CNREN), Ministry of Environment and Territorial planning), Philipp Schmidt-Thome (Geological Survey of Finland), Frederik Schutyser (EEA), Mario Silva (Institute for the Conservation of Nature and Biodiversity, Portugal),Balázs Sipos (Ministry of Rural Development, Hungary), Rijk van Oostenbrugge (Netherlands Environmental Assessment Agency), Dr. Erik van Zadelhoff (Ministry of Economic Affairs, Agriculture and Innovation, The Netherlands), Fernando Molina Vázquez (Autonomous Community of Andalucía), Juan Antonio Martín Ventura (Cantabrian Basin Administration, Ministry of Environment and Rural and Marine Affairs, Spain), Marcus Zisenis (ETC/BD), Vija Znotina (Faculty of Biology of the University of Latvia), Ágnes Zólyomi (CEEweb for Biodiversity).

TABLE OF CONTENTS

LIST OF ACRONYMS

BAS	Business as Usual
CAP	Common Agricultural Policy
CBD	Convention on Biodiversity
CSF	Common Strategic Framework (ERDF, ESF, Cohesion, EAFRD, EMFF)
Defra	Department for Environment, Food and Rural Affairs
DG ENV	Directorate-General for the Environment (EC)
EAFRD	European Agricultural Fund for Rural Development
ERDF	European Regional Development Fund
EC	European Commission
EEA	European Environment Agency
EFTEC	Economics for the Environment Consultancy
EIA	Environmental Impact Assessment
ELD	Environmental Liability Directive
EMFF	European Marine and Fisheries Fund
ERDF	European Regional Development Fund
ETC/BD	European Topic Centre on Biological Diversity
EU	European Union
EU-12	The 12 Member States of the EU which have joined since 2004.
EU-15	The 15 Member States of the EU prior to the 2004 enlargement.
EU-27	All 27 Member States of the European Union
ESPON	European Observation Network: Territorial Development & Cohesion
ESDP	European Spatial Development Perspective
ESF	European Social Fund
FSC	Forest Stewardship Council
GAEC	Good Agriculture and Environmental Condition
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIS	Geographical Information Systems
HNV	High Nature Value
ICZM	Integrated Coastal Zone Management
JRC	Joint Research Centre
LEP	Landscape Ecological Plan
LIFE+	EU Financial Instrument for the Environment
MEA	Millennium Ecosystem Assessment
MFF	Multi-annual Financial Framework
MS	Member State
MSC	Marine Stewardship Council
NGO	Non-Governmental Organisation
PES	Payments for Ecosystem Services
RBMPs	River Basin Management Plans
RDPs	Rural Development Programmes
RED	Renewable Energy Directive
SACs	Special Areas of Conservation
SEA	Strategic Environmental Assessment
SWOT	Strength, Weakness, Opportunity, Threat
TEN-T	The Trans-European Transport Networks
TEN-E	The Trans-European Energy Networks
TEEB	The Economics of Ecosystems and Biodiversity
UK	United Kingdom
US	United States of America
WFD	Water Framework Directive

EXECUTIVE SUMMARY

Key messages from the study

Widespread losses of biodiversity and associated ecosystem services are continuing in the EU, with associated detrimental economic and social impacts. This is in part due to the loss and fragmentation of Europe's existing green infrastructure which (as further defined below), includes core areas of important ecosystems, land that is being sustainably managed for multiple uses, urban green areas and features that connect these elements across the landscape. These impacts are primarily the result of widespread land use change and intensification, urbanisation and other developments. To address these impacts the EU intends to develop a Green Infrastructure Strategy that will contribute to a wide range of EU economic, environmental and social objectives, including implementing the EU Biodiversity Strategy (and thereby meet CBD obligations). By catalysing the transition towards smart, sustainable and inclusive growth, it will support the implementation of Europe 2020. It can in particular be expected to make a major contribution to achieving a resource efficient, climate resilient and low carbon economy.

However, to achieve significant green infrastructure benefits, significant policy changes are required across many sectors and at multiple scales of governance. This study has therefore highlighted the crucial role that an EU Green Infrastructure Strategy could play in delivering these benefits through increased policy coherence. In particular it is suggested that the EU Strategy should:

1. Increase practical understanding of the green infrastructure concept and awareness of the observed beneficial impacts of green infrastructure policy interventions with respect to biodiversity and associated ecosystem services, and their resulting economic, social and health benefits.

2. Support the new EU Biodiversity Strategy, by promoting the new restoration agenda, but also contribute to a wider range of policy objectives (eg relating to flood control, carbon storage, energy efficiency, human health) that can be delivered through an enhanced and better managed green infrastructure, many of which can be achieved more cost-effectively than relying on technology-based solutions, especially when costs are considered over the whole life cycle.

3. Provide leadership and guidance for Member States, in particular with regard to the use and adjustment of existing regulations and funding instruments in an appropriate and imaginative way. It should seize existing opportunities for promoting and supporting the green infrastructure approach across a wider range of policy areas, such as in regional policy investments (eg to deliver ecosystem based climate adaptation, water purification, flood control and risk prevention), cohesion policy expenditure (which needs to be more systematically proofed for its impacts on climate and biodiversity), the future European Marine and Fisheries Fund, the future Connecting Europe Facility, the Common Agricultural Policy (CAP), especially regarding current Pillar 1 reform proposals and the better use of agri-environment measures, and the better use of strategic environmental assessments (SEA), project-level environmental impact assessments (EIA) and spatial planning in protecting and enhancing green infrastructure.

4. Support the systematic consideration of the services delivered by ecosystems in policy-making at all governance levels, especially where there are potential benefits for implementing a green infrastructure approach.

5. Promote more research into the benefits of green infrastructure (including health benefits in urban and peri-urban areas) and better monitoring and reporting of the effectiveness of related policy initiatives. Horizon 2020 should prioritise research on green infrastructure to raise awareness of and help harness the benefits green infrastructure can provide across a wide range of policy areas.

6. Encourage European and national institutions to take further action to implement the principle of "measuring to manage", to ensure a better and regular stock-taking of green infrastructure elements at multiple scales. The Strategy should recognise that mapping exercises and the use of appropriate indicators to measure the variety of benefits ecosystems and green infrastructure interventions generate is key to developing a good understanding of the cost-effectiveness of green infrastructure policy interventions and the full costs of green infrastructure losses. The Commission needs to promote a clear coordinated strategy with regard to mapping, which would help ensure that green infrastructure investments are channelled where they are most cost-effective. This could also help raise private funds to support green infrastructure initiatives, including through payment for ecosystem service schemes (PES).

7. Emphasise the strong evidence that one of the most reliable and cost-effective ways of maintaining biodiversity and ensuring continued provision of ecosystem services is the conservation and enhancement of core areas (ie large and healthy ecosystems including for example sites designated as Natura 2000). In some cases these areas therefore need to be increased, more coherent and better managed. However, the Strategy should also recognise that the health and resilience of core areas depends on the sustainable management and enhancement of key green infrastructure elements in the wider landscape.

8. Encourage the strong protection, and where feasible, expansion of urban green infrastructure, because evidence shows that it delivers a wide range of benefits (especially relating to the quality of life) that outweigh costs, even when considering opportunity costs.

I. Context and Aim of the Project

The January 2010 Commission Communication *Options for an EU vision and target for biodiversity beyond 2010* explicitly called for the development of and investment in 'green infrastructure', to support biodiversity and ecosystems. It calls in particular for the restoration of ecosystems insofar as possible to strengthen their resilience and sustain the key ecosystem services they provide, while also achieving conservation objectives and enabling Member States to adapt to climate change. To address this and to contribute to other objectives the EU intends to develop a Green Infrastructure Strategy. To support the development of the Strategy DG Environment launched, in late 2010, the present study, as well as three other studies[1] relating to green infrastructure that have been undertaken in parallel.

This study's aim has been to assess the effectiveness and efficiency of policy initiatives to support green infrastructure across the EU in terms of biodiversity and broader ecosystem service benefits. It is envisaged that the results will support the assessment of measures that could be part of the future EU Green Infrastructure Strategy.

As the interpretation of what green infrastructure varies considerably it was necessary to define its meaning, for this and the related studies. After cross-study consultations the following definition was adopted:

"Green infrastructure is the network of natural and semi-natural areas, features and green spaces in rural and urban, terrestrial, freshwater, coastal and marine areas, which together enhance ecosystem health and resilience, contribute to biodiversity conservation and benefit human populations through the maintenance and enhancement of ecosystem services. Green infrastructure can be strengthened through strategic and co-ordinated initiatives that focus on maintaining, restoring, improving and connecting existing areas and features as well as creating new areas and features."[2]

While it has the drawback of being very broad, the definition has the advantage of making clear that green infrastructure is not only a nature conservation matter: all sectors influence green infrastructure and stand to gain from it. Therefore the conservation of protected areas is not sufficient for the maintenance of biodiversity and associated ecosystem services. Green infrastructure needs to be maintained and restored through proactive, strategic and coherent actions across all policies that influence the use of the land and sea.

The following six green infrastructure elements are commonly recognised and therefore were the focus of the study:

[1] Design, Implementation and Cost Elements of Green Infrastructure projects (led by Ecologic Institute); Costs, benefits and climate proofing of natural water retention measures (led by Stella Consulting); and Assessment of the potential of ecosystem-based approaches to climate change adaptation and mitigation in Europe (led by Ecologic Institute).

[2] Naumann, Sandra, McKenna Davis, Timo Kaphengst, Mav Pieterse and Matt Rayment (2011): Design, implementation and cost elements of Green Infrastructure projects. Final report

- **Core areas** (ie large areas of healthy and functioning ecosystems)
- **Restoration zones** (ie new areas of habitat for specific species or restored ecosystems for service provision)
- **Sustainable use/Ecosystem service zones** (ie areas that maintain or improve ecological quality through sustainable economic land uses).
- **Green urban and peri-urban areas** (eg parks, gardens, grassy verges and green roofs)
- **Natural connectivity features** (eg hedgerows and riparian river vegetation).
- **Artificial connectivity features** (ie features assist species movement, such as green bridges and eco-ducts).

This study set out to expand the knowledge base on green infrastructure initiatives in a number of ways. Firstly, the main existing EU policy measures that can help to support green infrastructure initiatives were identified and outlined. Extensive information was also collated on the variety of green infrastructure initiatives and their implementation in all EU Member States, and more detailed data obtained through seven in-depth case analyses. This evidence was then used to carry out an assessment of the contribution that green infrastructure can make to increasing the resilience of ecosystems and the provision of ecosystem services. As far as possible it attempted to quantify impacts on ecosystems and their services, and resulting health and socio-economic benefits. These benefits were compared with costs where feasible to provide an approximate assessment of the cost-effectiveness of the initiatives. These assessments provided the basis for the development and evaluation of the potential benefits of four different EU policy scenarios ranging from a business as usual scenario (no new policy measures) to progressively more ambitious options including integration of green infrastructure into sectoral policies and legislative measures. The impacts associated with the implementation of each one of those options were assessed.

II. Current Actions / Policies on Green Infrastructure

Initiatives that feature the main characteristics of green infrastructure are being developed and applied in all Member States, although they are not always identified as such. From an examination of about 100 initiatives it is obvious that a variety of approaches are being taken to maintaining and restoring green infrastructure. Initiatives have been developed by a variety of actors (eg governments, NGOs and businesses) and at various scales ranging from local to international. Some target a variety of land uses and stakeholders, whilst others are highly focused. While it is generally possible to identify a key tool or policy instrument around which green infrastructure initiatives have been structured, a wide set of implementing measures are almost always used, which may include strategies and action plans, information gathering and mapping, regulation of land use and planning, economic/market instruments, public investments, communication and advice and governance reform.

In general, existing programmes that were found to be closest in concept to green infrastructure are the ecological network initiatives, although they tend to focus on biodiversity issues and emphasise the importance of connectivity in increasing ecosystem resilience. There are also numerous urban green space initiatives that pursue the broader green infrastructure concept of the joint delivery of biodiversity and ecosystem services.

The analysis of green infrastructure initiatives in each Member State revealed seven major 'themes' that together provide a good overview of the main types of areas where green infrastructure approaches and initiatives have been adopted, promoted and applied in EU Member States. For each one of the following seven themes, three relevant initiatives were identified and studied in depth:

- **Ecological networks for biodiversity, connectivity and ecological coherence** (eg the National Ecological Network in the Netherlands)
- **Multifunctional use of farmland and forests** (eg the Pumlumon Project in Wales)
- **Multifunctional use of coastal areas**, (eg the protection and management of coastal habitats in Latvia)
- **Freshwater and wetlands management and restoration** (eg the Sigma Plan in the Scheldt Estuary, Belgium)
- **Urban green infrastructure** (eg the regional spatial plan for Lisbon, Portugal)
- **Grey infrastructure mitigation**, (eg wildlife passages in Austria)
- **Green infrastructure mapping for planning** (eg the SITxell territorial information system developed by Barcelona Province, Spain).

The results from the study relating to the benefits of using a green infrastructure approach show that maintaining and enhancing green infrastructure provides a wide range of benefits both to humans and biodiversity, which support a wide range of policy objectives. On the other hand, many EU policies, whose primary purpose is not the delivery of environmental objectives, affect green infrastructure in multiple ways. The future stock and state (quality) of Europe's green infrastructure will therefore heavily depend on them. This is particularly true for policies that lead to land-use intensification and fragmentation, such as some agricultural and transport policies. About forty EU policies and instruments were identified as relevant to the implementation of a green infrastructure approach with opportunities being identified in policy areas as diverse as agricultural policy, forestry policy, biodiversity and nature policy, water policy, soil policy, climate change policy, cohesion policy, transport and energy policy, resource efficiency policy, marine and coastal zones policies, health policy, research policy in the legislations governing impact assessment and damage prevention and remediation[3].

III. Measuring to Manage: Green Infrastructure Related Indicators

Many green infrastructure initiatives have an important aim of increasing the resilience of ecosystems, and populations of their associated species of conservation concern, to pressures, such as land use change and intensification, fragmentation and climate change. In this respect the study considered resilience to be "***the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organisation, and the capacity to adapt to stress and change".*** A further aim of increasing resilience through green infrastructure initiatives is the maintenance of ecosystem services and their benefits that would otherwise be reduced through ecosystem degradation.

[3] See IEEP Manual of European Environmental Policy: www.europeanenvironmentalpolicy.eu/

It is very difficult to assess the likely impacts of green infrastructure on ecosystem resilience directly, and therefore this study firstly considered which ecosystem attributes increase resilience. It then went on to consider what indicators could be used to measure and monitor the impacts of green infrastructure initiatives on these ecosystem resilience related attributes and, in turn, the provision of related ecosystem services (eg carbon sequestration, water storage).

There is good evidence that ecosystem resilience increases with habitat area, the population sizes of its component species (especially those of functional importance), functional complexity of species communities, and the overall ecological condition of the ecosystem (eg integrity of ecosystem processes). Species richness sometimes increases resilience but functional complexity often seems to be more important. The extent to which species are able to move between habitat patches (especially core areas), in other words their functional connectivity, is also often important. However, functional needs are species-specific and context-specific, and therefore increasing connectivity does not necessarily increase ecosystem resilience. In fact there are risks with increasing connectivity, such as reducing genetic diversity and facilitating the spread of alien invasive species. In general maintaining existing connectivity is beneficial (and cost-effective, as discussed below). But increasing functional connectivity is often difficult, unreliable and costly, and therefore care should be taken to ensure that such measures are justified and efficient.

The study reviewed a number of biodiversity indicators (including those selected for the assessment of the EU's performance with respect to its biodiversity target). This revealed that there is no single indicator at present that measures ecosystem resilience adequately. Instead it is suggested that a "basket" of indicators, is used to monitor key resilience related attributes. In some cases, existing indicators can be used to do this, but adequate data are lacking for some ecosystems and regions. The linkage between ecosystem resilience and ecosystem service provision needs to be better understood before ecosystem resilience indicators can be used to indirectly assess impacts on ecosystem services. The impacts of green infrastructure initiatives on ecosystem services therefore need to be measured directly. However, few ecosystem service indicators are widely or systematically monitored in a standardised way. Moreover, such indicators are often difficult to scale up to national or regional policy level.

IV. Ecosystem Resilience and Biodiversity Benefits of Green Infrastructure

This study reviewed evidence of the impacts of green infrastructure initiatives on biodiversity, including with respect to the EU's objective of halting overall biodiversity loss and more specific priorities relating to threatened habitats and species. This reaffirmed the potential benefits for biodiversity that could be realised in the EU through green infrastructure initiatives and the development and implementation of a Green Infrastructure Strategy. However, it is apparent, that some green infrastructure elements and approaches are more effective and efficient than others. Therefore their justification and prioritisation should be carefully considered. In this respect, it is suggested that:

- A high priority should be given to ensuring **core areas** form a coherent network that is adequate to achieve the EU's environmental targets, because such areas clearly provide substantial long-term, and robust biodiversity and ecosystem benefits in a cost-effective way. Such core area networks should extend beyond Natura 2000 sites to include other areas that together provide areas of habitat that are sufficiently large and, where necessary, functionally connected to maintain viable and resilient populations of targeted species, habitats and key ecosystem processes and services.

- **Ecosystem restoration** should be promoted more widely, as it can contribute to the enhancement of core area networks, for example by increasing the size of sites such so that they are able to support resilient ecosystems and viable populations of important species. However, restoration efforts should not be at the expense of existing viable ecosystems and species populations.
- There is good evidence that biodiversity in the wider environment benefits from intentional management as **sustainable use areas,** and such actions may also further support the resilience of core area networks, by increasing the ability of species to exist in and move through the wider countryside, which in itself provides important cultural ecosystem services.
- **Urban green infrastructure** generally provides habitats for generalist and adaptable species, but these are of high cultural importance, and can support other important ecosystem functions. Furthermore, some urban habitats, such as some post-industrial sites, can support rare species that merit protection through urban green infrastructure initiatives.
- **Natural connectivity features** provide habitats for species and ecosystems benefits in themselves, as well as connectivity functions. A high priority should therefore be given to protecting, enhancing, restoring and appropriately managing such features, especially where they have been shown to have important habitat and/or connectivity functions for species of EU and national conservation importance. However, there is little evidence that the **creation** of new specific connectivity features (especially narrow linear corridors) significantly mitigates the impacts of habitat fragmentation on species of conservation concern, and therefore such measures may be ineffective and in inefficient in terms of meeting the EU's priority conservation targets.
- Some **artificial connectivity features** such as fish passes provide important biodiversity benefits (including for some threatened species) whilst tunnels for amphibians and small-moderate sized mammals can provide cost-effective mitigation for more widespread species. However, there appears to be little published evidence that expensive habitat bridges over roads and railways provide significant or cost-effective population level benefits for species of high conservation importance. Therefore the appropriateness of such mitigation measures should be carefully considered individually (according to their specific context and ecological needs), especially where they are publically funded.

V. Ecosystem Services Benefits from Green Infrastructure

Healthy ecosystems provide a stream of benefits to society, such as the provision of natural resources (eg maintenance of soil fertility or contribution of pollination to production), water management (eg, water supply and quality, flood management), climate regulation and adaptation (eg temperature control, carbon storage and sequestration) or health and well-being (eg increased air quality, noise abatement and accessibility for recreation).

However, the quality and quantity of these benefits is influenced by the ecosystem composition and dynamics, and determined by the diversity and structure of habitats, species and genetic resources, as well as coherence and connectivity. The loss or degradation of ecosystem components can therefore lead to changes in the capacity of an ecosystem to supply a range of functions. Consequently, the promotion of green infrastructure is clearly important, not only for the conservation of the intrinsic value of biodiversity, but also for the benefits that it provides to the economy and society.

Drawing on recent assessments for the European Commission, this study reaffirmed the key role that is played by core areas (including the Natura 2000 network), in biodiversity conservation and the provision of a range of economic and social benefits. There is also evidence that complementing core areas with sustainable use zones can increase the resilience of ecosystems and provisioning services, thereby enhancing long-term investment and employment benefits. Green urban areas also attract investment and employment, facilitate adaptation to climate change (eg by local alleviation of high temperatures) and have beneficial impacts on human health and well-being. Green infrastructure has also been shown to enhance neighbourhood attractiveness in urban areas, with positive effects on property values, investment and employment opportunities.

The review of available literature on potential green infrastructure benefits revealed that the level of information available on monetary and quantitative impacts varies according to the services and elements considered. Although at least some data are available for protected areas, urban areas and the provision of services such as flood management and climate mitigation and adaptation, information on the benefits of natural and artificial connectivity features is much more limited.

VI. Cost-effectiveness of Different Green Infrastructure Elements and Added Value of Integrated Approaches

Although some studies provide insights into the costs and benefits provided by green infrastructure, comprehensive evaluations of the social rate of return of green infrastructure investments are rare. While the possibility of transferring values means that some conclusions may be drawn on the cost-effectiveness of green infrastructure these are generally only indicative. For a wide variety of green infrastructure types and locations, it has been demonstrated that the benefits can be substantial, often as large as those from competing land-use, and that they can often outweigh the costs for green infrastructure development. The evidence however shows a wide range of costs and benefits, pointing to the importance of factors such as type of green infrastructure initiative and local conditions. Larger core areas appear to provide stronger returns on investment than other elements for both the protection of habitats and species and ecosystem services.

The cost-effectiveness of restoration areas is to a large degree dependent on long-term estimates of pay-back, which tend to be difficult to predict. Nevertheless, the failure to see potential market opportunities in ecosystem service provision from conservation and restoration activities reflects in a poor measurement of the ecosystem service benefits from such initiatives. Still, restoration zones have proven potentially cost-effective, particularly where coupled with direct use and cultural values, and have demonstrated success in delivering conservation objectives. Attention is required to maximise the multi-functional use as a means of mitigating and financing the high costs of investment.

Green urban areas have been widely found to have high cost-benefit ratios, despite high opportunity costs. This is largely due to the large number of beneficiaries in densely populated areas, with the main benefits derived from direct use values and significant positive impacts on human health and well-being.

The high costs of restoration or creation of natural connectivity features, especially through large-scale initiatives such as inter-regional ecological corridors, make their cost-effectiveness uncertain in biodiversity terms. However, a greater share of benefits may arise from cultural or direct uses as opposed to their ecological value.

VII. Policy Options for Green Infrastructure

The potential impacts of four packages of policy options for the future implementation of a green infrastructure approach at EU level were investigated by this study. Each policy option package was developed for this study and are incremental and additive rather than mutually exclusive (ie option 2 = 1+2 and so forth).

Option 1, the "**Business as usual**" scenario, assumes no additional measures are taken to promote green infrastructure at an EU level and primarily relies on Member States' own initiatives. Based on a policy audit, it assumes that green infrastructure is only significantly addressed in a limited number of EU policy areas. Some substantial initiatives are taken by Member States, but these are typically in an uncoordinated and piecemeal manner.

O**ption 2**, is a scenario of "**maximising existing approaches**" through measures that aim to realise the full potential of green infrastructure under current EU legal instruments and policies. In addition, a core group of pro-active countries steer efforts towards a better integration and use of green infrastructure within the framework of the Open Method of Coordination. Additional activities include the development of an EU spatial planning toolkit for better integration of green infrastructure in spatial and regional planning, sector-specific guidance on green infrastructure integration/implementation and the setting up of an Information Gateway for European green infrastructure. All these changes are supported by an increase in funding for green infrastructure within existing funding instruments and technical assistance to ensure a good uptake of available funding

Option 3 is a "**full integration in EU policies**" scenario in which, in addition to the measures foreseen in option 2, wider integration of green infrastructure occurs in community policies through key amendments to financial and legal instruments. The EU policies that are revised/ amended include the CAP, Cohesion Policy, Common Fisheries Policy (CFP), and policies relating to transport and energy infrastructure. The need to implement green infrastructure is also reflected in the on-going revision of the EIA Directive and the 2016 revision of the SEA Directive and the next revision of the Regulation on environmental economic accounts. Harmonised maps of green infrastructure, that allow a more efficient allocation of funds and support biodiversity and climate proofing efforts are also produced.

Option 4, involves an Green Infrastructure Strategy that calls for a "**comprehensive, dedicated EU legal instrument**". It includes measures under previous options, but would involve a *Framework Directive for the Conservation and Restoration of Europe's Green Infrastructure,* which explicitly establishes new objectives, binding targets and dedicated funding instruments. Additionally Option 4 introduces an EU TEN-G fund, an EU-wide green infrastructure offset scheme and a European payment for ecosystem services system.

VIII. Assessment of the Four Policy Options for Green Infrastructure

Drawing from this study's review of the known costs and benefits of green infrastructure initiatives, each one of the four options was assessed in terms of its expected potential environmental, social and economic impacts in 2030, as well as its political feasibility, acceptability and coherence. The environmental situation in mid-2011 was used as a reference point against which the impacts of all options were assessed. Table 1 provides an overview of the expected impacts of each option.

Overall, option 3 seems to be the one which has the potential, IF properly implemented, to deliver substantial environmental, economic and social benefits most efficiently and with acceptable and reasonably certain costs. To be cost-effective, an EU Strategy on green infrastructure will need to reliably achieve practical impacts, but this is not guaranteed under option 2. However, the additional measures in option 3 complement those in option 2 and mutually reinforce each other, significantly increasing the effectiveness of the policy package as a whole, especially regarding the conservation of existing green infrastructure elements across the wider landscape. The benefits from green infrastructure implementation under option 3 results in measurable improvements in biodiversity and ecosystem services, in particular in the area of regulating services and human health. This results in cost savings that are proportionate to the additional financial means that have to be made available for the implementation of this option and some expected additional opportunity costs.

Option 4 is arguably the most coherent option and could probably deliver the highest returns, especially in terms of biodiversity benefits. While it would therefore be the most effective in meeting potential green infrastructure related objectives and other EU targets, these achievements would probably come at quite a high cost. The development of a new Directive would also be expected to result in political and practical challenges, and its enforcement would be problematical, not least because of the current difficulties of defining and measuring green infrastructure. It is clear that the Option 4 measures of comprehensive offsetting of residual impacts on green infrastructure and the development of schemes that provide payments for ecosystems services would provide substantial benefits. However, there is uncertainty over how these measures may be established and how effectively they would be implemented, with or without a supporting EU Directive. This uncertainty over the practicality and political acceptability of a dedicated green infrastructure Directive, as well its expected high costs and probable long development time, means that Option 4 is difficult to justify at this stage. Instead it would seem prudent to reconsider it when more experience has been gained from better implementing other green infrastructure policy measures.

Table 1: Synthesis: overview of impacts associated with implementation of options 1-4

Key: Upwards arrows indicate a beneficial change with respect to current conditions. Downward arrows indicate a detrimental change. Estimated magnitude of change, ↗↗↗↗↗ = Very high (eg >100%), ↗↗↗↗ = High (eg 50-100%), ↗↗↗ = Moderate change (eg 20-50%), ↗↗= Small change (eg 10-20%), ↗ = Minor change (eg <10%).

	Reference Point	**Option 1 -** *Baseline*	**Option 2**	**Option 3**	**Option 4**
General Issues					
Addressing the problem/challenge - biodiversity & ESS loss	Not sufficient. Loss ongoing (with some exceptions e.g. N2K)	↘↘	↘	↗	↗↗
Environmental Issues (synthesis)					
Biodiversity & habitats	Significant biodiversity benefits from existing GI	↘↘	↘	↗	↗↗↗
Overall coherence and resilience	Limited connectivity undermining effective coherence and reduce resilience	↘↘	↘↘	↗	↗↗
Provision of other environmental benefits (water and climate)	Significant range of very important benefits (provisioning, regulating, cultural and supporting services)	↘↘	↗	↗↗	↗↗↗
Economic Issues					
Administrative costs (at EU and MS level)	Core area (N2K): 5.8bn/year Other areas un-estimated tbc	↘	↘	↘↘	↘↘↘
Financial costs (one-off)		→ of action ↘↘↘ of non-action	↘↘	↘↘↘	↘↘↘↘
Financial costs (recurrent)		→ of action ↘↘↘↘ of non-action	↘	↘↘	↘↘↘
Opportunity costs		↘	↘	↘↘↘	↘↘↘↘
Social Issues					
Number/quality of jobs; economic activity generated	GI and its services an important foundation for the economy and livelihoods	→	↗	↗↗	↗↗
Health benefits/ quality of life	Important benefits	↘↘	↘↘	↗	↗↗
Recreation & Tourism	Important benefits	↘	↘	↗↗	↗↗
Other issues: Good governance / Practicability and Enforceability					
Practicability	n/a	Unchanged. →	↗↗	↗	↘
Enforceability	n/a	Unchanged. →	↘	↗↗	↘
Acceptability	Some lack of coherence; important public goods losses	Limited ↘	↗↗↗	↗	↗
Clarity, consistency, understandability	Insufficient integration and 'joined up thinking'	Lacking ↘	↘	↗↗	↗↗↗↗

IX. Recommendations

This study has reaffirmed the potential benefits for biodiversity and ecosystem services that could be provided through the development and implementation of an EU Green Infrastructure Strategy. However, the study also identifies a number of conditions that need to be fulfilled if these are to be realised. To generate understanding and support the Strategy will need to clarify and define the green infrastructure concept in more practical terms, and provide a clear vision for Europe's green infrastructure as well as carefully considered practical and realistic objectives and measures. Priorities relating to the maintenance and expansion of green infrastructure elements will need to be based on systematic consideration of the effectiveness of the different elements in delivering biodiversity and ecosystem service benefits and contributing to overall coherence and resilience.

The assessment of the options clearly suggests that, given the distribution of competences between the EU and the Member States, the success of a whole range of recommended changes, in particular those included under option 2, strongly depends on Member States pro-activeness and interest in promoting green infrastructure related measures and approaches. One of the important roles of the EU in the context of green infrastructure implementation is therefore one of support to willing Member States in developing green infrastructure policies and measures, including in areas in which the EU has only limited competence. At the same time, there is still a wide scope for the further integration of green infrastructure across EU policies and within specific instruments implementing EU policies.

For EU's Green Infrastructure Strategy to be fully implemented, it will be necessary to ensure that Member States make full use of **European sources of funding for investments in green infrastructure** whenever this appears an appropriate way to pursue a wide range of policy objectives. It will be important for the Common Strategic Frameworks to translate green infrastructure related objectives into an investment priority including in key actions and focus areas for green infrastructure. Proper coordination and targeting of spending across the different EU funding instruments should be ensured to amplify synergies and avoid duplications. The mainstreaming of green infrastructure under the different funding instruments requires that appropriate actions are undertaken depending on the specific rationale and intervention logic of each instrument.

In the area of **regional policy** green infrastructure is made a priority under the new thematic objectives of the Common Strategic Framework (CSF) funds including Cohesion Policy. This requires two parallel steps, which are mutually reinforcing. Firstly, step up investment in green infrastructure by increasing the share of expenditure allocated under the European Regional Development Fund (ERDF) and Cohesion Fund. The European Social Fund (ESF) should also be used to support awareness raising and capacity building of both managing authorities and beneficiaries. Secondly, ensure Cohesion Policy expenditure is effectively climate and biodiversity proofed. There is also a need for increased and better coordinated monitoring of the impacts of green infrastructure investments on ecosystem services, and mapping ecosystem inter-relations with economic and social systems. This would form an important evidence base and tool for helping design and implement more cost effective measures.

In the area of **transport and energy policy,** the need to better take into account the requirement to preserve and enhance Europe's green infrastructure should fully reflect in the future provisions governing the functioning of the Connecting Europe Facility. In particular, all project applications should be biodiversity and climate proofed and the EU share of co-financing should be variable depending on whether or not applicants for funding add to their project proposal a concrete plan to support the green infrastructure in close proximity to the proposed development.

In the **CAP**, the tools for green infrastructure overall seem to be there and implementation is key. Some aspects of their implementation can certainly be further focused and strengthened both within the CAP Pillar I and the CAP Pillar II. Under the CAP Pillar II (rural development) for example, the mandatory character of the agri-environmental measure and minimum spend requirements relating to them should be maintained, while the focus on habitat restoration in agri-environment measures could be strengthened. The proposed mandatory Pillar 1 greening measures (especially the provision of ecological focus areas) could significantly expand green infrastructure elements in the farmed landscape, and could be further supported by new mandatory GAEC standards explicitly relating to green infrastructure.

In the area of **marine and coastal zone policy,** the future European Marine and Fisheries Fund (EMFF) should support measures relying on green infrastructure, including restoration activities, to meet the objectives of the Marine Strategy Framework Directive (MSFD), in particular achieving good environmental status by 2020. Should the MSFD be revised, this should be used as an opportunity to include green infrastructure (actions) more explicitly and clarify what 'green infrastructure' is in the context of the marine environment. The revised Integrated Coastal Zone Management (ICZM) recommendations should strongly encourage Member States to include in their national Strategies for integrated coastal zone's management measures for the identification and protection of key green infrastructure and to identify restoration areas in view of adapting to climate change and invest in coastal defence. EMFF funds could make such investment more attractive through particularly favourable co-financing rates for ecosystem based solutions.

The **Horizon 2020 framework programme** should prioritise research on green infrastructure as part of the knowledge base needed to underpin the transformation processes towards a resource efficient green economy. Further research is required in a wider range of areas to investigate under which conditions green infrastructure can effectively contribute to meeting policy objectives across a wider range of policy areas including water, climate, soil, regional and marine policies.

The EU can already build on a number of existing EU level processes (eg 1999 European Spatial Development Perspective and 2011 Territorial Agenda) which offer a mandate for supporting best practice with regard to green infrastructure integration in **spatial planning**. The EU could promote spatial planning in a more pro-active way, by developing and disseminating a toolkit for spatial and regional planners. This toolkit could also underpin EU-financed capacity building activities (technical assistance) in some cases (eg ESPON 2013 Program). Key EU level Strategic documents (eg Territorial Agenda 2020) relating to spatial planning and integrated territorial development could be further aligned with the green infrastructure approach.

Future reforms of the **EIA and SEA Directives** should ensure that impacts on green infrastructure and its coherence are better taken into account and mitigated. The treatment of ecological and other green infrastructure issues in EIA and SEA needs to be improved, as well as the number of cases in which EIA and SEA are required further expanded. In addition, the potential of the EIA and SEA Directives to create and preserve green infrastructure can be strengthened by improving the scoping and public participation processes, to ensure a better integration of the green infrastructure concept, and in particular ecosystem services, in these.

In the area of **forestry policy** the Green Paper should result in an EU strategy on Forest Protection and Information, which would not only integrate the objectives of a green infrastructure in Europe, but could also be designed to complement the green infrastructure approach from a forestry perspective. The Commission should provide a concept for additional funding to fulfil the targets of the forest strategy in order to stimulate acceptance by Member States and to mobilise resources to implement the measures proposed therein

In the area of **biodiversity and nature policy** the Birds and Habitat Directives are the main EU instruments with a specific focus on biodiversity conservation. With their broad objectives and scope, which cover the whole of the EU territory and a wide range of species and habitats (and not just protected areas) their full implementation will contribute substantially to the envisaged aims of an EU Green Infrastructure Strategy. In particular Member States should increase their efforts to ensure their Natura 2000 sites, together with other protected core areas provide adequate, coherent and resilient networks at biogeographical scales. Where necessary the resilience of individual Natura sites should be improved, as appropriate, by expansion, improved management and enhanced functional connectivity, taking into account wider green infrastructure objectives and the provision of other ecosystem services. In addition, Member States should fully implement Article 10 of the Habitats Directive (and similar measures implied in the provisions of the Birds Directive), for example, through the establishment of national frameworks that assess strategic functional connectivity needs in an integrated way, followed by the planning and implementation of necessary actions. The efficiency and benefits of such actions could be enhanced through integration with habitat restoration as foreseen under target 2 of the EU Biodiversity Strategy.

In **water policy** EU guidance on drafting national River Basin Management Plans should be revised and complemented by a concept of how to apply water-related green infrastructure measures. The move to including assessments of ecosystems' role in water purification provision in water management plans should be supported as this could prove a valuable operational tool. Especially for effective management of floods and wetlands, coordination between Cohesion Policy investments and the measures under the Common Agricultural Policy must be enhanced, in particular in view of providing appropriate funding for ecological flood risk management under the Flood Risk Management Directive. Also valuable would be improved risk mapping and the adoption of preventative approaches that integrate ecosystem based responses as core measures.

In **climate change policy** it is recommended that greater efforts should be made to use ecosystem-based approaches to climate change mitigation and adaptation, especially where such actions can provide multiple benefits. Such actions could be further supported and integrated through an EU-wide research project to identify areas that are particularly vulnerable to climate change and at risk of losing ecosystem services if no restoration is undertaken. More targeted and effective action towards ecosystem-based adaptation in Europe would also raise the awareness of regional authorities on the role ecosystem capacities need to play in their adaptation strategies.

1 INTRODUCTION

1.1 Background to this report

The EU 2010 Biodiversity Baseline published by the European Environment Agency (EEA) in June 2010 (EEA, 2010) highlights that EU biodiversity remains under serious pressure and that the EU's target of halting biodiversity loss in Europe by 2010 has been missed. Despite some progress, with the implementation of the EU's 2006 biodiversity conservation strategy (COM (2006) 216 final), the European Commission has also recently acknowledged that the EU has failed to achieve its 2010 biodiversity target (COM(2010) 548 final). Furthermore, the conservation status of many species and habitats of Community interest, which are the focus of the Birds and Habitats Directives, is of particular concern. According to recent reporting under the Habitats Directive, nearly 65 per cent of the 701 Annex 1 habitats are in unfavourable condition (37 per cent UFC – BAD, 28 per cent UFC – Inadequate) and only 17 per cent of the habitats assessments are favourable. Biodiversity indicators also clearly show that declines are also continuing in some widespread species, such as birds and grassland butterflies (EEA, 2010).

These impacts on species and habitats are affecting the overall health of ecosystems, and their ability to provide important ecosystem services, such as those associated with water resources, soils, carbon, flood management, recreation and tourism. Consequently a recent assessment, carried out as part of EU's Rubicode project, found that Europe's ecosystems are degrading to such an extent that many are no longer able to deliver the optimal quality and quantity of basic services (EU RUBICODE project, 2010).

The severity and implications of ongoing biodiversity losses and ecosystem degradation is increasingly recognised and there is consequently a renewed political ambition to tackle the problems, which has resulted in the new 2020 target for biodiversity and ecosystem services.

The January 2010 Commission Communication *Options for an EU vision and target for biodiversity beyond 2010* explicitly called for the development of and investment in 'green infrastructure', to support biodiversity and ecosystems in "83 per cent of EU territory falling outside the Natura 2000 network". It calls in particular for the restoration of ecosystems insofar as possible to strengthen their resilience and sustain the key services they provide, while also achieving conservation objectives and enabling Member States to adapt to climate change. The post-2010 biodiversity strategy is expected to put much emphasis on the need for restoration in view of enhancing the services ecosystems provide. In this Communication, the Commission announces that it will promote and support exchanges of best practice as a basis for an EU Strategy on Green Infrastructure to be developed after 2010.

On 26 March 2010[4] the Council agreed on EU's new 2020 target for biodiversity and ecosystem services, namely '*To halt the loss of biodiversity and the degradation of ecosystem*

[4] European Council, 25/26 March 2010. Conclusions. www.consilium.europa.eu/uedocs/cms_Data/docs/pressdata/en/ec/113591.pdf

services in the EU by 2020, restore them in so far as feasible, while stepping up the EU contribution to averting global biodiversity loss'.

The EU is currently developing a strategy on green infrastructure which will contribute to achieving the objectives set out in the EU Biodiversity Strategy to 2020 which the Commission adopted in May 2011. Target 2 of the Strategy focuses on maintaining and enhancing ecosystem services and restoring degraded ecosystems by incorporating green infrastructure in spatial planning. The target is that "by 2020, ecosystems and their services are maintained and enhanced by establishing green infrastructure and restoring at least 15 per cent of degraded ecosystems." Action 6 includes promoting the "deployment of green infrastructure in the EU in urban and rural areas, including through incentives to encourage up-front investments in green infrastructure projects and the maintenance of ecosystem services".

In view of supporting the development of a Green Infrastructure Strategy, DG Environment launched, in late 2010, the present study as well as three other studies relating to green infrastructure which have been undertaken in parallel. The study 'Design, Implementation, Costs Elements of Green Infrastructure Projects' (ENV.F.1/ETU/2010/0052r) focused on gathering information on costs and the benefits of Green Infrastructure at project level and the task of setting up a typology of green infrastructure projects and defining green infrastructure has been assigned to this project. This study has now been completed and the report's findings (Naumann et al., 2011) have been taken into account in this study. Two other studies that focused on more specific aspects relating to green infrastructure included the study 'Assessment of the potential of ecosystem-based approaches to adaptation and mitigation in Europe' (ENV.B.2/SER/2010/0066r) and the study 'Costs, benefits and climate proofing of natural water retention resources' (ENV.D.1./SER/2010/0054r).

While the three other green infrastructure related studies launched by DG ENV in late 2010 had a different focus, all the contractors shared information and exchanged draft reports to exploit synergies and avoid overlaps whenever possible. It, however, needs to be pointed out that this study's focus lies on green infrastructure initiatives that are in place at higher tiers of policy-making at national or regional level, while the other studies tended to focus more on project level initiatives and, two of them, focus on specific types of Green Infrastructure.

1.2 Aim of this report

The overall aim of the study is to support the development of an EU-level Green Infrastructure Strategy by assessing the effectiveness and efficiency of green infrastructure measures across the EU in terms of biodiversity and broader ecosystem service benefits. It is envisaged that the results of this study will support the assessment of the different measures that could be part of the future EU Green Infrastructure Strategy. To achieve its aim, the specification for the study required six tasks to be completed as briefly summarised below:

1. Produce an inception report including an assessment of the current state of knowledge on green infrastructure, its impact and benefits; and a detailed methodology for the study, pilot country files and draft in-depth case analysis.

2. Through the development and analysis of appropriate indicators, assess the efficiency of green infrastructure initiatives and their elements, in particular with regard to their contribution to ecosystem resilience, and produce policy recommendations to support their implementation.
3. Analyse the costs of implementing green infrastructure initiatives at Member State level and estimate the potential costs and savings of a coordinated and integrated EU-level approach.
4. Gather information on the variety of green infrastructure initiatives and their implementation across the EU, and carry out an in-depth case analysis of the most advanced approaches to assess their socio-economic and biodiversity benefits.
5. Analyse the environmental, social and economic impacts of implementing green infrastructure initiatives at Member State and EU levels according to four different policy options.
6. Interlink all tasks and provide integrated conclusions on green infrastructure opportunities, constraints and efficiency, in particular regarding the potential added value of a Green Infrastructure Strategy for Europe.

This study has completed all these tasks, but this report presents the results in a slightly reorganised way in the following chapters:

Chapter 1 (ie this chapter) provides the background and context to this report and outlines the aims of this study. It also provides the rationale for the approach used throughout the project and outlines the study's methods (see below).

Chapter 2 explains how the term "green infrastructure" was interpreted in the context of this study, describes the types of "green infrastructure elements" that are distinguished throughout the report and used to refine much of the analysis, both on the costs and the benefits of the green infrastructure and the assessment of the impacts of the different options. It also illustrates how the concept of green infrastructure relates to different policies and clarifies what the main objectives a future Green Infrastructure Strategy would most probably be.

Chapter 3 provides an overview of green infrastructure initiatives that were subject to an in-depth analysis (as fully documented in Annex I). Additionally, it presents a typology of policy tools and instruments that can support green infrastructure implementation, which are illustrated through case examples.

Chapter 4 assesses the potential benefits that green infrastructure may provide in terms of increasing ecosystem resilience, and reviews potential indicators of ecosystem resilience (supported by a detailed assessment provided in Annex II) and ecosystem services.

Chapter 5 reviews evidence of the potential impacts of the various green infrastructure elements on ecosystem resilience and biodiversity.

Chapter 6 provides an assessment of the ecosystem services benefits of green infrastructure initiatives and elements, and the typical costs associated with green infrastructure initiatives. This is followed, for each of the elements, by an integrated assessment of the elements' cost-effectiveness, considering both the biodiversity (from Chapter 5) and ecosystem service benefits. Two Annexes relate to this chapter: Annex III presents additional information on the costs of green infrastructure initiatives, and Annex IV includes a synthetic overview table of the main benefits associated with each green infrastructure element.

Chapter 7 describes four different sets of policy options for the implementation of the future Green Infrastructure Strategy that were developed for this study, as well as a more detailed presentation of each one of the options. An overview, based on a Strength Weakness Opportunity Threat (SWOT) analysis, of existing EU policies and instruments relevant to green infrastructure is also presented. This analysis was used to define policy option 1, which is a baseline scenario (BAS). The full SWOT analysis can be found in Annex V and a detailed account of the policy changes included under options 2 to 4 can be found in Annex VI.

Chapter 8 presents a synthesis of the assessment of each one of the four policy options, which allows their impacts to be compared. The full assessment of the options is available in Annex VII.

Chapter 9 provides a number of key policy recommendations that arise from the evidence reviewed in this study and its conclusions. This includes recommendations relating to the green infrastructure elements that appear to be the most cost-effective, and identifies measures that would most effectively support the implementation of the future Green Infrastructure Strategy. It also highlights where there is potential for EU added value activities and identifies the policy option set that would appear to have the most beneficial impacts.

1.3 Approach and methods used in the analysis

This section of the report describes how data for this study were collected and used to develop recommendations.

1.3.1 Data collection on green infrastructure policy initiatives in the Member States

One of the first tasks carried out for this study was the identification and collection of evidence, in particular with regard to the biodiversity and ecosystem service impacts of green infrastructure initiatives, as well as their costs and economic benefits. This evidence base underpinned the subsequent analysis of the potential impacts of green infrastructure policy scenarios. The focus of the data collation was on high level national or regional policy level green infrastructure initiatives, rather than projects. However, detailed information on such policy level initiatives was relatively sparse and uneven, and therefore project level information was taken into account where it could be used to draw policy related conclusions.

The compiled evidence was drawn from published studies and available data, including results from the other green infrastructure related projects commissioned by DG ENV, including those running at the same time as this study. Much of the national level data used in this study were identified through an initial scoping exercise for each Member State. The resulting 27 country files identified three to five examples of green infrastructure initiatives that could be considered to be implementing the green infrastructure concept (see definition in section 2.1), even if the initiatives did not explicitly consider themselves to be linked to the concept. These were selected to provide a representative range of examples, including transboundary, national, regional and local policy initiatives, NGO initiatives and thematic programmes or projects that focus on ecosystem services, climate change mitigation or adaptation, water, flood or disaster control, and coastal protection or maritime spatial planning.

Further detailed data were then collected on seven initiatives that were most promising in terms of providing information and data on a range of effective green infrastructure initiatives. The resulting seven in-depth analyses focused on seven themes that characterise the different facets of green infrastructure as it is being implemented across Europe, and are provided in full in Annex I. Each in-depth analysis selected a relevant initiative from the country files as a lead example and provides detailed information on its background, objectives, costs, benefits and impacts. Two further examples were included for each theme to provide supplementary information on how green infrastructure initiatives that are pursuing similar objectives are being developed and implemented in other contexts.

Information for the in-depth case studies was largely collated through contact with relevant competent authorities at national and/or regional levels. Other partners in the initiatives, such as local and national NGOs, were also contacted where appropriate, to complement the information provided by public authorities.

1.3.2 Methods for assessing the overall impacts of policy options relating to the implementation of a EU Green Infrastructure Strategy

Four sets of policy options for implementing a future EU Green Infrastructure Strategy were identified, and these were used as a basis for the analysis of the potential environmental, social and economic impacts and costs of such a Strategy. The options were developed by firstly compiling, with the help of the Commission, a list of EU specific tools and instruments that can support the maintenance and enhance of green infrastructure. A SWOT analysis was then carried out of the main sectoral policy measures with respect to their current potential for supporting green infrastructure objectives. This SWOT analysis was then used to define the Option 1 baseline scenario (BAS) and assess its likely impacts on green infrastructure and, in turn, biodiversity and ecosystem services and their associated benefits. Each of the other three sets of policy options then included further progressively ambitious green infrastructure measures, many of which were drawn from the best-practices identified in various Member States (as documented in the country files and in-depth case analyses).

2030 was used as the dateline for the assessment of the policy options because this is the halfway point between the setting of the current biodiversity strategy targets (in 2010) and the 2050 biodiversity vision target. Although reference could have been made to the 2020 target, this would be too early, because many green infrastructure initiatives will require at least 10 years to be planned and implemented and then to have a significant ecological impact. However, as some impacts might arise as early as 2020, these are briefly identified and discussed for each one of the options. It is important to note that the overall likely impacts of each one of the options could not be determined with precision, largely because the exact scale and intensity of some actions (eg spending) remain uncertain under each option. Furthermore, it is uncertain how ecosystems will react to some of the measures, especially in the face of future pressures (such as climate change) that are likely to increase to some extent. Nevertheless, where possible the assessments were based on quantified indicative estimates based on expert judgements informed by the findings from the present study, and in particular the findings of the detailed case-studies with respect to the costs and benefits of green infrastructure initiatives. More specifically, the judgements build on the some of the material presented in this report and on the insights on biodiversity/resilience indicators in chapter 4 and 5 and, costs and cost and benefits as well as efficiency in chapter 6.

2 WHAT IS EUROPE'S GREEN INFRASTRUCTURE?

2.1 Green Infrastructure: how the term is to be understood

Green infrastructure is a relatively new and flexible term: it has been interpreted in different ways since no official definition exists. For example, 'green infrastructure' has been referred to as an "interconnected network of natural areas and green artificial features"[5], an "approach"[6] and a "conceptual framework for understanding the valuable services nature provides the human environment"[7]. As this situation is causing some confusion DG ENV tasked the study on *Design, Implementation and Cost Elements of Green Infrastructure projects* with the development of a consistent and agreed definition that should be used in the Commission's current green infrastructure studies.

Early discussions between both project teams agreed that typically green infrastructure should have the following characteristics:

- have special value in terms of potentially providing positive biodiversity and multiple ecosystem service benefits (ie above average service provision);
- be a definable structure and/or area; and
- be the result of a strategy / plan/ decision that provides added value in terms of conservation/protection, management, restoration or creation

However, further discussions resulted in the following definition, which has been adopted by this study: ***"Green infrastructure is the network of natural and semi-natural areas, features and green spaces in rural and urban, terrestrial, freshwater, coastal and marine areas, which together enhance ecosystem health and resilience, contribute to biodiversity conservation and benefit human populations through the maintenance and enhancement of ecosystem services. Green infrastructure can be strengthened through strategic and co-ordinated initiatives that focus on maintaining, restoring, improving and connecting existing areas and features as well as creating new areas and features."*** (Naumann et al. 2011).

These characteristics and the above mentioned definition means that the different components/elements of a green infrastructure may be found in almost all land uses across the landscape and that it may take various forms, as suggested by the green infrastructure elements that have been identified as part of this project.

2.2 The elements of Europe's green infrastructure

This study has also identified a number of elements that are commonly considered to constitute parts of an area's green infrastructure, and these are outlined in table 2.1. and will regularly be referred to throughout this report. While this classification of green infrastructure elements below has some drawbacks, including their tendency to overlap, it

---

[5] 2010 DG ENV Factsheet on Green Infrastructure

[6] Draft Recommendations of the Working Group on Green Infrastructure

[7] American Society of Landscape Architects, URL: http://www.asla.org/greeninfrastructure.aspx

has proved to be the most effective way to distinguish different components of a green infrastructure, and their associated supporting policy measures, costs and benefits. While table 2.1. provides only a succinct overview, these green infrastructure elements are presented in more detail in chapter 5 and their effectiveness in contributing to biodiversity conservation and ecosystem service provision assessed in chapter 6.

Table 2.1 Typology of green infrastructure elements

Green Infrastructure element	Includes:
Core areas	Areas of high biodiversity importance, including large areas of healthy and functioning ecosystems with minimal intervention required, and smaller areas that require management; such as Natura 2000 areas and other protected areas (eg IUCN categories I, II and IV).
Restoration zones	Reforestation zones, new areas of habitat for specific species or restored ecosystems for service provision.
Sustainable use/Ecosystem Service Zones	Areas that are managed sustainably for economic purposes, whilst maintaining healthy ecosystems and proving a range of ecosystem service benefits (eg multi-use forests and High Nature Value farming systems). Such areas help maintain the permeability of the landscape (ie enable species to exist in the wider landscape and move between core areas)
Green urban and peri-urban areas	Parks, gardens, grassy verges, green walls, green roofs.
Natural connectivity features	Ecological corridors (hedgerows, wildlife strips, stone walls) stepping stones (ie patches of habitat that enable species to move between core areas), riparian river vegetation, etc.
Artificial connectivity features	Features that are designed specifically to assist species movement, such as green bridges (ie bridges that are covered by an appropriate habitat to encourage the movement of animals across them), tunnels and fish passes.

2.3 The effects of policies on Europe's Green Infrastructure and its potential role in supporting a wide range of EU policy objectives

As discussed further in chapter 3, a wide range of EU policies have the potential to support the maintenance, restoration and enhancement of green infrastructure now and in the future (EEA, 2011). These include environmental policies with green infrastructure related objectives. In particular the full and effective implementation of the provisions of the Birds and Habitats Directives, would considerably advance many green infrastructure objectives. The backbone of these Directives is the protection and management of the Natura 2000 network (ie core sites) but importantly, the Directives also require the conservation of species and habitats of Community importance (as well as other migratory birds) in the wider environment; and therefore require integrated and landscape scale actions.

However, the wider fate of green infrastructure in the EU is largely dependent on a range of EU and national policies that do not aim to advance green infrastructure objectives, or even broader environmental objectives (EEA, 2011). This is particularly true for policies resulting in land-use changes and in particular those leading to the development of grey infrastructure (ie built infrastructure, such as roads, railways and hard flood or coastal defences). The future stock and state (quality) of Europe's green infrastructure will heavily depend on the extent to which adverse impacts resulting from a wider range of EU level policies will have effects on Europe's green infrastructure. Most notably fragmentation of habitats or further loss of connectivity features will have impacts on the overall quality of the green infrastructure and its potential to contribute to a range of policy objectives. The extent to which adverse impacts on green infrastructure will be avoided and mitigated can be expected to determine the extent to which it may contribute to ecosystem resilience and its capacity to deliver ecosystem services.

Of particular importance will be the extent to which the future reformed CAP will be able to maintain and restore green infrastructure elements in the farmland landscape. In this respect measures such as cross-compliance, additional Pillar 1 greening measures (especially the creation of ecological focus areas) and agri-environmental measures will be of particular importance. Such policy measures will have a profound influence on the delivery of multiple ecosystem services in agricultural areas, and thus the potential for proactive management of "sustainable use areas", as well as appropriate sustainable management of semi-natural habitats in Natura 2000 sites and other core areas.

The development of grey infrastructure through cohesion policy and, in particular, the support to road and energy infrastructure development through the TEN-T, TEN-E may have significant implications with regard to green infrastructure. Adequate consideration of the different options to deliver such projects or programmes in line with the EIA and SEA Directives are essential if adverse impacts are to be avoided and when this is not feasible, effectively mitigated. Effective maritime spatial planning policies and integrated coastal zone management equally have a role to play in diverting developments away from the most sensitive parts of a green infrastructure and identifying where green infrastructure creation and restoration zones might support meeting those instrument's objectives.

The extent to which climate change mitigation and adaptation objectives, including those laid out in the Commission's White Paper, as well as flood and drought risk management and coastal protection are pursued through ecosystem based solutions will also have significant implications on green infrastructure. As discussed later in this report, there is considerable potential for green infrastructure to contribute to climate change adaptation, eg through flood management, sensitive management of carbon-rich soils and protection of water resources through water retention measures.

2.4 The reference point: the current status of the different green infrastructure elements

This section briefly examines the current status of the different green infrastructure elements to establish a reference point for this study, as summarised in Table 2.2 below. This assessment draws on a wide range of evidence reviewed in this report, but in particular:

- BISE (EC, 2010)
- Biodiversity Baseline Report (EEA, 2010)
- Composite assessment of the status of habitats and species of Community interest (CEC, 2009)
- DG ENV Land Services study (IEEP & Alterra, 2010)
- European Commission Assessment of the EU BAP (CEC, 2010)
- Landscape fragmentation in Europe (EEA and FOEN, 2011)

- A spatial assessment of ecosystem services in Europe: Methods, case studies and policy analysis – phase 1 (Maes et al., 2011)

Table 2.2: A summary of the current and recent trends in the quantity and quality of green infrastructure elements in the EU

GI Element	Stock	Quality	Recent trends
Core areas	Includes the Natura 2000 network, which by the end of 2009 covered 17.9% of the terrestrial area of the EU (755,000 km^2) + 168,000 km^2 of marine areas; but additional protected areas that comprise core areas in each MS have not been explicitly defined and are unknown.	In 2006, 65% of habitats and 52% of species of Community interest had an unfavourable status; and the majority of these habitat areas and species populations occur in N2K sites and other core areas.	Significant increases in the extent of the Natura 2000 network have occurred in recent years, and the terrestrial network is almost completed according to the Commission, but progress with the marine network has been slower. Trends in terms of quality are uncertain (as only one comprehensive assessment of the status of habitats and species, as required under the Habitats Directive has been carried out), but the 2006 assessment identified many pressures that appear to be on going. This observation together with data on many threatened species suggests that the ecological condition of habitats in many core areas continues to decline.
Restoration zones (and activities)	Element very difficult to define because restoration can be for various reasons and can occur to varying degrees and from a variety of actions, including reductions in pressures that result in natural ecosystem recovery. Therefore the area of this element has not been defined spatially or quantified. Some areas will also overlap with core areas and sustainable use zones.	By definition, some aspect of the ecosystem within all restoration areas is in poor condition and would benefit from restoration.	There is good evidence of an increase in ecosystem restoration activities in recent years for nature conservation purposes (eg through CAP and LIFE funded measures) and for other ecosystem services benefits (eg flood plain restoration, water quality, soil carbon) but it is not possible to quantify this at an EU level.
Sustainable use/ Ecosystem service zones (HNV farming, certified forests etc.)	These elements have not been clearly defined or mapped, so it is not possible to quantify their extent in the EU. HNV farmland is an important component of such zones, and has been estimated to cover some 23 – 43% of the EU, but much of this area will be within Natura 2000 and other Core Sites.	Very difficult to assess because information on the ecological condition of such areas is sparse and not standardised; furthermore such areas will vary considerably according to the focus and intensity of their management	The status of these areas is uncertain, but evidence from some species monitoring data clearly indicates that biodiversity is declining over a high proportion of these areas. Some pressures are declining (eg water and air pollution), but many, such as the spread of invasive alien species, agricultural intensification, urban and infrastructure expansion, and the abandonment of High Nature value farmland under extensive management are on going.
Green urban and peri-	A large number of cities have undertaken green infrastructure mapping,	EU data on the condition of green infrastructure	Comprehensive EU data are not available, but there is some evidence from some countries (eg London) [check and add

GI Element	Stock	Quality	Recent trends
urban areas (parks, grassy verges, green roofs, etc.)	but EU level data are not available and studies indicate cities vary considerably in their green infrastructure	components in urban areas are unavailable, but conditions are likely to be highly variable and context specific	example] that private urban green areas are declining (eg as a result of conversion to hard standing for vehicles and housing) and brown-field sites and public 'waste ground' tend to be a focus of much development
Natural connectivity features (ecological corridors, hedgerows etc.)	These elements are difficult to define and measure in an objective way as their connectivity functions are species and context specific.	As with their stock the condition of these elements cannot be measured in an objective and meaningful way.	Although the extent and condition of these elements cannot be measured directly, there is some evidence that the extent and quality many features, such as hedgerows are declining over much of Europe.
Artificial connectivity features (green bridges, eco-ducts)	The extent of these features is unknown at an EU level, but it is clear that they are relatively rare in most countries	The quality of these features depends on their ecological functionality, and although there is evidence that they are used by target species, there is little good evidence that (with the exception of fish passes) they have significant beneficial population level impacts.	Overall EU trends cannot be quantified, but it is clear that many countries increasingly require connectivity features to be installed as mitigation measures during the construction of new roads and railways. A number of river restoration projects are also installing devices to allow fish to pass weirs etc.

2.5 The main objectives the four policy options pursue

It is envisaged that a Green Infrastructure Strategy would support the implementation of a green infrastructure approach with the overarching general objective of contributing to the adequate provision of ecosystem services that our societies and economies depend on, and the conservation of biodiversity for its own intrinsic values, in accordance with the EU's target of "halting the loss of biodiversity and ecosystem services in the EU by 2020, and restoring them in so far as feasible"; and the longer-term EU vision of ensuring that "by 2050, European Union biodiversity and the ecosystem services it provides – its natural capital – are protected, valued and appropriately restored for biodiversity's intrinsic value and for their essential contribution to human wellbeing and economic prosperity, and so that catastrophic changes caused by the loss of biodiversity are avoided". To contribute to this objective, by reducing and reversing the impacts of habitat loss, fragmentation and degradation on biodiversity and ecosystem services, green infrastructure initiatives, should have the following specific objectives:

- Safeguard ecosystems and the adequate provision of associated valuable ecosystem services in appropriate locations, and increase the resilience of those that are vulnerable to climate change and other pressures.
- Contribute to the restoration or enhancement of undersupplied ecosystem services in appropriate locations.
- Ensure the Natura 2000 network and other supporting core areas (eg national protected area / ecological networks) are sufficiently coherent (ie adequate in terms of size and representation and functionally connected) and resilient (eg to climate change) that habitats and species of Community interest are maintained or restored to favourable conservation status.
- Contribute to no-net-loss of biodiversity and ecosystem services in the wider environment by avoiding and reducing the impacts of ecosystem and habitat loss, fragmentation and degradation, through appropriate mitigation measures and compensation for unavoidable residual impacts (eg by habitat restoration of degraded habitats).
- Contribute to the restoration of biodiversity, particularly where this increases the resilience of habitats and species that are vulnerable to climate change and other pressures (such as habitat fragmentation).

The above mentioned general objective and sub-objectives will require measures including identification/mapping/spatial planning, maintenance/protection, legal designation of green infrastructure areas/features, restoration and creation of green infrastructure elements, research/analysis, increasing public awareness and reporting/monitoring to be taken.

3 POLICY TOOLS AND INSTRUMENTS FOR GREEN INFRASTRUCTURE IMPLEMENTATION: TYPOLOGY AND CURRENT PRACTICE IN EU MS

This section provides an insight into existing initiatives in the EU-27 that can be regarded as green infrastructure and the types of policy measures and initiatives identified in the context of this study as implementing the green infrastructure approach or including aspects of a green infrastructure implementation in their approach. Effective green infrastructure implementation relies on a range of policy tools and instruments which are also identified in this chapter. In addition, practical cases are used to clarify how these tools and instruments may be used.

3.1 Snapshot of Member State Implementation of Green Infrastructure

In the course of conducting the country analysis, the project team identified initiatives that could qualify as green infrastructure initiatives as defined in this project or used a green infrastructure approach to delivering their policy objectives. Priority was given to initiatives that pursued specific objectives, including:

- biodiversity conservation/ecosystem resilience as their primary objective (at national, regional or municipal levels, including those initiated NGOs);
- ecosystem service delivery as their primary objective which can be expected to also deliver benefits to biodiversity (ie habitat and species protection);
- climate change mitigation/adaptation as their primary objective (but also provide benefits to biodiversity);
- water/flood/disaster control as their primary objective (but also provide benefits to biodiversity);
- coastal protection or maritime spatial planning as their primary objective (but also provide benefits to biodiversity).

Around 100 initiatives from across all EU-27 Member States were identified and analysed. The objective was not to identify all existing green infrastructure initiatives but rather to provide an insight into the variety of initiatives which could be seen as implementing the green infrastructure concept or some elements of the concept. The initiatives identified operated at a range of scales, from local to transboundary. While slightly more than half (52) were national initiatives, most others were regional and local initiatives, with about 10 per cent (9) being transboundary initiatives. While most of the green infrastructure initiatives in the Member States have been led by governments, 15 were driven by other types of organisation, principally environmental NGOs, research institutes and businesses. The largest number of initiatives identified corresponded to ecological networks (35) followed, in order of importance, by freshwater and wetland management (15), multi-functional use, coastal zones (11), urban green infrastructure (10), multi-functional use of forests (6), green infrastructure mapping (6) and mitigation of grey infrastructure (4), multi-functional use of farmland (3) and a few others, a majority of which included climate change mitigation and adaptation (8).

The identification of initiatives showed that the green infrastructure concept (as understood within the context of this project) is not yet being implemented in an integral form. The closest equivalent can be found in Ireland, where the concept, also using the appellation "green infrastructure", is being developed at the county level but has not yet been operationalised. It should also be noted that the term 'green infrastructure' and its equivalents in other languages does not yet have a commonly accepted scope or definition. In addition to Ireland, the concept is starting to be introduced in other Member States, such as Cyprus. Luxembourg's landscape plan focuses on "infrastructure verte", which literally means 'green infrastructure'. Interestingly, the French ecological network programme, the Trame Verte et Bleue, is now officially translated in English as "Green and Blue Infrastructure" and the government's publications are now emphasising the broader benefits of the approach beyond biodiversity conservation. "Green Infrastructure" spatial strategies and plans are being widely developed in England and also in Sweden ("Grönstruktur") and in the Latvian city of Liepaja ("Zaļā infrastruktūra"), but these use the term to refer to a spatial planning model rather than prioritising biodiversity conservation (ie species and habitat protection) (although the Swedish plans aim to reduce ecological fragmentation. While the concept of "ecological networks" is at this stage more widespread, especially in the new Member States, one needs to underline that it cannot be considered an equivalent to 'green infrastructure' given its more restricted scope and purpose. It is also worth noting is that the term 'green infrastructure' as used for several years in UK spatial planning gives a significantly lower priority to biodiversity/ecological coherence than the 'green infrastructure' concept used by the EC and in this project. The concept of green infrastructure is also well known in the US where it has been used for quite some time, although the approach as applied by, for example, the Conservation Fund, appears to correspond more to the ecological network model. These are potential sources of confusion for anyone trying to understand the concept (and for those who already think they understand it).

With regard to biodiversity conservation, the ecological coherence element of green infrastructure is most closely realised within the various ecological network programmes across Europe. In this regard, only a few Member States, such as the Netherlands, Denmark, Luxembourg and Poland, have explicitly included ecological coherence in provisions implementing the EU Strategic Environmental Assessment Directive. The provision of ecosystem services, particularly recreation, water quality and quantity, is another element of green infrastructure that is prominent within the initiatives.

A wide range of green infrastructure projects and measures exist although they are not always identified as such. Initiatives reported as implementing green infrastructure take place in a variety of contexts. To name just a few:

- use of green infrastructure in and around urban areas, eg for micro-climate regulation, water provision, recreation, urban biodiversity;
- wetlands and floodplains restored and managed for flood risk management, climate change adaptation/mitigation, biodiversity, increase in overall resilience;
- multifunctional use of green infrastructure in farmland, forests and coastal areas, eg provision of food, wood, recreation, biodiversity conservation, etc.

Green infrastructure implementation is characterised by a wide variety of approaches. These include:

- broad-ranging initiatives that target a wide variety of land uses and stakeholders, but also programmes that are highly focused;
- timeframes that vary from a few years to decades;

- a wide range of policy tools and instruments, varying from awareness-raising and stakeholder processes through financial instruments to prescriptive legislative programmes;
- actions that affect a broad range of natural landscape features in multiple ways.

Existing measures generally combine different policy tools and instruments to protect, manage and develop Europe's green infrastructure. While it is generally possible to identify a core tool or instrument around which a green infrastructure implementing measure is structured, green infrastructure implementing measures are almost always a combination of a wider set of tools and instruments.

3.2 Insights into a Selected range of Green Infrastructure Initiatives across Themes

Using a database in which the about 100 initiatives discussed above were compiled; initiatives which were most suitable for an inclusion in seven in-depth case analysis were identified. Each one of the seven in-depth case analysis, which are one of the deliverables of this project and can be found in Annex I to this report, corresponds to a specific 'green infrastructure theme' (see seven sub-sections below) and includes three initiatives pursuing similar objectives which are analysed in more depth. The overview below provides brief summaries of the full case studies which have been included in seven in-depth case analyses. Readers who wish to have more detailed accounts of the implementation of the initiatives mentioned below and more specific aspects including identified costs, benefits and barriers/challenges are invited to consult the full in-depth case analysis in Annex I.

The range of initiatives presented below reflects the diversity of initiatives which are already taking place in Member States and which need to be considered an integral part of the baseline scenario (BAS/option 1). While the application of such initiatives, and the measures included within them, has increased substantially across the EU over the past decade these should not be considered common practice.

3.2.1 Ecological Networks for Biodiversity, Connectivity and Ecological Coherence

Three examples of ecological networks were examined in depth in the context of this study: the National Ecological Network in the Netherlands, the Green Network in Estonia and the Ecological Continuum Initiative and ECONNECT in the Alps. The Dutch and Estonian examples are broadly comparable in that they are comprehensive national programmes that form the primary framework for the countries' respective nature conservation policies and established targets which will take decades to achieve. The Ecological Continuum/ECONNECT programme, by contrast, is a shorter-term initiative that essentially comprises a series of pilot projects. Based on the example studied, it is clear that ecological networks, if/where they are being implemented on the ground, do deliver benefits in terms of strengthening ecosystem integrity (and the conservation of associated services) thus also potentially delivering a range of services beyond the conservation of biodiversity (ie habitats and species).

The three ecological networks and several other examples identified show that extensive linked systems of core areas have succeeded in attracting broad support in many countries and are also implementable. It is notable that some of these initiatives, the Dutch National Ecological Network and the Estonian Green Network for example, were planned as long-term programmes with an implementing horizon that extended decades into the future. The concept of developing and implementing an ambitious programme that aims to strengthen ecological coherence in combination with other functions has therefore been tried and tested in practice. However, it is also clear that these types of programme are vulnerable to changing political priorites and funding over time. The experience with these programmes has also generated many valuable lessons that can be taken into account when comparable initiatives are being considered (eg practical experience with ecological network design and management, stakeholder cooperation and connectivity programmes).

3.2.2 Multifunctional Use of Farmland and Forests

Three examples of green infrastructure initiatives falling under this theme provided quite different perspectives and approaches to the provision of green infrastructure through the multifunctional use of farmland and forests. The three initiatives studied differ also in their approaches to implementation. 'Protection Forests' constitute a nationwide policy initiative in Austria that applies to a particular landscape type throughout the country. The Protection Forests initiative in Austria particularly stands out as an initiative almost entirely established for the mitigation of natural hazards rather than for the protection of biodiversity. Landscape Ecological Plans in Finland operate over a wide area but almost exclusively on state owned land, whereas the Pumlumon Project in Wales is based mainly on private land and is implemented through voluntary agreements with the intention of sustaining the work through the creation of new markets. The significant success of the Finnish Landscape Ecological Plans has been the ability to satisfy multiple demands on land and to provide considerable areas of restored habitat and structural connectivity. The Pumlumon Project has demonstrated some interesting ideas and achievements over the past several years including the securing of a large area of peatland for carbon sequestration, the improvement of typical upland habitat and attracting an Osprey pair to settle in the area covered by the initiative, which has generated significant revenue from tourism, thus improving the local attitudes towards the maintenance of green infrastructure. Inviting landowners to opt-in to the scheme has been successful in securing a mutually positive relationship with stakeholders.

3.2.3 Multifunctional Use of Coastal Areas

Several initiatives aiming to conserve and/or enhance the capacity of coastal ecosystems to deliver ecosystem services underwent a more in-depth analysis. The first initiative "Protection and management of coastal habitats in Latvia" provides an example of a strategy developed to ensure the provision of cultural and recreational services through the management of the inflow of visitors while preventing the degradation of habitats linked to tourism. Actions were developed in 14 demonstration sites, with the support of EU funding through the LIFE programme, including mapping important habitats, and integrated management of the sites. Actions involved liaising closely with local stakeholders and the general public. This example is moreover interesting in presenting the detailed costs of each of the actions undertaken.

The two other initiatives considered here provide insights into the development of the concept of green infrastructure and the delivery of other types of ecosystem services in coastal areas. The Strategy for Integrated Coastal Zone Management in Spain presents an initiative to integrate the management of the Spanish coast into cross sectoral and long-term activities and planning of the area. The assessment of the costs associated with land purchase is a particularly interesting aspect of this example. Finally, BaltCICA, which is the third example studied, presents an approach to manage the coast as a way of improving adaptation to and mitigation of the effects of climate change.

The initiatives studied seemed to have made useful contributions to overall conservation, restoration and management of protected species and habitats, the expansion of sustainable tourism through the management of visitor/user flows, economic development, cooperation with local stakeholders and the general public as well as awareness- raising.

3.2.4 Freshwater and Wetlands Management and Restoration

Three policy initiatives representing this type of green infrastructure initiatives were studied in depth. The first example selected for analysis is the Sigma Plan II in the Scheldt Estuary (Belgium), shows the importance of seizing opportunities to integrate ecological restoration objectives when restoring a modified river system under pressure from many human activities and illustrates that the use of green infrastructure through combining flood protection with nature restoration is a cost efficient means to improve protection of Natura 2000 areas. The second case, the Lower Danube Green Corridor, is similar to the first in terms of using green infrastructure (wetlands) with multiple benefits (flood protection and nature restoration) in an international river basin, but both the size (160,000 additional hectares compared to 5,000 hectares in the Scheldt) and socio-economic context are very different. The benefits are well documented, with interesting comparisons with the lead case. The third case concerns “Innovative measures to ensure enhanced/continued ecosystem service delivery from freshwater ecosystems” in France. The focus of this case is the adaptation of infrastructure (dams) on rivers and restoration of wetlands. It complements the other examples as it illustrates the importance of Green Infrastructure for ecological continuity and indicates the positive benefit-cost ratios of smaller interventions and investments on rivers (compared to the other large scale projects) where flood safety benefits are not the main concern.

The successes these initiatives have demonstrated include: avoided costs for water management, the protection and restoration of riverine habitats and biodiversity, including legal protection, the development of short and long term management plans for ecological restoration and more integrated river management plans, the restoration and/or protection of wetlands that will provide important benefits for flood protection and water quality improvements (allowing to save on costs for water management, particularly related to flood protection measures). The measures have also led or are expected to lead to improved conditions for recreation and tourism and related enhanced local economic opportunities, including increasing the productivity of natural resources and the diversification of local livelihood strategies.

3.2.5 Urban Green Infrastructure

The three examples were thought to reflet (but not fully cover) the variety of green infrastructure initiatives in urban areas. The Regional Plan of Territorial Planning in the Metropolitan Area of Lisbon is an example of a proactive approach to creating and conserving green urban areas by integrating principles relating to its protection and enhancement into regional spatial planning, in particular by minimising negative impacts and enhancing the positive effects arising from the implementation of projects. The initiative is implemented in the Lisbon Metropolitan Area through the Metropolitan Ecological Network (*Rede Ecológica Metropolitana*, REM). The objectives of the REM are to maintain connectivity features and ecological continuity on the territory and to achieve other environmental goals concerning the stability and quality in the metropolitan area, such as protection of water resources, soil and landscape. The two other examples included in the analysis were the planning of the network of ecological corridors in the Autonomous Community of Madrid (Spain), and the Green Roofs of Basel (Switzerland), but using different policy instruments. The Spanish initiative aims at creating a metropolitan green ring (suburban green corridors) based on the existing urban and metropolitan parks and focuses on ecosystem service provision and ecosystem resilience, investments for which a rather favourable cost-benefit ratio is reported. The Swiss initiative is funded from an Energy Saving Fund and emphasizes energy-saving benefits. The interesting aspect is that is also delivers co-benefits such as overall micro-climate regulation, better rainwater runoff management and some biodiversity benefits, leading the assessment of the initiative to conclude to a positive cost-benefit ratio.

3.2.6 Grey Infrastructure Mitigation

Three pieces of legislation were examined targeting the negative effects of grey infrastructure were examined in the context of this in-depth case analysis. These examples indicate the widespread support for and feasibility of implementing mitigation measures in many countries and contexts, particularly regarding transport infrastructure. While all three cases illustrate public sector support for green initiatives to address grey infrastructure effects via the creation of targeted legislation, the development and nature of these initiatives serve to distinguish them. The potentially influential role of nature conservation organisations in implementing change within the area of transport mitigation is illustrated by the revision of Austria's motorway construction law in response to efforts by NGOs. Denmark's Traffic Action Plan addresses mitigation and compensation measures for new grey infrastructure construction, but also extends its perspective by engaging the general public in healthier, more environmentally friendly transport decisions. Finally, the Dutch Defragmentation Programme adopts a cross-sectoral approach and engages both the private and public sectors, including NGOs, to implement the legislative measures outlined.

Drawing conclusions applicable to other cases with regard to the costs-benefit ratio of such initiatives has proved challenging because of a lack of comprehensive data on costs and benefits associated with grey infrastructure mitigation legislation, both for the studied cases and more generally. However, costs are available for specific measures falling under these legislative plans and can inform a judgement with regard to the cost effectiveness of such measures. In the case of the Austrian Directive on Wildlife Protection in Road Construction, for example, the cost of two green bridges constructed over existing freeways were found to be EUR 1111.1 per square metre (€/m^2) and 726.2 €/m^2. These figures were considered representative of the average costs likely to be incurred for the construction of similar bridges over previously constructed expressways. It is often thought that bridges planned and built at the same time as the highway are cheaper, but data to make the comparison were not found.

3.2.7 Green Infrastructure Mapping for Planning

Three examples were selected and studied in depth to illustrate the utilisation of mapping tools in green infrastructure spatial planning processes. The main example explored, SITXELL ("Including Natural Values and Ecosystem Goods and Benefits into Integrated Land Planning"), was chosen for its representativeness of the measures considered most central to this theme. In particular, SITXELL utilises a GIS mapping scheme to support land planning processes at the Barcelona Provincial Government. The tool provides accurate ecological and socio-economical information and has resulted in the "greening" of public administration, and of companies involved in land planning and also support territorial development that reflect a more balanced consideration of ecological, social and economic imperatives. An additional two examples were also examined. These presented alternative approaches to the use of mapping in green infrastructure planning, while still pursuing the same overarching objectives. The first of these, the Cambridge Green Infrastructure Strategy and Green Vision (from the UK), uses mapping tools to identify the green space needs of the growing population and identify opportunities for green infrastructure in the region for the next 20 years, enabling economic growth and the preservation of natural features. In France, the Green and Blue Infrastructure Initiative targets regional fragmentation and aims to include an ecological network supporting biodiversity needs in its territorial and urban planning schemes.

While each initiative offered different insights, one of the most marked attributes shared by the case studies explored was the central role of collaboration with a diversity of stakeholders from inception through to the implementation and maintenance stages. Green Infrastructure maps offer a strategic framework that allows complementary insights from various stakeholders regarding regional priorities and opportunities, optimising the relevance of subsequent actions taken and the effectiveness in achieving the desired goals and objectives.

3.3 The Use of Existing Tools and Instruments for Green Infrastructure Implementation

3.3.1 Strategies and Action Plans

Setting out an overall strategic approach to Green Infrastructure provision: The type of measures under this category generally involve the adoption of a non-binding forward looking, strategic document identifying the need to take measures to identify, preserve and/or invest in (new) green infrastructure. This is guidance with political commitment. It can potentially include (new) objectives (including targets) or general principles to allow for green infrastructure to be taken into account to a greater degree in policy-making across all policy areas and governance levels (EU, Member State, local) and in particular in spatial planning. In some cases a strategy or action plan will announce that concrete priorities and measures will be taken in some policy areas (eg biodiversity) or geographic regions (eg Danube River Basin Strategy). Strategies may also apply to the management of green infrastructure in specific ecosystems (eg National Forest Strategy, UK) or sectors (eg agriculture), although a holistic green infrastructure strategy will generally be translated better into sectoral Action Plans, announcing the more specific measures to be taken in support of green infrastructure in particular policy areas. We note that there are already existing green infrastructure strategies at Member State or regional level, even if they are not always called as such (eg biodiversity strategies, forest strategies). Box 7.10 in chapter 7 provides a good example of provides insights into the green and blue infrastructure in France which takes an overall strategic approach to green infrastructure implementation.

3.3.2 Information Gathering and Mapping

Identification and mapping of green infrastructure elements and requirements: This category of measures involves drawing up maps for identifying current green infrastructure elements that need to be protected and/or enhanced as well as areas where new connectivity features, restoration measures or other green infrastructure elements are required to enhance the overall coherence and resilience of ecosystems and the delivery of ESS. This is an essential element of spatial planning and is useful at different geographic scales, from local to continental. Box 7.4 in chapter 7 on the Sitxell project provides insights into the implementation of such a mapping initiative.

Monitoring of green infrastructure elements involves monitoring their quantity, quality and impacts. This is linked to the development and use of indicators for monitoring and reporting of performance of measures and instruments. In particular, appropriate biodiversity and ecosystem service indicators appear useful for monitoring the health of green infrastructure elements, their impacts in terms of biodiversity and ecosystem service benefits and green infrastructure implementation more generally as monitoring also includes assessing trends (ie accounting of the stock of the different green infrastructure element types over time). The development of indicators and monitoring also allows baselines to be set and can inform the selection of instruments and setting of targets (EEA, 2011).

Analysis of green infrastructure benefits in view of integration into decision-making: Integrating green infrastructure benefits into decision-making would require these to be identified, quantified and valued. This might for example need to be done in a given area (eg a forest) to identify ways in which these could be secured or enhanced by integrating this value in policy-making, setting up PES schemes or purchasing the land. This can be at the local level (eg a city exploring the importance of its green belt) to EU level (eg integration into impact assessment).

3.3.3 Regulation and Spatial Planning

Regulation of land use: This would involve a political institution, whether at the local, regional, national, or European level adopting new legislation (or revising existing legislation) to regulate the use of land in an attempt to avoid further deterioration of the identified green infrastructure. The political institution must clearly set out how land foreseen for the provision of green infrastructure is to be treated, thus avoiding land use conflicts, further degradation and fragmentation of green infrastructure to ensure the provision of certain ecosystem services (eg water provision) and biodiversity benefits. Depending on the level at which they have been adopted, legislative proposals might have to be translated in local land use plans (eg Natura 2000), as is for example the case in France (see Box 7.10 in chapter 7).

Spatial planning/integrated territorial development involves spatial planning at local, regional, national or supra-national levels, generally resulting in the creation of a spatial plan reflecting the choice to preserve or enhance green infrastructure. This would ensure that planning decisions do not lead to a development which would further undermine the provision of ecosystem services and biodiversity conservation objectives. It is generally recognized that spatial planning has a key role to play in green infrastructure implementation (EEA, 2011). The aim would be a balanced development which acknowledges the need to preserve strategic natural elements in the landscape, for example to support territorial cohesion. Examples of initiatives which could be relevant in this context include Integrated Coastal Zone Management, UK Shoreline Management Plans, the French Coastal Law ('Loi littoral') and the Finnish Landscape Ecological Plans (LEPs) (see Boxes 3.1 and 3.2 below). In a great majority of countries, spatial planning systems generally already exist and most of them do protect some elements of green infrastructure, such as core areas, but often fail to protect or consider green infrastructure as a coherent whole.

Box 3.1: French coastal zone law – "loi littoral"

Adopted in 1986, the French coastal zone law is a long-standing attempt to organise land use planning in coastal areas in view of preserving natural heritage. The law enhanced existing zoning regulations, has allowed to avoid large scale developments, encouraged densification and pushed urbanisation away from the sea. As regard to ecosystem and biodiversity benefits, the law has been credited for slowing down the reduction of natural spaces in coastal areas.

Source: In-depth case analysis on the multifunctional use of coastal areas, Annex I

Box 3.2: Finland's Landscape Ecological Plans (LEPs) on state-owned land (mainly forests)

In Finland, since 2000, LEPs have been developed on a regional level. LEPs outline the general principles and goals of land use on state owned forest areas for 10 years. In the LEPs, ecological objectives are set but the goal of ensuring existence of nature-based sources of livelihood is also pursued. The LEPs therefore take an integrated approach to forest management. In 2009, area under LEP in-state owned forests included 168 000 ha with high biodiversity value and 181 000 ha of land designated as ecological connections (additional to Protected Areas).

Source: In-depth case analysis on the multifunctional use of farmland and forests, Annex I

Procedural requirements: EIA/SEA: Environmental Impact Assessment (EIA) and Strategic Environmental Assessment (SEA) legislation has the potential to consider the possible impacts on the overall coherence of green infrastructure and the delivery of ecosystem services to a greater degree than presently. There should possibly also be an encouragement or requirement for avoidance, mitigation and offsetting measures to be taken before a particular development is authorised (for EIA) or a plan or programme adopted (SEA), to ensure "no-net loss" or a "net positive gain" of biodiversity or ecosystem services. EIA and SEA already consider impacts on some green infrastructure elements but in many cases there is arguably an opportunity to expand this, for example through additional requirements and/or guidance.

Standards: Requirements may for example be included within building regulations stating, for example, that for a given surface of built or sealed land a determined share of land has to be dedicated to green infrastructure to facilitate the provision of ecosystem services (even if this is restricted to only requiring the creation of private green spaces). This primarily encompasses but is not limited to, building/development regulations.

Liability and compensation: This category of measures involved introducing a liability of operators for unauthorised environmental damage they cause through the requirement to return the environment back to its original state (eg before the accident occurred) and/or offset the environmental damage caused elsewhere (possibly strategically, through habitat banking, taking into account where restoration could best contribute to overall coherence of the green infrastructure). The way in which Natura 2000 protected areas are treated in the Environmental Liability Directive could be expanded to some of the green infrastructure elements. Arguably, this policy instrument could also have been included under the category below (MBIs) as the costs involved by operators who need to seek insurance coverage for this type of risks are thought to act as an incentive to improve environmental management to decrease the risks and lower insurance premiums (Munchmeyer et al, 2009).

3.3.4 Economic/Market Instruments

Resource pricing (eg taxes, charges, fees, land values): The pricing of certain resources is used to increase the incentive to preserve different types of green infrastructure elements because of the ecosystem services they provide. Developing land important for the provision of green infrastructure benefits could be disincentivised through the introduction of a taxation system which would direct development of the land (eg for housing developments) towards areas which result in limited loss of ecosystem services and green infrastructure. This could also include the introduction of water pricing. The income generated by such taxes can be used to finance enhancing green infrastructure elsewhere as a compensatory measure or to finance payment for ecosystem service schemes. In other instances, revolving loans have also been used to pursue environmental policy objectives and have been used for ecosystem based projects for floodwater management and energy efficiency (eg green roofs) both in the EU and the US.

Box 3.3: The Danish 'New forests adapted to future climate' project

The project "New forests adapted to future climate" addresses the sectors of water and, to a lesser degree, forestry, agriculture and nature protection. The Danish project is a joint initiative by the Danish Forest and Nature Agency, Copenhagen Energy (KE) and Hillerød Municipality which addresses climate change in two afforestation projects and aims to protect and optimise groundwater resources. As of 2010, 140ha of land has been purchased for the project. KE is financing these purchases through a user levy of approximately DKK 0.50 per m3 of drinking water.

Source: Naumann et al. (Forthcoming)

Land management contracts/agreements (including Payment for Ecosystem Service (PES)-schemes): Land management contracts or agreements may be negotiated between the leaseholder and the land owner to ensure the sustainable use of the land for the term of the lease. Such agreements may or may not include a PES-scheme[8]. These schemes may be public and based on legal obligations or private schemes with little government involvement.

[8] A PES is defined as a voluntary transaction where a well-defined ecosystem service, or services, is 'bought' by at least one ecosystem service buyer from at least one ecosystem service provider if and only if, the ecosystem service provider secures ecosystem service provision. Payments for Ecosystem Services therefore involves setting up a system through which those benefitting from a particular ecosystem service (eg direct beneficiaries such as water companies, irrigation authorities, etc) compensate those who provide it (eg foresters, farmers), thus providing them with an incentive for improving land-use and management practices in view of supplying those services.

They have so far primarily been used to support activities such as the provision of flood control or the management of practices that support water quality. Scales might also differ depending on the beneficiaries, the providers and the spatial relationship between them. There is a fine line between PES and a subsidy. European expenditure, which could also qualify as PES-schemes (eg agri-environment schemes) were considered “EU expenditure” under this classification.

Box 3.4: The Finnish METSO Programme

The METSO Programme (2008 - 2016) aims to improve conservation on both state-owned and private forests Voluntary participation of landowners interested in carrying out conservation measures in their forests. The funding guaranteed to the programme up to 2012 is €182 million. During 2008 - 2009, the programme yielded approx. 14,000 hectares of strictly protected area (of which about 4,000 hectares are private); 6,400 hectares of forest protected area (of which 300 hectares are private). Environmentally friendly forestry practices were supported in approximately 21,000 hectares of private forests.

Source: In-depth case analysis on the multifunctional use of farmland and forests, Annex I

Public procurement: There is also some scope for using public procurement to support green infrastructure. This could happen on the one hand via procurement requirements for road, rail and energy infrastructure and on the other hand by encouraging the development of labels for and purchase of “greener products”, such as organic, Forest Stewardship Council (FSC) or Marine Stewardship Council (MSC) certified. As regards greening grey infrastructure - public procurement may be relevant in relation to green infrastructure where the list of criteria for awarding contracts would consider the effort of producers to implement practices which ensure that green infrastructure elements were not determinately affected in the production of the good/service. The weight given to the criteria referring to green infrastructure would be given an appropriate weight, for a more appropriate consideration of the value of the services delivered by green infrastructure. Applicants should be penalised when their proposals are likely to have a high adverse impact on the green infrastructure. For example, when commissioning a building of new grey infrastructure, public authorities may assess offers against criteria including the extent to which the proposed development preserves/enhances green infrastructure. Projects going beyond the sheer compensation and seizing opportunities for creation of valuable green infrastructure may rank higher in recognition of the additional value they deliver to the community.

3.3.5 Public Investments

EU expenditure for green infrastructure (national to local and private detailed below): This involves using the different funding instruments of the EU (including EAFRD, EFRD, CAP, EFF, LIFE+ etc.) to support the maintenance or enhancement of green infrastructure or to support ecosystem based solutions rather than grey infrastructure for the delivery of certain services (eg water cleansing and wastewater treatment). Some of this expenditure, for example agri-environment schemes, could arguably also have been included under PES-schemes, discussed above. See below for a discussion of private expenditure and EU expenditure at national to local levels.

Land purchase: Public authorities, NGOs or private actors may purchase land to protect or manage green infrastructure elements. Owners may be given the possibility to leave their land to the public authorities requesting that it be managed in the wider public's interest. Statutory bodies such as the National Trust in the UK, or the Conservatoire du Littoral in France (see box 3.5), may be created to manage these lands according to clear criteria.

Green infrastructure restoration and creation projects/programmes (including reducing impacts of grey infrastructure): Green infrastructure restoration projects or programmes may be undertaken to restore green infrastructure elements for biodiversity and the provision of ecosystem services, to ensure overall coherence/resilience of ecosystems. Restoration may be initiated at various levels of governance and can be backed with funding from different sources. Creation projects or programmes are most often funded by the public or NGOs. Also included here could be projects or programmes by public authorities to reduce fragmentation caused by existing grey infrastructure. Section 6.2.2 in chapter 6 gives insights into the costs and benefits of green infrastructure restoration.

Securing long-term financing/maintenance: Public authorities commit to long term financing of the management of green infrastructure, for example through creating publicly funded institutions or creating permanent jobs, the purpose of which is to preserve and enhance green infrastructure. Public authorities may also create funds, the proceeds of which pay for green infrastructure. This is a separate category within this report as securing long-term finance is a recognised specific need (eg with regard to protected areas internationally).

3.3.6 Governance

Institutions: This involves establishing an institution, a statutory body or expanding the mission statement of existing institutions to allow them to take measures to preserve green infrastructure and/or deliver their objectives through ecosystem based approaches and allow them to allocate some of their budget to such approaches. River basin authorities with an expanded mission statement, to allow support for ecosystem based solutions, would also fall under this category.

Box 3.5: Conservatory of the Coastal Areas in France

The 'Conservatoire du Littoral' is a public administrative body created in France in 1975 to ensure protection of outstanding natural areas on the coast. Its original mission was to buy fragile or threatened land. End of 2010, the land is was responsible for managing covered 138,000 hectares of natural spaces of which it owned 82,000 hectares and managed 56,000 hectares for the state. 580 coastline guards recruited by managing institutions are in charge of surveillance and maintenance of the sites.

Source: In-depth case analysis on multifunctional use of coastal areas, Annex I

Participatory decision-making process: This involves strengthening the participation of a wider range of stakeholders in decision-making processes with implications for green infrastructure. The specific objective should be to ensure that the benefits derived from green infrastructure elements are not undervalued by only focusing on economic interests.

Reporting on implementation: This would involve reporting on the extent to which measures which were foreseen have been implemented on the ground and/or reporting on the state of green infrastructure (stock and quality) as part of wider reporting requirement relating to natural capital. Regarding the former, this may encompass: the extent to which the funds allocated to projects have resulted in their implementation, how the adoption of legislation or regulation at national level has resulted in effective implementation of requirements. Regarding the latter, this support the collection of information which may feed into natural capital accounts and extended income accounts – eg linked to national accounts.

Coordination of policies: Encompassed here are legislative measures leading to the amendment of existing policies and/or the drafting of legislative proposals to ensure a consistent approach with regard to green infrastructure across all relevant policy areas. This can also include policies outlining how ecosystem services will be delivered through green infrastructure in synergy with other policies. Might be best achieved by further exploration f the green infrastructure benefits supporting policy objectives set in different policy areas.

3.3.7 Communications and Advisory Measures

Awareness raising involves increasing the overall awareness of the benefits of green infrastructure through campaigns targeted at policy-makers and/or the wider public. This may even include reform of educational programmes within schools and universities (eg in engineering and architecture) to increase awareness of the benefits of green infrastructure.

Advice and guidance: Guidance documents to be issued targeted at the different stakeholder groups (eg key staff in local or regional authorities, farmers and foresters, NGOs) that may need support in implementing new requirements or interpreting new legal provisions meant to ensure green infrastructure is preserved and enhanced and that the provision of ecosystem services through green infrastructure is optimised.

Capacity building/technical assistance: Through targeted training/technical assistance on green infrastructure and its benefits, public authorities ensure that those meant to implement green infrastructure measures are appropriately skilled and aware of the objectives they are required to promote. Capacity building will often be required for staff working in public administration, who may have to change their perception with regard to the value of green infrastructure and the use that can be made of these to deliver policy objectives. Technical assistance for policy-making at EU level may involve EU support to Member State administration for the interpretation and implementation/transposition of new EU-level requirements in the area of green infrastructure across a wider range of policies. At MS/regional levels, technical assistance may also be required for the potential beneficiaries of EU-financed projects, who initially might need support to develop successful bids for projects and programmes delivering objectives through ecosystem based solutions.

3.3.8 Cross-Cutting Measures

Given the multifunctionality of green infrastructure and its potential to support policy objectives across a wider range of policy areas, efforts to conserve and promote it should not be limited to specific measures taken within individual policy areas. Cross-cutting measures, underpinning the effective use of a wide range of tools and instruments across a wider range of policy areas are needed and may include:

- **Green Infrastructure Strategies** designed to meet multiple objectives within a defined geographic area and identifying the green infrastructure elements of particular value in that geographical area.

- **Mapping of green infrastructure** elements across Member State territories, in the regions or at the local level, which may highlight the multi-functional aspects of green infrastructure for example by identifying the beneficiaries of ecosystem services in view of establishing PES-schemes
- Including stocks of green infrastructure elements in **natural capital accounts** covering various green infrastructure elements, including information green infrastructure quality (ecosystem health) and monitoring and reporting on the flows of benefits.
- Taking into account a wider range of green infrastructure elements in **spatial planning regulations** to account to a greater degree for the contribution it can make to meeting different objectives.
- **Public investments in green infrastructure**, where these meet multiple objectives across different policy areas (eg an **EU TEN-G fund** which would provide funding to Member States for co-ordinated projects of European value (see section section 7.2.5, change 4b).
- **Communications and advisory measures** aiming to promote green infrastructure in general and highlighting the various objectives to which it contributes.
- **Governance measures** supporting the range of initiatives outlined above.

It is important to provide clarity with regard to the level of development of cross-cutting policy initiatives under each one of the four scenarios which are presented in chapter 7 of this report as one must assume that they may have policy knock-on effects. Commitments to develop further the use of cross-cutting measures under options 2-4 may provide a context for further more specific (eg sectoral) policy developments across the different policy areas relevant for green infrastructure. Section 7.2.2 provides an overview of the extent to which the cross-cutting initiatives outlined above have been developed to date.

4 INDICATORS OF GREEN INFRASTRUCTURE IMPACTS ON ECOSYSTEM RESILIENCE AND ECOSYSTEM SERVICES

4.1 The meaning of ecosystem resilience

The first aim of Task 2 (as described in chapter 1) was to identify indicators that can be used to measure the contribution that green infrastructure can make to ecosystem resilience and the provision of ecosystem services. This therefore requires consideration of the definition of 'ecosystem resilience', as this is a complex concept that has been defined in a number of ways. Resilience is a major topic in the context of sustainability (Perrings et al. 1995, Kates et al. 2001, Foley et al. 2005) and is used by various scientific disciplines as an approach to analyse ecological as well as social-ecological systems (Anderies et al. 2006, Folke 2006).

One well known definition of resilience by Begon et al (2006) is "the speed with which a community returns to its former state after it has been perturbed and displaced from that state". However, this seems to be a rather narrow definition in that it only refers to communities that have been altered in some way and their subsequent response. Thus it does not include the ability of a community (or broader ecosystem) to resist or buffer change in some way, thereby avoiding change in the first place. Such an ability to avoid change is particularly important and is normally the primary goal of conservation measures rather than promoting the ability to recover.

Thus we suggest that the term resilience can be more usefully interpreted as "the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks" as defined by Walker at al (2004). This is sometimes referred to as an *ecological* definition of resilience as it recognises that ecosystems can exist in multiple stable states. So, for example some species interchange may occur as a result of a perturbation without significant impacts on ecosystem resilience, providing that the new species fulfil the same ecological functions as the lost species. This definition is also in accordance with the Intergovernmental Panel on Climate Change (IPCC), which defines resilience as "***the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organisation, and the capacity to adapt to stress and change***."[9] Furthermore, it is similar to the simpler definition used by the European Commission in its Impact Assessment on the EU 2020 Biodiversity Strategy, which states that resilience is: "The ability of an ecosystem to buffer and adapt to changes as well as recover after being disturbed."

When operationalising the concept of resilience, it is necessary to specify resilience of "what to what" - in other words, both specify (and quantify) the ecosystem and its constituents and the disturbing factor(s). This is not an easy task as it implies knowledge between "good" and "bad" states of the ecosystem as well as at least a rough estimation of cause-effect relations between degree of disturbance and ecosystem state. Moreover, used in this way, resilience differs from system to system and from disturbance to disturbance and it is difficult, if not impossible, to deduce generalities (Carpenter et al. 2001). In this respect, Cumming et al.

[9] IPCC Fourth Assessment Report, glossary http://www.ipcc.ch/publications_and_data/ar4/syr/en/annexessglossary-r-z.html

(2005) made a further contribution by focusing on "identity" of an ecosystem. They defined resilience in this context as "the ability of the system to maintain its identity in the face of internal change and external shocks and disturbances". Ecosystem indicators therefore usually need to relate to ecosystem - specific resilience properties and thresholds.

Walker et al (2004) have also suggested that resilience has the following four components listed below (of which the first three can apply both to a whole system or the sub-systems that make it up).

1. Latitude: the maximum amount a system can be changed before losing its ability to recover (ie before crossing a threshold which, if breached, makes recovery difficult or impossible).
2. Resistance: the ease or difficulty of changing the system, ie how "resistant" it is to being changed.
3. Precariousness: how close the current state of the system is to a limit or "threshold".
4. Panarchy: because of cross-scale interactions, the resilience of a system at a particular focal scale will depend on the influences from states and dynamics at scales above and below. For example, external oppressive politics, invasions, market shifts, or global climate change can trigger local surprises and regime shifts.

The assessment of ecosystem resilience indicators in this study therefore attempts to take latitude, resistance and precariousness components of ecosystems resilience into account, both in the identification of resilience indicators and in the assessment of green infrastructure initiatives in increasing ecosystem resilience. However, the concept of panarchy is too complex and ill-defined to be considered further as an ecosystem state property that can be measured in practice and used to assess resilience.

4.2 Identifying resilience indicators

To identify appropriate indicators it is necessary to consider what aspects of an ecosystem are of concern with respect to resilience. In this respect, it is clear that we need to focus on the two primary functions of green infrastructure initiatives, namely; the conservation of biodiversity *per se* (for its intrinsic value) and the maintenance and enhancement of associated ecosystem services (for their utilitarian values). In the following sections we therefore firstly consider what properties of an ecosystem contribute to its resilience. Proposed indicators of these properties are then identified, and their advantages and disadvantages assessed with respect to the measurement of the ecological impacts of green infrastructure initiatives.

Secondly, the most important ecosystem service benefits provided by green infrastructure initiatives are identified and the advantages and disadvantages of the most commonly used ecosystem service indicators are assessed. It is important to stress that some aspects of ecosystem resilience will have significant links to the provision of ecosystem services and therefore these will also be identified (eg the dependency of sustainable food production on soil condition).

This study also considers which of these ecosystem and ecosystem service indicators are appropriate for measuring the various contributions that green infrastructure elements (ie core areas, restoration zones, sustainable use / ecosystem service areas, green urban areas, natural connectivity features and artificial connectivity features) can make to ecosystem resilience.

Unfortunately, direct indicators of resilience that fulfil the above criteria have not been developed yet. Furthermore many authors (eg Thrush et al, 2009) state that at the present level of knowledge, it is not possible to quantify ecosystem resilience in such a way that it can be used to forecast the occurrence of so-called *catastrophic shifts;* sudden and irreversible changes in system components and functioning (Scheffer and Carpenter, 2003). Assessing resilience in terms of its latitude and precariousness components is therefore particularly difficult. Theory-based work on early warning signals for critical transitions suggests that increasing variance in key ecological parameters and slow recovery after perturbations are indicative of a nearby catastrophic shift (Carpenter and Brock, 2006; Van Nes and Scheffer, 2007). Unfortunately, such work is insufficiently backed up by field data (Thrush et al, 2009).

4.2.1 Ecosystem properties that increase resilience

Consequently, the present study focusses on identifying ecosystem proprieties that increase resilience and can therefore be used as indirect indicators of resilience. In particular we have assessed the potential contribution that green infrastructure can make to ecosystem resilience on the basis of the assumptions below:

1. Resilience increases with species richness;
2. Resilience increases with structural or functional complexity;
3. Resilience increases with (meta) population size;
4. Resilience increases with habitat area;
5. Resilience increases with coherence;
6. Resilience increases with ecosystem condition.

Although there is a general belief amongst most ecosystem researchers that the above-mentioned assumptions are generally valid, the assumptions are simplistic and in reality the relationships between these ecosystem properties and resilience is complex and not always well understood. Consequently, there are large differences in the amount of available scientific evidence that sustains these assumptions. The following sections therefore briefly assess the scientific evidence supporting each of these assumptions and their general validity, and drawing from this Table 4-1 at the end of the section summarises the potential for green infrastructure elements to increase ecosystem resilience.

A. Resilience increases with species richness

Species richness (the number of species present in an ecosystem) is an important component of biodiversity. It is considered to influence ecosystem resilience positively (Loreau *et al.* 2001, Hooper *et al.* 2005, Balvernera *et al.* 2006, Drever *et al.* 2006). In some literature, the term species-richness is used interchangeably with biodiversity or diversity; where diversity is referred to in this section, the focus is on species richness. However, species richness is the most simplistic measure of diversity. Other measures of diversity are more complex because they take into account the abundance of each species (Ricklefs & Schluter 1993; Van der Maarel 2005).

It is also important to realise that species richness and other diversity measures are scale dependent properties, resulting from the interactions between the variety of habitats (and variation within these) and the scale of elements in the landscape. Traditionally ecologists distinguish three broad scales of diversity. Local community diversity, which is referred to as alpha (α) diversity, is often measured in terms of species richness at a very small-scale, for example species per square metre. Habitats with high α diversity tend to be regarded as being of high conservation value. However, the diversity between communities/ habitats, (ie their variety and distinctiveness), known as beta (β) diversity, is also important. Alpha and beta diversity components contribute to overall landscape diversity, referred to as gamma (ϒ) diversity (Anderson et al, 2011).

A meta-analysis of studies indicates that increasing species richness reduces fluctuations in ecosystem processes such as productivity or carbon sequestration (Srivastava *et al.* 2005, Balvernera et al. 2006). In a model-based comparison of habitat productivity studies, the complementary and positive interactions that occur within mixtures of plant species are found to result in higher productivity (Hector *et al.* 1999). Increasing plant species richness, each species with its own typical rooting depth, leads to a more complete exploitation of available resources in the root zone (Cardinale *et al.* 2006), which might be important in the removal of potentially polluting nutrients like nitrogen or phosphorus from ecosystems (Engelhardt *et al.* 2001)..

In areas with high species richness, several species may perform the same task in ecosystem functioning (Gunderson *et al.* 2000). This functional redundancy (or the so-called 'insurance hypothesis') contributes to resilience in terms of maintaining ecosystem functions in the face of fluctuations in individual species (Gunderson *et al.* 2000, Diaz *et al.* 2001). In general a small number of the most productive species are responsible for most of the ecosystem's production, and their loss will have the greatest impact on the ecosystem (Cardinale *et al.* 2006). In more diverse communities such losses may be better accommodated, since other species may show a different response to the disturbance and take over the function of the previous key species, thus buffering these systems against impacts of disturbances (Diaz *et al.* 2001).

Increasing ecosystem resilience should not only focus on species diversity but should also include the genetic diversity within species (Reusch *et al.* 2005, Sgro *et al.* 2011). This intraspecific genetic diversity promotes species richness in plant communities. For example, in seagrass communities genotypic diversity plays a role analogous to species diversity by increasing the rate of recovery after a disturbance (Reusch *et al.* 2005). Higher genetic diversity may positively influence the persistence of a population in the current state, eg by increasing the likelihood that some individuals may survive extreme events (thus increasing the potential latitude of resilience). In addition it also provides the raw genetic material from which populations are able to adapt to changing conditions, such as climate change. Such evolutionary change is the norm in nature and generates and maintains biodiversity (Sgro *et al.* 2011). Further discussion of the effects of genetic diversity is provided below.

Overall, species richness increases ecosystem resilience by stabilising the variability in system functions and services, and reduces the effect of species loss through higher functional redundancy.

B. Resilience increases with structural or functional complexity

Several studies mention a positive relationship between *functional complexity* and ecosystem resilience, most likely because the probability that feedback mechanisms exist that counteract effects of (external) disturbances increases with ecosystem complexity (Diaz and Cabido, 2001; O'Gorman et al, 2011; Parrott, 2010). The loss of functions or functional types generally decreases ecosystem resilience (Balvernera *et al.* 2006), with the severity of the decline dependent on what function is lost (Diaz *et al.* 2003, Allen *et al.* 2005). It was shown that if disturbance occurs on one functional scale, the ability to self-organise within that scale reduces the effects on the wider ecosystem (Forys *et al.* 2002, Angeler *et al.* 2010); if disturbances affect multiple scales, the impact on the ecosystem is much greater.

Drever *et al.* (2006) describe two implications of across-scale interactions which should contribute to ecosystem resilience: 1) a hierarchical structure with asymmetrical interactions across scales leads to conserving and stabilising conditions in which the larger and slower levels constrain the smaller and faster levels and 2) generation and testing of innovations such as mutations or new species assemblages occur within each level (Drever *et al.* 2006).

However, the impacts of functional complexity on ecosystem resilience are not always positive. In ecosystems that are functionally very rich, the loss of a function by mere chance is more likely (Fonseca *et al.* 2001, Petchey *et al.* 2009). This would make functionally complex systems less resilient. In two communities with equal species richness, the community with fewer functional groups will have higher functional redundancy. The loss of one species in this community would be less severe than in a more functionally-rich system with fewer species per functional group. Conservation of redundant species within the different functional groups might reduce this risk, maintaining functional complexity and increasing ecosystem resilience (Petchey *et al.* 2009).

Functional groups and interaction across scales have a strong positive effect on resilience by stabilising ecosystem functioning. However, more functional groups can also make ecosystems more vulnerable.

C. Resilience increases with (meta) population size

An important rationale behind this assumption is that larger populations have a much lower chance of extinction by stochastic processes (Lande, 1995). A second rationale is that larger populations are likely to have greater genetic variation which increases their ability to adapt to changing conditions (Young et al, 1996). Sgro *et al.* (2011) define the adaptability of species as ‘evolutionary resilience’ and find that individual populations need to be maintained at a large enough size to allow ongoing evolution (Sgro *et al.* 2011). To maintain genetic variation and evolutionary potential, relatively large effective population sizes are needed. However, there is much discussion in the scientific literature about the average values and general applicability of minimal viable population size. Average populations of 5,000 to 7,000 individuals are generally considered to be the minimum viable size (Reed *et al.* 2003, Flather *et al.* 2011).

Large populations may be divided into smaller subpopulations, amongst which immigration and emigration occurs creating a ‘meta-population’ (see Box 4.1). This means that whilst small subpopulations may go extinct, the metapopulation as a whole tends to persist and can be a source of recolonisation for extinct populations if suitable habitats remain.

Different subpopulations differ in their genetic composition, each representing a part of the genetic diversity of the whole population. The different subpopulations are adapted to their specific habitats. They are likely to react differently to potentially detrimental environmental changes, making the whole population less vulnerable (Griffen *et al.* 2008a). Gene flow plays an important role in the genetic health of both the individual subpopulations and the population as a whole. If migration rates are high, homogenisation of all subpopulations occurs, making them all equally vulnerable. Conversely, if there is very limited migration, inbreeding may increase the extinction risk of subpopulations from environmental change, because the probability of adapted genotypes being present will be low.

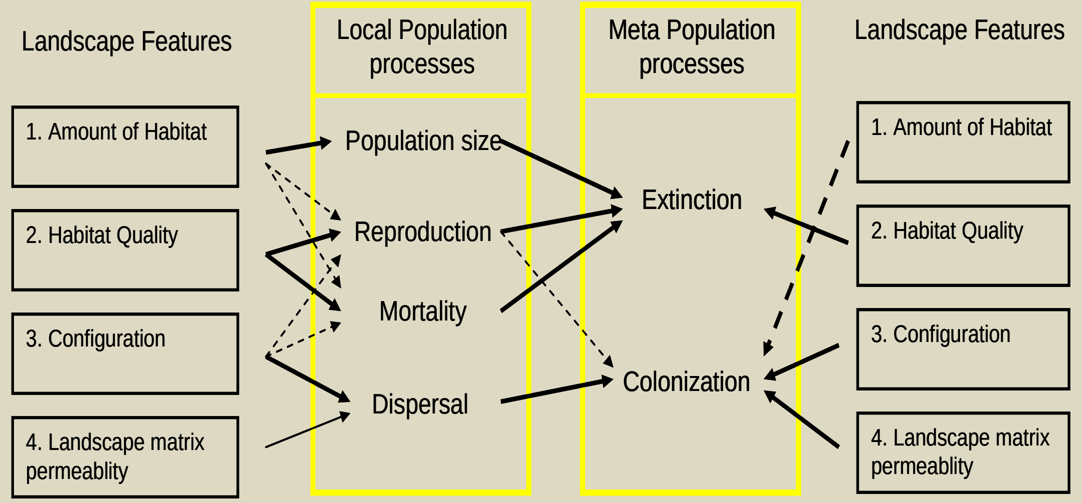
Although large population sizes are needed for the genetic health of species, the relative abundance of a species is not necessarily a good indicator of its importance within an ecosystem (Hooper *et al.* 2005). Relatively rare species may be 'keystone' species, which can strongly influence pathways of energy and material flows. These species are especially vulnerable to genetic impoverishment due to their relatively small population sizes.

Box 4.1: Main principles of the metapopulation theory (from Opdam 1991)

The metapopulation theory states that in fragmented landscapes animal and plant populations do not live in a continuous habitat but in a network of habitat patches, which are mutually connected by dispersal movements (Levins, 1970; Hanski, 1994; Andrén, 1996; Opdam, 2002).

A set of populations distributed over a number of habitat fragments is called a **metapopulation** as long as the subunits (subpopulations) are interconnected by dispersing individuals. Levins (1970) used the concept for 'a population of populations which go extinct locally and recolonize'. The metapopulation is the demographical unit at the landscape level. Its degree of organisation is of a higher order compared to that of the subpopulations in the fragments. The metapopulation dynamics are the result of the combined dynamics of the subpopulations and the between-fragment dispersal flow.

The driving forces of metapopulation dynamics are local extinctions and recolonisations of vacant patches. Local extinctions may be the outcome of birth and death processes in the subpopulations, partly determined by local habitat quality and fluctuations, partly by other types of local disturbance such as nest predation or nest parasitism (affecting reproduction). The relationships between the rates of local extinction and recolonisation determine the mean longevity of subpopulations and, by consequence, the survival time of the metapopulation.



Factors influencing metapopulation dynamics

The balance between local extinction and recolonisation is determined by the local birth/death processes resp. the intensity of the dispersal flow between habitat patches. The local demography is affected by patch size, habitat quality (including heterogeneity) and nest predation (among other factors not discussed), the dispersal flow is related to the landscape structure.

In fragmented landscapes species can still maintain viable populations as long as local extinctions of small populations can be outbalanced by recolonisation. The key process for sustainability thus is dispersal (Opdam, 1990). Which habitat patches belong to a network for a particular species depends on the distance between patches and the quality of the intervening landscapes (barriers, landscape resistance and presence of corridors).

In general most biodiversity policies and measures tend to focus on species or communities, to the detriment of efforts to conserve genetic diversity (Margulus *et al.* 2000, Bobin *et al.* 2007). This is despite the fact that genetic diversity is depleted in a wide range of taxa, due to inbreeding or genetic drift in small populations, and this impoverishment may threaten such species populations. In a meta-analysis of inbreeding studies, inbreeding depression was recorded in 90 per cent of the studies and its deleterious effects were found to be similar across the major plant and animal taxa (Crnokrak *et al.* 1999). In several cases conservation efforts were made to save species that were on the edge of extinction due to inbreeding depression. Box 4.2 summarises a few well known documented cases of inbreeding impacts on species.

Box 4.2: Examples of the impacts of inbreeding on small populations

The Florida Panther (*Felis concolor coryi*) is a clear example of an isolated population almost driven to extinction by the reduction and fragmentation of suitable habitat and consequent inbreeding depression (Roelke *et al.* 1993). The impacts, and potential for their reversal, were confirmed by the translocation of eight female panthers into the population. As a result the panther population increased threefold, genetic heterozygosity doubled, survival and fitness measures improved and inbreeding measures showed a significant decline (Hedrick and Frederickson 2010; Johnson *et al.* 2010a).

A European example is the Grey Wolf (*Canis lupus*) population in Sweden and Norway. This population was founded by one breeding pair that migrated from the large Finland-Russia population (Vila *et al.* 2003, Hedrick *et al.* 2010). The population size remained relatively stable at around 10 individuals in the following years, but after a third wolf immigrated from the Finland-Russia population, the population expanded to 100 individuals. The new migrant led to increased heterozygosity in the population, significant outbreeding (inbreeding avoidance), a rapid spread of new alleles and exponential population growth (Liberg *et al.* 2005). However, after some time inbreeding increased again resulting in a decline in the number of surviving pups and a subsequent drop in the population.

This impact is not confined to mammals and there are examples in other taxa in which artificial translocation of some genetically healthy individuals might contribute to the genetic rescue of inbred populations. For example, in a population of adders (*Vipera berus*) isolated for 100 year and suffering from inbreeding depression, the introduction of males from a healthy population resulted in increased recruitment of males, greater genetic variability and fewer stillborn young (*Madsen et al.* 1996). A number of other examples from different taxa are reviewed by Tallmon *et al.* (Tallmon *et al.* 2004).

The rate of migration or gene flow for genetic rescue differs between different taxa. It was estimated by Hedrick *et al* that the amount of gene flow required for genetic rescue was 20 per cent for the first generation, and 2.5 per cent for the following generations (Hedrick *et al.* 1995). This expectation was realised in the case of the translocation of Florida Panthers, as described in Box 4.2. However, Tallmon *et al.* find that for plant species, rates of migration as low as one individual per generation is sufficient for genetic rescue (Tallmon et al. 2004) and in water fleas the introduction of only a few individuals into existing (meta)populations resulted in 35 times more offspring than in populations without such introduction (Ebert *et al.* 2002, Edmands 2007).

Although there are examples of positive effects of artificial translocations for inbred populations, it is emphasized that genetic rescue is not the ultimate solution for the recovery of endangered species (Hedrick *et al.* 2010, Johnson *et al.* 2010b). There is no quick or universally accepted solution to conserve small, endangered populations, and it may provide only a temporary solution. The introduction of genetically more distinct individuals may also lead to outbreeding depression, ie a loss of fitness due to the disruption of either the intrinsic interactions between genes or the extrinsic interactions between genes and the environment (Edmands 2007). Without further study, it is difficult to predict with any certainty whether the net genetic effects will be positive or negative for the system (Tallmon *et al.* 2004).However, if genetic rescue can provide a temporary solution to population health, this may provide time to address the environmental or other problems endangering the species

D. Resilience increases with habitat area

There is a strong interdependence between the previous assumptions and the influence of habitat area on ecosystem resilience scale (Bruhl et al, 2003; Kerkhoff and Enquist, 2007). Species richness, functional complexity and population size all increase with habitat area and quality and consequently, the provision of sufficient high-quality habitat is a perquisite for these factors to contribute to ecosystem resilience. Species richness invariably increases with the size of the area measured (Schoener, 1976; Wiens, 1989). Huston (1994) mentions three main causes for this species-area relationship. Firstly, at small scales, it may often be a sampling artefact. Secondly and more importantly, the diversity of habitat types (and variations in habitat) increases with area as a result of environmental heterogeneity. Thirdly, the relationship may result from an equilibrium between extinction rates and immigration rates as postulated by the theory of island biogeography (MacArthur and Wilson, 1967).

Continuous and intact areas of native habitat has the greatest positive effect on biodiversity, genetic diversity and ecosystem resilience (Sgro *et al.* 2011). Additionally, gradients within areas are also important for resilience, since more environmental variation creates greater opportunity for niche specialisation, which positively influences biodiversity. A number of controlled experiments have shown that habitat size and variation therein are equally important in reducing extinction risks (Griffen and Drake 2008a,b).

The need for a large habitat differs between trophic levels, with the higher trophic levels (especially large carnivores) requiring a greater area (Weaver *et al.* 1996, Dobson *et al.* 2006). A decline in habitat area and quality affects the upper trophic levels first and will result in a sequential loss of trophic diversity. Thus, although a decrease in habitat area may result in a relative small loss of species, this may entail the loss of whole trophic levels and with them, their associated ecosystem services (Dobson *et al.* 2006).

Life history traits also influence the way in which species respond to habitat loss. For example in a review paper comparing studies on the implications of life history traits of insects, Ockinger et al (2010) conclude that species with low mobility, a narrow feeding niche and low production rates are most strongly affected by habitat loss. Thus, habitat reduction may not only result in the loss of species but may also change the species composition.

Overall, resilience increases with habitat size, since larger areas can support more species and bigger populations. Loss of habitat affects species differently, with the most severe consequences at the higher trophic levels, especially large herbivores and predators.

E. Resilience increases with ecosystem connectivity

According to metapopulation theory, the viability of the population as a whole depends on four important landscape attributes:

- amount of habitat;
- quality of habitat;
- spatial configuration of the habitat within the landscape;
- landscape permeability.

In combination, these factors affect the capacity of populations to disperse in the landscape, to have sufficient opportunities to feed, roost, find shelter and to encounter other individuals in order to reproduce, and to maintain a large and healthy population. If (sub) populations become small and isolated, demographic and environmental stochasticity may have a significant influence on extinction probability, and be more important than the impacts of reduced genetic variation – see below (Burger *et al.* 1995, Sgro *et al.* 2011).

Habitat fragmentation is considered by many conservationists as one of the greatest threats to biodiversity (Hanski, 1998) and its impact is particularly severe in the context of environmental dynamics, especially climate change. Increasing connectivity has been proposed frequently as an effective strategy to address biodiversity decline within fragmented habitats (Bailey, 2007). Model simulations for random landscapes have shown that approximately 60 per cent of the landscape must be covered by suitable habitat in order to ensure the movement of organisms between patches (Gardner et al. 1989). However, in real landscapes this percentage can be much lower if *corridors* exist which connect habitat patches (Van Diggelen 2006). Logically, (Heller and Zavaleta, 2009) found in a recent review of recommendations on increasing ecosystem resilience in the light of climate change, that improvement of landscape connectivity was the most frequent recommendation. However, they also say "despite widespread favor (sic) for ecological networks, assessment of their effectiveness remains in its infancy". Similar statements have been made by other authors (Gaston et al, 2006). Even in the case of 'eco-ducts' and other road crossing structures, which, compared to other connectivity structures are well-studied and their positive effect on population viability undisputed (Clevenger and Waltho, 2005), there is no knowledge of their long-term and large scale effects on biodiversity (van der Ree et al, 2011).

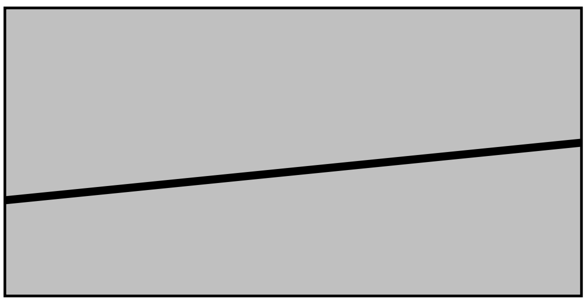
This does not mean that fragmentation is not a problem, nor does it mean that connectivity is not essential for a viable meta-population. Grashof-Bokdam (2009) found a positive relation between the occurrence of 28 of 40 forest plant and animal species in 1000 1*1 km grid cells in the Netherlands and the degree of connectivity between forest patches in this grid. They found the strongest effect for species with a low dispersal capacity. Further support for a clear effect of connectivity on species dispersal, and thus on community composition, can be found in road ecology. Roads and other linear transport structures such as railroads and canals have been shown to enhance vastly the dispersal of vascular plants (eg Ernst, 1998; Hansen and Clevenger, 2005).

Large, continuous and intact native habitats are widely considered to be the optimal solution for conserving biodiversity, genetic diversity and ecosystem resilience (Sgro *et al.* 2011). There is a wealth of literature showing the impacts of fragmentation and isolation (ie loss of connectivity) on ecosystem resilience properties listed above, such as species richness, metapopulation stability and genetic diversity. However, in many cases the greatest biodiversity impacts resulting from habitat fragmentation are the result of overall habitat loss, rather than the loss of connectivity between habitat patches (Fahrig 2003). **Figure 4-1** provides a schematic overview of how barriers such as roads, habitat loss and habitat degradation can result in habitat fragmentation and reduced connectivity.

Figure 4-1: A diagrammatic representation of a hypothetical progression in habitat fragmentation

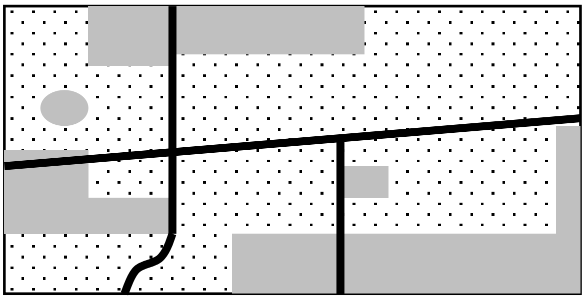
Key: Shaded = semi-natural forest. Hatched = Intensive managed forest. Stippled = semi-natural grassland with scattered trees (i.e. parkland). Unshaded = agriculturally improved grassland.

a. Construction of a road across an area of continuous semi-natural ancient forest



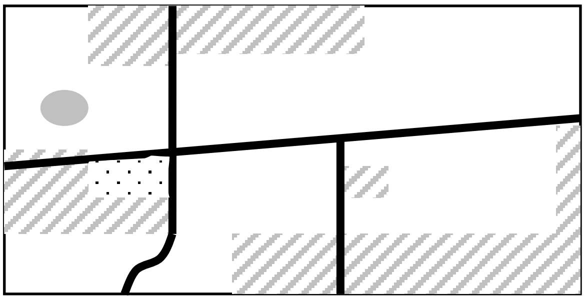
Impacts: No significant direct habitat loss, but creation of some edge habitat. Fragmentation of forest habitat for some species (eg some invertebrates) that cannot cross roads. Some disturbance impacts may reduce effective habitat size for some disturbance sensitive species.

b. Clearance of some forest and conversion to semi-natural parkland (grassland with scattered trees). Some further road construction



Impacts: Substantial habitat loss and fragmentation. Likely loss of disturbance sensitive species and species requiring large forest areas and/or interior habitats. Connectivity between forest areas now much reduced but many species can move through semi-natural parkland landscape matrix. New habitats created and benefits for forest edge species leading to an overall increase in species diversity.

c. Intensification of forest and agricultural management



Impacts: Widespread habitat degradation leading to habitat loss for many species. Reduced connectivity between forest fragments due to reduced permeability of the surrounding matrix. Only small isolated patches of semi-natural forest and parkland remain. Overall impact: substantially reduced species diversity.

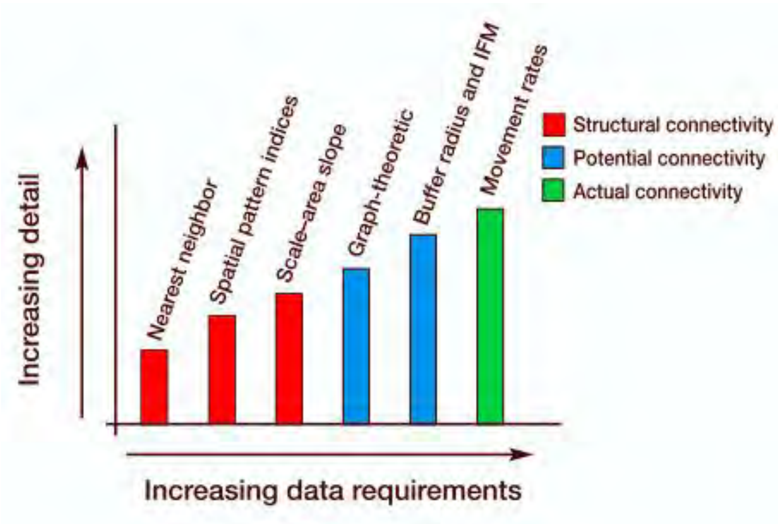
Source: Kettunen et al (2007)

The relationship between connectivity and ecosystem resilience is also highly complex because the importance of connectivity *per se* is dependent on many factors. Firstly, one of the key lessons from scientific studies of ecological connectivity is that functional connectivity is a species-specific property (Noss & Daly 2006; Taylor et al 2006). This is because a species' connectivity requirements depend on a number of factors that are species-specific, including their spatial distribution and population dynamics, and movement, dispersal and colonisation abilities. Secondly, these requirements will also vary from place to place according to the configuration of habitat patches and the properties of the surrounding landscape matrix. For example, many forest species are usually averse to crossing open areas (eg open fields), but heterogeneous matrix areas (eg fields with scattered trees or hedgerows) can alleviate this effect. Thus the ability and way in which individuals move through the landscape changes with landscape structure (Goodwin and Fahrig, 2002a). But many species require particular habitat types, such as forest interior species, and they will not leave such habitats. They therefore require physically connected areas of particular high quality habitat types.

Because functional connectivity is a species and landscape-specific property it is difficult to identify meaningful and practical indicators of connectivity. Measures of structural connectivity (ie physically connected habitats) can be misleading. For example, linear features such as hedgerows and similar corridors may provide structural connections but research shows that their value to species in terms of providing functional connectivity is highly variable (see Section 5.2). Such functional connectivity can be assessed using 'least-cost' approaches (Adriaensen et al 2003; Bunn et al 2000) that take the properties of the intervening landscape matrix into account. Another approach is to use '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). Unfortunately, both approaches are at present not applicable in large-scale analyses because of data demands and computational requirements (Calabrese and Fagan, 2004) (**Figure 4-2**).

Figure 4-2: Schematic representation of the trade-off between information content and data requirement among several connectivity metrics

Source: Calabres & Fagan 2004



Furthermore, apparently isolated habitat patches may in fact be functionally connected and part of a habitat network for those species that can cross the intervening habitat matrix. It is important to realise that increasing connectivity is not necessarily beneficial and can be highly detrimental for some species and communities, eg by increasing the likelihood of competition from invasive alien species, or increasing predator access to habitat patches (see Box 4.4).

As a result of the considerations above, it is argued by Hodgson *et al* (2009) that the uncertainties associated with connectivity are generally higher than those with habitat area and quality. Increasing habitat area and quality are more certain ways to increase population size and resilience than by increasing connectivity in the hope that it will enhance dispersal, unless it is already known that isolation is the main constraint on the population. A suitable habitat is a prerequisite for ensuring the beneficial effects of emigration.

Box 4.4: Potential advantages and disadvantages of the use of corridors as conservation tools to facilitate connectivity.

Potential advantages	Potential disadvantages
1. Increase immigration rate, which could: Increase or maintain species diversity. Provide a 'rescue effect' to small, isolated populations by augmenting population sizes and decreasing extinction probabilities. Permit re-colonisation of extinct local populations, potentially enhancing persistence of meta-populations. Prevent in-breeding depression (ie reduced fitness in a given population as a result of breeding of related individuals) and maintain genetic variation within populations.	1. Increase immigration rate, which could Facilitate the spread of infectious diseases. Facilitate the spread of alien species, eg exotic predators and competitors. Facilitate the spread of weedy or pest species. Decrease the level of genetic variation among sub-populations. Cause 'out-breeding suppression'(i.e. situation where crosses between offspring of individuals from different populations have lower fitness than offspring from crosses between individuals from the same population) by disrupting local adaptations and co-adapted gene complexes.
2. Permit daily or seasonal movements for foraging, breeding, migration, or other behaviours	2. Facilitate spread of wildfires and other catastrophic abiotic disturbances
3. Facilitate dispersal of animals from natal ranges to adult breeding ranges	3. Create a 'mortality sink' by increasing exposure of animals in corridors to humans, native and exotic predators and competitors, pollution, and other deleterious 'edge effects'
4. Accommodate natural range shifts due to global climate change	4. Riparian strips, often recommended as corridors might not enhance dispersal or survival of upland [ie non-wetland] species
5. Provide predator-escape cover for movement between patches	5. High economic cost to purchase, design, construct, restore, maintain and protect corridors
6. Provide wildlife habitat for transient or resident animals within corridors	6. Trade-off costs and conflicts with other conservation acquisitions, including conventional strategies for enlarging core areas and preserving endangered species habitat
7. Provide alternative refuges from large disturbances (a 'fire' escape)	7. Political costs from altering human land-use patterns
8. Continuance of ecological processes and ecosystem services such as succession, seed dispersal, and flow of water, nutrients, and energy	
9. Provide 'green belts' to limit urban sprawl, abate pollution, provide recreational opportunities, and enhance scenery and land values	

Source: Crooks & Sanjayan (2006), modified from Noss and Soulé (1987), in Kettunen et al. (2007)

F. Resilience increases with ecosystem condition

Intuitively this assumption seems very logical but almost all support stems from its negation, ie evidence that increasing environmental pressures decrease the stability and resilience of ecosystems and ecosystem services (Power 2010). From the start of systematic ecological studies it was obvious that adverse habitat conditions affect ecosystem performance negatively (Odum 1953) and human-induced pressures are no exception (Maskell et al, 2010; Stevens et al, 2010). Indeed, in terrestrial ecosystems, land use change is considered to have by far the largest influence on the stability of natural systems (Sala *et al.* 2000). For example, recent experimental work, aimed at disentangling the effects of environmental stress and fragmentation (eg Griffen and Drake, 2009), showed that the negative effects of nitrogen stress are larger than those of a decrease in connectivity, at least in the short term.

Ecosystem impacts can be attributed partly to direct loss of habitat (see section D) but even when land use change does not result in area loss, the quality (ie condition) of the ecosystem often declines due to a variety of pressures (EEA, 2010a; EEA, 2010b; EEA and FOEN, 2011) including:

- Intensive agricultural management, including frequent cultivations (loss of permanent grassland), fertiliser use, pesticide use, high stocking densities, crop specialisation (and loss of fallow land), early and frequent cutting of grassland, loss of non-farmed habitats and features (eg trees, hedgerows and ponds).
- Agricultural marginalisation and abandonment, leading to reduced extensive livestock grazing, ecological succession and loss of open semi-natural habitats.
- Afforestation and intensive forestry practices, including clear felling and monoculture replanting, removal of deadwood, planting with exotic species, and use of pesticides
- Fertiliser use and eutrophication from water and air-borne pollution.
- Changes in soil condition, eg loss of organic matter, contamination, erosion and compaction.
- Hydrological change, eg drainage, reductions in water tables, changes in water chemistry, river channel re-engineering and impoundments, and flood defences.
- Disturbance from human presence, activities and noise.
- Over exploitation of species (eg from hunting and fishing).
- Spread of invasive alien species.
- High predation rates resulting from human-induced increases in predator numbers.
- Accidental fires and inappropriate intentional management burning (eg of upland heaths and grasslands).
- Climate change impacts.

The degree to which the remaining natural ecosystems are affected by such large scale processes depends both on size and intensity. Smaller natural areas are especially vulnerable to external impacts because they are more heavily influenced by what is going on in the area surrounding them than large areas (Maiorano *et al.* 2008). Also the intensity with which surrounding areas are used has large effects. For example, agro-chemical pollution and sedimentation of waterways will increase and severely compromise the stability of natural systems and their services (Power, 2010).

These factors may exacerbate the negative impacts on system resilience described above, including habitat fragmentation, and the negative effects of genetic impoverishment will become more pronounced under stressful conditions (Griffen et al, 2008 and references therein). In a comparative study on inbreeding depression under benign and stressful conditions, inbreeding depression increased 69 per cent under stress (Armbuster and Reed, 2005). Furthermore, the evolutionary potential to adapt to a change in circumstances is reduced in genetically impoverished populations.

In the light of the above it seems logical that improved environmental conditions through restoration or conservation activities lead to increased ecosystem resilience. Unfortunately very few examples of this effect have been published yet. This is in part due to the long time span needed for recovery (Haapalehto, 2011; Read, 2011), but also because unexpected internal processes slow down the recovery process. Examples of the latter are for instance internal Phosphorus mobilisation processes after reducing external loadings (Gulati, 2002).

At present attempts are being made to formulate frameworks to assess benefits from conservation and restoration activities in terms of ecosystem functioning (Cadotte, 2011; see further discusion in Chapter 5).

Table 4-1 below provides a summary, on the basis of the evidence reviewed above, of the contributions that Green Infrastructure elements can potentially be expected to make to ecosystem resilience in appropriate circumstances. Chapter 5 reviews the evidence for actual observed ecosystem condition and resilience impacts from Green Infrastructure initiatives.

Table 4-1: Summary of the main potential contributions that green infrastructure elements can make to ecosystem resilience

Green Infrastructure element	Contribution to ecosystem resilience
Core areas: Large areas of healthy and functioning ecosystems with minimal intervention required (eg national parks, forest reserves, IUCN categories I and II); Smaller areas that require management intervention (eg Natura 2000, IUCN category IV).	Maintenance of ecosystem characteristics and processes that are required for the conservation of the most important areas for threatened habitats and species, but which also underpin many ecosystem services.
Restoration zones: Reforestation zones, increased foraging areas, new areas of habitat for biodiversity and restored ecosystems for services.	Strengthened ecosystems through improved integrity of ecosystem processes and habitat condition, potential stepping stones for specific species that are vulnerable to habitat fragmentation; increased area for habitats and species.
Sustainable use/Ecosystem Service Zones: areas for improved ecological quality and permeability of landscape. Sustainable economic land uses that help maintain or restore healthy ecosystems (eg IUCN categories V and VI, biosphere reserves)	Maintenance of ecosystem processes that underpin key ecosystem services, whilst also contributing to the maintenance of overall habitat quality, larger areas of habitat and landscape permeability to improve connectivity (mainly for generalist species).
Green urban areas (parks, gardens, grassy verges, green walls, green roofs)	Increased area of habitat, improved connectivity, enhanced ecosystem services.
Natural connectivity features: ecological corridors (hedgerows, wildlife strips, stone walls) stepping stones, riparian river vegetation, etc.	Improved connectivity amongst habitat patches for species that are vulnerable to habitat fragmentation.
Artificial connectivity features ie those designed specifically to assist species movement, eg green bridges, eco-ducts etc.	Improved connectivity amongst habitat patches for species that are vulnerable to habitat fragmentation.

4.2.2 Potential indicators of ecosystem resilience and green infrastructure contributions to it

This section summarises a review of existing indicators, in particular the SEBI set, that was undertaken for this study with respect to their relevance to ecosystem resilience, as discussed above, and their practicality, taking into account the necessary properties of efficient indicators (as summarised in Box 4.5). The assessment also took into account the findings of the Green Infrastructure Expert Workshop[10] held by the Commission on the 7 September 2011 (see Box 4.6). The detailed review of the indicators is provide in Annex II, where they are grouped according to the ecosystem property and resilience assumptions described in section 4.1.

[10] Ecologic, GHK & IEEP (2011) Green Infrastructure Expert Workshop, (7/9/2011) Summary of Working Groups

Box 4.5: Key properties of indicators that may efficiently support EU biodiversity policy goals

1. Policy relevant and meaningful: indicators should send a clear message and provide information at a level appropriate for policy and management decision-making by assessing changes in the status of biodiversity (or pressures, responses, use or capacity), related to baselines and agreed policy targets if possible.
2. Biodiversity relevant: indicators should address key properties of biodiversity or related issues as pressures, state, impacts and responses.
3. Progress towards 2020: indicators should show clear progress towards the 2020 target. [Note updated from the 2010 target]
4. Well founded methodology: the methodology should be clear, well defined and relatively simple. Indicators should be measurable in an accurate and affordable way, and constitute part of a sustainable monitoring system. Data should be collected using standard methods with known accuracy and precision, using determinable baselines and targets for the assessment of improvements and declines.
5. Acceptance and intelligibility: the power of an indicator depends on its broad acceptance. Involvement of policy-makers as well as major stakeholders and experts in the development of an indicator is crucial.
6. Routinely collected data: indicators must be based on routinely collected, clearly defined, verifiable and scientifically acceptable data.
7. Cause-effect relationship: information on cause-effect relationships should be achievable and quantifiable in order to link pressures, state and response indicators. These relationship models allow scenario analysis and represent the basis of the ecosystem approach.
8. Spatial coverage: indicators should ideally be pan-European and include adjacent marine areas, if and where appropriate.
9. Temporal trend: indicators should show temporal trends.
10. Country comparison: as far as possible, it should be possible to make valid comparisons between countries using the indicators selected.

Sensitivity towards change: indicators should show trends and, where possible, permit distinction between human-induced and natural changes. Indicators should thus be able to detect changes in systems in timeframes and on scales that are relevant to the decisions, but also be robust enough to measure errors that do not affect interpretation.

Source: SEBI (2007)

Box 4.6: Outputs of expert Green Infrastructure workshop on identifying indicators and measuring efficiency of green infrastructure

The workshop outputs provided a series of principles on which indicators for GI could be identified and developed. These are briefly outlined below:

1. Define the audience

Indicators should be identified based on who they are intended to be used by and how they are to be used. The target audience may include the health sector, water companies, and the tourism sector. However, these indicators may need to be at a high level (eg improvements in health) and therefore at times difficult to attribute to Green Infrastructure without structured research.

2. The use of a basket of indicators

GI requires multiple indicators to represent its multi-facetted functions. This will need to acknowledge the competition and trade-offs between certain Ecosystem Services and make these explicit to decision-makers.

3. Consider indicators for different time-scales

GI implementation often requires long time-periods for benefits to come into effect; these are frequently too long for shorter policy cycle requirements. The use of a basket of indicators (above) should allow separate indicators to be used over different timescales, with simpler indicators such as hectares of habitat restored used in the short run and indicators about biodiversity and ecosystem services used in the medium to long term.

4. Using existing indicators from relevant sectors

It is clear that the Commission will not be able to increase the reporting burden on MS through a GI strategy. Therefore the use of existing indicators for which data is already being collated is an important consideration that could help ensure there is a consistent flow of adequate data is collected. This may extend to indicators being used by other sectors and DGs (eg DG Agriculture). Nonetheless, caution is warranted as these indicators have been designed with a different function in mind, and will have to be considered within the context a basket of other indicators.

5. Importance of including socio-economic indicators

The attendees highlighted the importance of indicators that reflected the potential benefits to society that GI has the potential to provide. These can include 'softer' indicators such as the degree of local engagement in initiatives, public perception of place or environment, wildlife in the local surroundings and so on. In some cases, these may be collated through existing data collection processes and questionnaires (eg EuroBarometer or national government surveys). The engagement of citizens can also have the knock-on effect of improving participation in the development of the initiative, for example through citizen science projects to improve data collection to support the indicators.

6. Potential indicators

These may include the new Community Specialisation Index, which reports on the homogenisation of ecosystems by the gradual removal of specialist species. The fragmentation index used in the latest EEA report, effective mesh size, was also touted as a useful indicator. The use of Ministry of Finance/Government cost-benefit analysis assessments and accepted methodologies (such as Net Present Value) were seen as a very useful way of mainstreaming the indicators and gaining policy acceptance.

7. Moving along the DPSIR framework

Rather than focusing on State, indicators can be used that provide information on other aspects, such as pressures and responses.

As mentioned in Box 4.5, a key issue that constrains the selection of indicators is the availability of data. This is a particular issue for indicators that rely on species data, because the monitoring of species is generally very labour intensive and there are a wide variety of taxa and habitats that need to be monitored to be able to draw balanced and representative conclusions. In order to reliably describe effects on a regional scale, all indices mentioned below need relatively detailed data on species abundance, preferably for both the present and past. Although data availability is vastly improving in several countries, it is obvious that data at this level of resolution in space and time is only available for some species at specific sites. The most promising groups in terms of quantitative data availability are birds, higher plants and butterflies. In certain areas, qualitative information on other groups of vertebrates (mammals, reptiles, amphibians and possibly fish) and easily recognisable groups of invertebrates (mainly dragonflies and carabid beetles) is also available or likely to become available in the near future. If this restriction is accepted, data availability for calculating biodiversity-based resilience-indicators is considered reasonable to good in national databases, especially for indicators based on birds, higher plants and/or butterflies.

Indicators at the community level, potentially much more powerful, are much less readily available, apart from a limited number of specific communities in a limited number of areas in a limited number of regions. However, here as well trends may become visible when they are based upon a few communities only, provided these communities can be considered as representing a range of different habitats. A major disadvantage of this type of indicator is that experience shows that the necessary data are likely to be mainly available in scattered local and regional organisations and are much less likely to be found in centralised databases.

In addition, the following criteria were also taken into account in the evaluation of potential sets of green infrastructure resilience indicators:

- Representative: the set of indicators provides a representative picture that provides information on all components of the widely used DPSIR chain (ie Drivers, Pressures, State, Impacts and Responses).
- Small in number: the smaller the total number of indicators, the easier it is to communicate cost-effectively to policy-makers and the public.
- Aggregation and flexibility: aggregation should be facilitated on a range of scales.

In summary, the detailed review provided in Annex II indicates that at present there is no single indicator that measures ecosystem resilience adequately on its own. It is the combination of the information of several, admittedly, sub-optimal, indicators that together give an indication of ecosystem resilience and changes therein. We therefore strongly advocate the use of a “basket” of indicators, taken from the different aspects of resilience mentioned above. In some cases, existing indicators can be used or need only a slight adaptation whereas for other aspects, new indicators need to be developed. We summarise our findings in Table 4-2 below.

Table 4-2 Summary of the potential suitability of existing indicators for assessing ecosystem resilience

RESILIENCE PROPERTY	INDICATOR	METRIC (REF)	SEBI-INDICATOR	ADVANTAGES	DISADVANTAGES	FEASIBILITY TO ASSESS RESILIENCE
Species composition	Species richness	Abundance and distribution of selected species	Yes	Existing data for species covered in SEBI can be used	Limited number of species included and richness not directly measured	Low-Moderate
	Occurrence of rare species	1. Red list index of European species 2. Species of European interest	Yes Yes	Existing data from SEBI; Reliability better than previous indicator	Only birds covered, and not necessarily an indication of high resilience	Low
	Occurrence of keystone species	Abundance and distribution of keystone species	No	Presumably good indicator of ecosystem resilience	Identity of keystone species poorly known	At present not suitable
	(Meta)-population stability	Changes in abundance and distribution of selected species. To be developed further into metrics like *Farmland Bird index*	Partly	Existing data for species covered in SEBI can be used	Limited number of species included at present in this indicator	Low-Moderate
Community composition	Intactness of community	Saturation index	No	Presumably good indicator of ecosystem resilience	Data availability likely to be reasonable to good but poorly accessible	Poor but prospects good in the near future
	Deviation from undisturbed conditions	1. Natural Capital Index 2. Mean Species Abundance	No No	Presumably good indicators of ecosystem resilience	At present applied only at a very high spatial level	Low
Ecosystem complexity	Complexity	Functional complexity	No	Presumably good indicator of ecosystem resilience	Data availability likely to be reasonable to good but poorly accessible	Poor but prospects good in the near future
	Food web stability	At present none	No	Presumably good indicator of ecosystem resilience	Scientific progress not far enough	At present not suitable
	Structural diversity	Spatial heterogeneity	No	Data availability good: relatively easy deducible from digital images	Indicative value for ecosystem resilience not proven; expert input necessary for interpretation	No experience yet but prospects good in the near future
Meta-	Meta-population size	Abundance and distribution of	Yes	Existing data for species	Limited number of species	Low-Moderate

population size		selected species		covered in SEBI can be used	included at present in this indicator	
Habitat patch area	Population viability	Size and variability of selected habitat types	Partly	Can be derived from existing data (CORINE, SEBI data on fragmentation etc.)	Present habitat coverage in SEBI is poor, needs further development	At present fair, prospects good in the near future
Functional habitat area/ connectivity	Fragmentation of natural and semi-natural areas	Share of natural lands in fragmented pattern and in unfragmented pattern per region, Average patch size of unfragmentated core natural pattern. Interface zones types	Yes	Uses existing land cover/use data (Corine)	Fragmentation differs for different groups, requiring cross-ecosystem study & present habitat coverage input data is poor, needs further development	At present moderate but significant improvements are possible
	Habitat fragmentation	Effective mesh size	No	Easily understandable concept of fragmentation; uses existing land cover/ use data	Does not take into account habitat quality or requirements of different taxa	At present moderate but significant improvements are possible
	Habitat connectivity	Habitat connectivity index for species dispersal capability (equivalent connected area of the habitat pattern in the landscape)	Partly (only minor difference)	Based on dispersal probabilities, intra and inter-patch connectivity, landscape permeability. It can distinguish impacts of changes in connectivity, from changes in habitat area and overall matrix quality	*High data and computational demand but pre-operational at JRC *Knowledge of dispersal capacities is lacking for many species	Good to very good
Habitat quality / condition	Environmental stress	Critical load Nitrogen, IAS, freshwater quality	Yes	Reliable existing indicators with a high spatial resolution	Nitrogen is now indicative for a range of stresses; may change under increasing success of nitrogen reduction policy	Moderate
	Habitat conservation status	Assessments under Article 17 of the Habitats Directive	Yes	Mandatory monitoring by Member States according to a consistent reporting framework, which should include an integrated assessment of condition	Only carried out for habitats of Community interest, and only every six years, assessment methods vary in practice	Moderate

4.3 Ecosystem services indicators

This section briefly considers the link between ecosystem resilience and the provision of ecosystem services. It then reviews the main indicators that have been proposed for the measurement of ecosystem service provision (Table 4-3), and considers which of these may help assess the contribution that Green Infrastructure initiatives make to the maintenance, restoration or enhancement of such services. However, it is beyond the scope of this study to provide a comprehensive or detailed analysis of the use of existing indicators in monitoring Green Infrastructure impacts on ecosystem services. This is in part because current indicators for most ecosystem services are not comprehensive and are often inadequate to fully capture the diversity and complexity of the benefits ecosystems provide (Layke, 2009). Furthermore, the relevance of indicators will vary according to needs; such that a set of headline indicators could be used for communicating the benefits of Green Infrastructure, whereas a more comprehensive basket of indicators capturing multiple ecosystem services would be adequate for monitoring.

Table 4-3 Ecosystem service indicators for measure green infrastructure effectiveness

Ecosystem Service	Indicator
Provisioning services	
Food provision	Crop production from sustainable [organic] sources
	Area of agricultural land
	Livestock production from sustainable [organic] sources
	Fish production from sustainable [organic] sources (eg proportion of fish stocks caught within safe biological limits)
	Number of wild species used as food
	Wild animal/plant production from sustainable sources
Water (quantity)	Total freshwater resources
	Population served by renewable water resource
	Renewable water supply
	Water storage capacity
Raw materials	Forest growing stock, increment and fellings
	Felling to increment ratio
	Industrial roundwood in million m^3 from natural and/or sustainably managed forests
	Pulp and paper production in million tonnes from natural and/or sustainably managed forests
	Cotton production from sustainable [organic] resources in tonnes and/or hectares
	Forest biomass for bioenergy in million tonnes of oil equivalent (Mtoe) from different resources (eg wood, residues) from natural and/or sustainably managed forests
Genetic resources (for food security)	Number of crop varieties for production
	Livestock breed variety
	Number of fish varieties for production
	Number of species that have been the subject of major investment or have become a commercial product
Medicinal resources	Number of species from which natural medicines have been derived
Ornamental resources	Number of species used for handcraft work
	Amount of ornamental plant species used for gardening from sustainable sources
Regulating services	
Air quality regulation	Atmospheric cleansing capacity in tonnes of pollutants removed per hectare
	Downward pollutant flux, calculated as the product of dry deposition velocity

	and pollutant concentration
	Pm_{10} removal by tree cover
Climate/climate change regulation	Total amount of carbon sequestered / stored =sequestration / storage capacity per hectare x total area (Gt CO_2)
	Net Carbon Exchange
	Net Ecosystem Productivity
	Evapotranspiration rate
	Canopy stomatal conductance
Moderation of extreme events (eg storm protection and flood prevention)	Trends in number of damaging natural disasters
	Probability of incident
	Flood attenuation potential: residence time of water in rivers, reservoirs and soil
	Floodplain water storage capacity
	Soil capacity to transfer groundwater
	Wave attenuation potential
	Surface area of coastal wetlands and dunes
Regulation of water flows (eg natural drainage, irrigation and drought prevention)	Water infiltration capacity/rate
	Soil water storage capacity in mm/m
	Floodplain water storage capacity in mm/m
Waste treatment (especially water purification)	Water quality in aquatic ecosystems (sediment, turbidity, phosphorous, nutrients, etc.)
	Biological indicators: eg Index of Biological Integrity, European Water Framework Directive Ecological Status, Wetland Biological Condition, species traits as indicators of environmental stress
	Nitrogen retention
	Nitrogen removal
Erosion prevention	Soil erosion rate by land use type
	Functional traits as proxy indicators of service provision, eg rooting depth and structure of plants
	Soil quality indicators: infiltration capacity, bulk density as indicator of compaction
Maintenance of soil fertility (resulting from soil formation)	Soil carbon content
	Species composition, aggregated in functional groups (eg biomass of decomposers, proportion of different trophic groups) as an indicator of process capability
Pollination	Abundance and species richness of wild pollinators
	Range of wild pollinators (eg in km, regular/aggregated/random, per species)
	Proximity to natural habitat
Biological control (eg seed dispersal, pest and disease control)	Abundance and species richness of biological control agents (eg predators, insects, etc.)
	Landscape complexity in agro-ecosystems
	Range of biological control agents (eg in km, regular/aggregated/random, per species)
	Changes in disease burden as a result of changing ecosystems
Noise regulation	Persons/year where defined threshold in dB is not exceeded due to natural sound absorbers
Cultural services	
Landscape and amenity values	Changes in the number of residents
	Changes in the number of visitors to a site to enjoy its amenity services
	Number of products whose branding relates to cultural identity
	Comparative value of real estate nearer to nature
Opportunities for recreation and tourism	Number of visitors to protected sites per year
	Amount of nature tourism
	Number of recreational users of green space
	Number of recreational anglers and hunters

Cultural values and inspirational services, eg education, art and research	Total number of visits to sites specifically related to education or cultural reasons
	Number of TV programmes, studies, books etc. featuring sites and the surrounding area
Supporting services	
Nutrient cycling	Soil organisms/functional groups
	Nutrient retention/removal rates
Primary production	Net primary production
Provision of habitat	Conservation status of habitats and species
	Number of species for which the GI element provides habitat
Maintenance of genetic diversity	Species diversity
	Phylogenetic diversity
	Area managed for gene conservation
	Degree of connectivity

In many cases, the delivery of ecosystem services depends on the maintenance of biodiversity (Díaz et al, 2005) and ecosystem resilience, as discussed in the section 4.2. Supporting services in particular, such as primary production and nutrient cycling, are critically dependant on biodiversity. Soil biodiversity is a major factor in soil formation and its loss may have damaging consequences on the provision of other services. Similarly, there is evidence that the spread of pathogens is less rapid in more biodiverse ecosystems and that a diverse soil community can help prevent loss of crops due to soil-borne pests and diseases. The presence of a diverse pool of pollinators tends to produce greater crop yields (EASAC, 2009). However, the precise mechanisms by which biodiversity enhances the delivery of ecosystem services are in many instances poorly understood (EASAC, 2009) and it is difficult to establish quantitative links between biodiversity and ecosystem services (TEEB, 2010).

One mechanism explaining the link between biodiversity and ecosystem services is 'niche complementarity': an increase in diversity often leads to an increase in productivity due to complementary traits among species for resource use, and productivity itself underpins many ecosystem services (Díaz et al, 2005; TEEB, 2010). The positive effects of species diversity on ecosystem processes can also be explained by a 'sampling effect': the greater the number of species in an ecosystem, the higher the probability that species performing particularly well under certain conditions will be present therein (Díaz et al, 2005).

A growing body of scientific evidence suggests that it is functional diversity, rather than species diversity *per se*, that enhances ecosystem functions (Loreau et al, 2001). Redundancy of functional traits (ie the presence of more than one species performing the same functional role in an ecosystem process) has been shown to increase resilience and to help maintain ecosystem services (TEEB, 2010). Proposed indicators of functional diversity may therefore have some potential for measuring the delivery of some regulating services. It has also been suggested that the diversity of responses to environmental change among species contributing to the same ecosystem function is critical to ecosystem resilience (Elmqvist et al, 2003). Such species may replace each other, contributing to the maintenance of ecosystem functions over a range of environmental conditions (Elmqvist et al, 2003). Luck et al (Luck et al, 2003) suggest that population diversity, with its four key components, population richness, size, distribution and genetic differentiation, has implications for service provision.

Koch et al. (Koch et al, 2009) underline the importance of accounting for non-linear relationships between ecological traits and ecosystem function, and between ecosystem function and service delivery. The responses independent variables such as ecosystem size, seasonality, disturbance and species interactions generate in ecosystem functions are highly dynamic and non-linear across space and time.

Indicators of quantity measure the status and trends in habitat area and species population and often show clear links to some provisioning services. They can also be applied to the measurement of cultural services linked to ecosystems and species of social or cultural value. They are potentially useful indicators of regulating services that rely on biomass or a particular habitat, such as carbon sequestration, pollination, erosion control and water flow regulation (Reyers et al, 2009, cited in TEEB, 2010).

Indicators of condition focus on the quality and integrity of the ecosystem assessed. However, the links to service provision are not evident, given our limited understanding of the relationship between ecosystem integrity and benefit flow, as well as gaps in our knowledge of functional thresholds (TEEB, 2010). The scientific literature on resilience has shown that when critical thresholds are reached and a regime shift in an ecosystem occurs, the ecosystem's capacity to provide ecosystem services can change drastically and in a non-linear way (Folke et al, 2002, cited in (TEEB, 2010). The distance to an ecological threshold affects the value of ecosystem services given the state of the ecosystem (Limburg et al, 2002, cited in (TEEB, 2010)). Ideally, ecosystem service indicators should allow us to anticipate proximity to such tipping points. However, few of the available indicators are able to do so; further advances in scientific knowledge are needed in order to anticipate shifts with precision (TEEB, 2010).

A range of biodiversity indicators have been developed and tested at global and EU level (some of which are review in section 4.3 above), however, their primary purpose is to monitor biodiversity status and trends and ecosystem condition or pressures, rather than ecosystem services provision. In so far as they can be applied to the measurement of ecosystem services, such indicators reflect the stock of services rather than the flow of benefits. Among the headline indicators developed by the Biodiversity Indicators Partnership under the CBD, some can be used to assess provisioning services (eg forests and agricultural areas under sustainable management, proportion of products derived from sustainable sources, crop genetic diversity) and ecosystem condition that underpins some regulating services (eg water quality of freshwater ecosystems, forest fragmentation, river fragmentation and flow regulation).

The Singapore Index on Cities' Biodiversity (CBI) comprises indicators of ecosystem services provided by urban biodiversity, but they reflect the stock of urban Green Infrastructure rather than the benefits delivered. The regulation of water quantity during periods of high precipitation is measured in the CBI as the proportion of all permeable areas to the city's total terrestrial surface. The ratio of tree canopy cover to the total terrestrial area of the city is used as an indicator of vegetation's carbon storage and cooling effect.

The scientific community has also developed indicators for the measurement of specific ecosystem processes, however, in most cases, the measure of such processes is not easily linked to the benefits they underpin; for example, it is not straightforward to quantify a service provided by tree cover, such as air quality or local climate regulation, based on canopy stomatal conductance or plant evapotranspiration rates. Moreover, such indicators are often difficult to scale up to national or regional policy level.

Some of the specific indicators proposed in the existing scientific literature are discussed below.

4.3.1 Provisioning services indicators

Available indicators for provisioning services provide for a more complete understanding of the service than for most regulating and cultural services (Layke, 2009). Many of these indicators are derived from other sectors (eg forestry, agriculture, fisheries) where they have been used to quantify tradable commodities.

Indicators of food provision services include direct measures of crop, livestock and fish production and the number of wild species used as human food. One limitation of such measures is that the actual level of service provision might not indicate the level at which the service can be provided in the long-term. To assess the sustainability aspect of a service, it has been proposed that all relevant supporting ecosystem functions and components that are needed for the provision of this service be considered. For instance, to estimate whether current levels of agricultural production can be sustained (eg without long-term losses in soil fertility), the underlying supporting services including soil formation, erosion, and nutrient cycling need to be taken into account (Paetzold et al, 2010).

Common indicators for the provision of timber include standing stock volume and stock increment (Maes et al, 2011). Forest inventory data or estimates of dry matter productivity (DMP) have been used to measure stock increment. The DMP index provides a measure of the vegetation growth in kilograms of dry matter per hectare and represents the annual amount of new dry matter created by the ecosystems (TEEB, 2011). Stock increment reflects the ecosystem’s capacity to produce timber, but does not give an indication of its sustainable use. To address sustainability, SEBI indicator 017 represents the ratio of felling to increment. Timber increment, however, may be due to increased use of fertiliser or the planting of alien species (EEA, 2010c).

Measuring the provision of timber in isolation risks overlooking inevitable trade-offs between provisioning and regulating services. As TEEB (2011) underscores, forests provide a bundle of ecosystem services, including carbon sequestration, scenic values, watershed protection and cultural services, which interact with one another in a dependent and non-linear fashion. Harvesting timber may cause declines in other forest-related services.

Indicators of water quantity include total freshwater resources, renewable water supply, and ecosystems’ water storage capacity. Since the total quantity of water available is also affected by a number of abiotic attributes, such as topography and temperature, it is often difficult to specify what proportion of fresh water supply is related to biodiversity as such (Kettunen et al, 2009).

4.3.2 Regulating services indicators

Indicators of regulating services are generally less developed, partly due to the complexity of quantifying processes. Another challenge to identifying suitable indicators for regulating services is that in certain cases the indicator would be a measure of avoided change. This entails measuring a negative occurrence that has not happened due to the contribution of a regulating service (Layke, 2009).

Some of the existing indicators for regulating services have been developed in other policy areas, eg with respect to climate change or pollution control. For example, carbon sequestration/storage capacity and changes in carbon stock are used to measure the impact of deforestation and forest degradation in the context of REDD. Air cleansing capacity has been used to indicate the air quality service provided by tree cover, while the avoided early mortality and hospital admissions are an indicator of the net health benefits associated with this service.

To quantify the regulation of air quality, Maes et al (Maes et al, 2011) use dry deposition velocity as an indicator expressing the capacity of vegetation to capture and remove air pollutants. This is then multiplied by concentrations of NO_2, SO_2 and NH_3 to assess the service flow. One limitation is that the indicator does not take into account critical loads, ie the maximum amount of pollutants ecosystems can tolerate without being damaged (Maes et al, 2011). Although average values of deposition velocity exist and could be potentially transferred, the process is influenced by a range of context-specific factors, such as humidity, wind velocity, air temperature, soil moisture availability, and tree health (Jim and Chen, 2008).

Global climate regulation is the only regulating service deemed to have a relatively comprehensive set of indicators in the assessment of Layke (2009). However, most of the indicators for this service were given only medium scores for their "ability to convey information", indicating that they require further improvement.

The carbon sequestration/storage capacity of ecosystems is the most commonly used indicator of global climate regulation services. Whereas the measurement of carbon sequestration by forests is relatively well established and accurate, the measurement of carbon sequestration by soil, water and other biomes is less developed and not standardised (TEEB, 2009). A review of current knowledge on the interrelations between soil and climate change reported a lack of systematic, reliable and comparable data across the EU on the soil carbon stock and changes therein. Moreover, no harmonized EU-wide system for monitoring soil carbon storage is in place (Schils et al, 2008).

Of particular relevance to urban green infrastructure is regulation of the local or regional climate. Indicators proposed for this service include canopy stomatal conductance and the evapotranspiration rates of vegetation (Forest Research, 2010).

The presence and surface area of land cover associated with the provision of hazard protection services have been used as proxies for the ecosystem's capacity to modulate the effects of extreme events. For example, Maes et al (Maes et al, 2011) mapped the area of coastal wetlands and dunes as an indication for the capacity of ecosystems to protect against the consequences of sea-borne storms affecting the coast. Their model, however, does not take into account differences between types of coastal wetland in reducing the impact of storms. Wave attenuation weights could be assigned to each land cover class to determine how much each ecosystem contributes to reducing wave height (Maes et al, 2011). To quantify the actual benefits derived, the annual probability of a storm would also have to be taken into account. Constanza et al (Constanza et al, 2008) performed a multiple regression analysis using data on 34 hurricanes that have hit the US since 1980 with relative damages as the dependent variable and wind speed and wetland area as the independent variables. The resulting relationship between wetland area and hurricane-related damage was then combined with data on annual hurricane frequency to derive estimates of the annual value of wetlands for storm protection.

An indicator of flood attenuation potential in the inland water system is the residence time of water in rivers, reservoirs, and soils. This is defined as the time during which water falling as precipitation remains within a system, before continuing around the hydrological cycle. The longer the residence time, the larger the ecosystem's buffering capacity to attenuate peak flood events (de Guenni et al, 2005). Several ecosystem conditions underpin this process and could be used as proxy indicators. The soil's water retention capacity is dependent on soil texture and structure (de Guenni et al, 2005).

In general, indicators of water flow regulation, such as water infiltration capacity, are largely dependent on local characteristics, making them difficult to scale up beyond project level.

Indicators of water quality in freshwater ecosystems are relatively advanced. They include Biochemical Oxygen Demand (BOD), nitrate concentration, suspended sediments (indicating the degree to which the drainage basin has been eroded or disturbed and related changes in the water flow regime), water pH and temperature. However, as Linstead et al (Linstead et al, 2008) point out, when measuring the water quality regulation service, "it is the degree to which ecosystems mediate the translation from pressure to state that is of interest". Indicators of pressure and of state should therefore be combined to give an indication of the magnitude of service delivery.

A more direct measure of water purification services is the level of nitrogen retention or removal by a given ecosystem. This indicator has been applied, for example, to measure the efficiency of wetlands in controlling water pollution (Gren, 1995; Mustafa et al, 2008).

With regard to erosion control, a review of existing ecosystem service indicators applicable to the UK context (Linstead et al, 2008) found no indicators that could be used to directly monitor the provision of this service. Several proxy indicators exist to measure the potential for ecosystems to regulate erosion, based on inferred relationships between erosion and ecosystem traits. For instance, the length of hedgerows and boundary features has been used as an indicator of the potential for erosion regulation because of the role played by linear landscape features in controlling soil movement. The area of land under agri-environment schemes was also considered a good indicator of the potential for agricultural areas to provide the erosion control service given the measures that are implemented under such schemes for the control of erosion (eg Soil Management Plans) (Linstead et al, 2008). Indicators of soil quality, such as soil infiltration capacity and bulk density (an indicator of compaction) (Herrick, 2000) and species' functional traits, such as the rooting depth and structure of plants (Layke, 2009), could also be used as a proxy for erosion control.

Maes et al (Maes et al, 2011) measure the capacity of ecosystems to provide erosion control services by intersecting the map of annual soil erosion risk (based on the MESALES model) with a map of the CORINE Land Cover classes of natural vegetation. The resulting map was used to spatially identify ecosystems situated in areas of different erosion risk, giving more weight to ecosystems in high-risk areas.

The process of soil formation depends on the nature of the parent materials, biological processes, topography and climate (TEEB, 2010). Physical, chemical, and biological indicators have been applied to measure soil quality. Physical indicators measure effects on root growth, the speed of plant emergence and water infiltration. They include soil depth, bulk density, porosity, aggregate stability, texture and compaction (Martinez-Salgado et al, 2010). Chemical indicators include soil pH, salinity, organic matter content, phosphorus availability, cation exchange capacity, nutrient cycling, and the presence of contaminants such as heavy metals and organic compounds. Such indicators determine the availability of nutrients and water for plants and other organisms, and the mobility of contaminants (Martinez-Salgado et al, 2010).

The progressive accumulation of organic materials is regulated by the activity of a wide range of microbes, plants and associated organisms. Nitrogen cycling, in particular, underpins soil quality and depends on the presence of key functional groups (TEEB, 2010). Although the use of soil biota as indicators of soil quality has a long tradition in applied ecology, most soil quality indices still require further comprehensive work in terms of validation and standardisation (Feld et al, 2007).

The RUBICODE project found that biotic indicators predominate in existing research on soil quality, with micro-organisms being most commonly used. Two thirds of the indicators reviewed by the RUBICODE project referred to direct measures such as soil respiration (used to measure microbial activity related to decomposition of organic matter in soil) and soil organic matter content, microbial biomass measured by phospholipid fatty acids and enzymatic activity, as well as abundance, biomass and species composition of organisms (Feld et al, 2007; Martinez-Salgado et al, 2010). Soil organisms are considered to be sensitive indicators, as they reflect the influence of land management and climate change (Martinez-Salgado et al, 2010).

Soil organic carbon content is considered one of the most important indicators of soil quality (Martinez-Salgado et al, 2010). It promotes water infiltration, storage and drainage and is directly related to the maintenance of soil structure, the presence of different groups of microorganisms, mineralisation of organic matter, and nutrient availability (Martinez-Salgado et al, 2010). Some researchers have pointed out, however, that changes in total soil organic matter content as a result of land management changes may be difficult to detect (Haynes, 2000; Chan et al, 2002, cited in Martinez-Salgado et al, 2010).

Breure et al (Breure et al, 2005) underscore the need for a holistic approach in measuring soil quality, taking chemical, physical, and biological characteristics of the soil into account and recognising the complexity of ecological interactions. In this respect the use of indicators based on the composition and abundance of soil invertebrate communities, could be highly appropriate, because invertebrates are an important component of soil function and highly responsive to changes in a variety of soil properties (Lavelle et al, 2006).

The abundance, species richness and range of wild pollinators have been used to measure pollination services. The spatial distribution of resources at landscape level and the foraging and dispersal movements of wild pollinators are key to the provision of this service (Kremen et al, 2007). A review of landscape effects on crop pollination services found strong evidence of a sharp decline in pollinator richness and visitation rates with increasing isolation from natural nesting habitat (Ricketts et al, 2008). The distance between natural habitats and agricultural fields is therefore a good predictor of pollination service delivery. However, the main benefit resulting from this service is crop productivity and further research is needed to measure the effects of pollinator richness and visitation frequency on productivity (Ricketts et al, 2008). The size and quality of habitat required for the sustainability of pollinator communities can be used as a proxy indicator for service provision, but this approach requires a reasonable understanding of the relationships between habitat, pollinators and service delivery (Vandewalle et al, 2010).

Abundance and species richness are also applied to measure biological control (Balmford et al, 2008). However, the expected benefits of diversity on the provision of biological control may be countered by antagonistic effects between different natural enemy species, such as competition and intra-guild predation (Kremen and Chaplin-Kramer, 2007, cited in (Balmford et al, 2008). Natural enemy populations respond positively to greater landscape heterogeneity, which can therefore be used as a proxy indicator of the biological control service. Both abundance and enemy activity (eg measured as rate of predation) were found to increase with landscape complexity in the majority of studied cases (Kremen and Chaplin-Kramer, 2007, Bianchi et al 2006, in (Cai et al, 2008). However, the existing empirical literature is inconclusive with regard to the effect of landscape complexity on pest pressure, as increased spatial heterogeneity may sometimes also benefit pests. Overall, the experimental evidence suggests that agricultural areas interspersed with area of non-crop habitat will generally exhibit more diverse and active natural enemy communities and, at least in some cases, experience lower level of pest pressure (Cai et al, 2008).

4.3.3 Cultural services indicators

Evaluations of landscape and amenity values associated with an ecosystem often use the comparative value of real estate as an indicator. However, property values may be influenced by a range of attributes, making it difficult to isolate the effect of landscape aspects. The number of people visiting a site to enjoy its amenity values or to make use of the recreation and tourism opportunities the site provides is the other commonly used indicator for cultural services.

4.3.4 Supporting services indicators

Most indicators of nutrient cycling relate to soil processes and the functional or taxonomic groups of organisms underpinning them. The contribution of soil organisms to nutrient cycling has been quantified for a number of ecosystems. Some of these processes, especially in the nitrogen cycle, are carried out only by very specific organisms, while others, such as organic matter decomposition and nutrient mineralisation, are mediated by interactions within a diverse group of bacteria, fungi, protozoans and invertebrates (Swift et al, 1998). While the relationship between key species or functional groups and nitrogen cycling is well established, the role of soil species richness in ensuring resilience of nutrient cycles under changing environmental conditions (eg climate or land use change) is less clear (Swift et al, 1998). At the landscape level, various characteristics of the ecosystems known to play a role in nutrient cycling have been suggested as proxy indicators of service provision, eg the density and distribution of buffering zones such as riparian forests or the diversity of land-use types in mosaics (Lavelle et al, 2006). The rate of nutrient retention or removal by ecosystems is another indicator that has been applied, for example, to evaluate wetland functioning in relation to nutrient loadings in water bodies (Feld et al, 2007).

Regarding maintenance of genetic diversity, an indicator already applied to sustainable use zones is the area managed for the conservation of genetic resources and seed production. Applied to forest ecosystems, this is, for example, one of the Pan-European Indicators for Sustainable Forest Management under the criterion ‘maintenance, conservation and appropriate enhancement of biological diversity’. Since landscape pattern influences the process of gene flow, the degree of connectivity (ie the degree to which the landscape facilitates or impedes the movement of species with specific dispersal capabilities), can be used as a proxy for the maintenance of genetic diversity (Forest Europe et al, 2011).

A summary of the relevance of key ecosystem service indicators to the potential impacts of Green Infrastructure initiatives, and their potential use in this respect, is provided in Table 4-4 below.

Table 4-4 Summary of the relevance of key ecosystem service indicators to the potential impacts of green infrastructure initiatives

Key: N = Nil; L = Low, M = Medium, H = High; V = variable, ? = uncertain

Indicator	Proxy or direct ES indicator?	Indicator of service or of benefit?	Indicator sensitivity	Link to biodiversity	Dependency on ecosystem resilience	Potential GI benefits
Crop / Livestock / Fish / Wild foods production from sustainable sources	Direct	Benefit	L	Yes (soils, pests, pollinators)	H (soils and low)	L
Groundwater recharge	Direct	Service?	L	Vegetation	L	M
Population served by renewable water resource	Direct	Benefit	M	Vegetation	L	V
Forest growing stock, increment and fellings	Direct		M	Yes	L	M
Felling to increment ratio	Direct		M	Yes	L	M
Atmospheric cleansing capacity	Direct	Service	?	Yes	L	M / H in urban areas
Total amount of carbon sequestered / stored	Direct	Service	M	Yes (soil & vegetation)	V (eg H in some peatlands)	M
Trends in number of damaging natural disasters	Proxy	Benefit	M	V	V	M
Probability of incident	Proxy	Benefit	M	V	V	M
Residence time of water in rivers, reservoirs and soil	Direct	Service	L	Yes	L	H
Floodplain water storage capacity	Direct	Service	L	No	N	H
Flood return period	Direct	Benefit	H	Yes	L	H
Wave attenuation potential	Direct	Service	M	Yes (vegetation)	M	H
Surface area of coastal wetlands and dunes	Proxy	Service	L	Yes (vegetation)	M	H
Water quality in aquatic ecosystems	Direct	Service	V	Yes	M	M
Nitrogen retention	Direct	Service	?	Yes	M	M
Nitrogen removal	Direct	Service	?	Yes	M	M
Soil erosion rate by land use type	Direct	Service	M	Yes	L	H
Soil quality (infiltration capacity, bulk density, etc)	Proxy	Service	L	Yes	H	M
Abundance and species richness of wild pollinators	Proxy	Service	M	Yes	M	M
Proximity to semi-natural habitat	Proxy	Service	L	Yes	H	H
Presence of nectar-producing flowers	Proxy	Service	M	Yes	M	M
Abundance and species richness of biological control agents	Proxy	Service	M	Yes	H	M
Changes in disease burden as a result of changing ecosystems	Proxy	Benefit	M	Yes	M	M

Indicator	Proxy or direct ES indicator?	Indicator of service or of benefit?	Indicator sensitivity	Link to biodiversity	Dependency on ecosystem resilience	Potential GI benefits
Number of visitors for nature tourism	Proxy	Benefit	M	Yes	M	H
Number of products whose branding relates to cultural identity	Direct	Benefit	L	V	V	L
Number of recreational users of green space	Direct	Benefit	M	Yes	L	H
Number of hunters / anglers	Direct	Benefit	M	Yes	M	H
Total number of visits to sites specifically related to ecosystem related education or cultural reasons	Direct	Benefit	M	Yes	M	H

5 THE CONTRIBUTION OF GREEN INFRASTRUCTURE TO ECOSYSTEM RESILIENCE AND BIODIVERSITY CONSERVATION

5.1 What is connectivity?

One of the most commonly stated aims of green infrastructure, and especially initiatives that attempt to spatially integrate multiple elements, is the maintenance and enhancement of ecological connectivity. This chapter therefore starts with a brief discussion of what ecological connectivity is and why it is important. Connectivity concerns the degree of movement of organisms or processes through a landscape, but there is no single accepted definition of this concept within ecology and conservation (Crooks and Sanjayan, 2006). One frequently cited definition (Taylor et al, 1993; cited in Crooks and Sanjayan, 2006) describes connectivity as the degree to which the landscape impedes or facilitates movement among resource patches.

The theory of island biogeography (MacArthur and Wilson, 1967) provides much of the scientific rationale for the restoration of connectivity at the landscape scale within conservation practice. Habitats can be characterised as 'islands' in a 'sea' of inhospitable habitat, known as the 'matrix'. The long-term survival of many organisms is strongly dependent on their ability to move between habitat patches, allowing the flow and exchange of genetic information, access to food and to mates, and the ability to migrate away from potentially damaging environmental stressors to more suitable areas. High quality sites containing the range and area of habitat required by species, and the connections between these sites, comprise an ecological network (Lawton et al, 2010). Such networks operate at a range of geographical scales.

Connectivity has two important components. The first is structural connectivity, which describes the physical relationships between components of an ecological network, such as habitat patches or corridors. Functional connectivity in contrast takes into account the behavioural response of species to the structure of the landscape, its degree increasing when a change in the landscape structure increases the movement or flow of organisms through this landscape (Taylor et al, 2006). A habitat does not need to be structurally connected to be functionally connected and vice versa; for example, a habitat cannot be considered to be functionally connected if physically ('structurally') connected by an underpass beneath a roadway which species do not use (Taylor et al, 2006). Functional connectivity is the most important in providing ecologically valuable connections between landscapes (Kettunen et al, 2007).

Understanding the connectedness of landscape only makes sense in relation to a target species under consideration, as different organisms make use of and move through landscapes in very different ways. A multi-taxonomic approach is therefore necessary to evaluate the effectiveness of measures for the mitigation of the impacts of grey infrastructure, such as roads and railways, on wildlife (Crooks and Sanjayan, 2006), or the effectiveness of natural connectivity features such as hedgerows.

5.2 Core Areas

5.2.1 What is a core area?

Core areas are sites of high ecological quality and conservation interest, where the conservation of biodiversity takes primary importance (Kettunen et al, 2007). These areas form the heart of an ecological network, acting as refuges where species can thrive and from which they can disperse. For these reasons, core areas are the elements of ecological networks that are afforded protected status most frequently.

Within the EU core areas should undoubtedly include all Natura 2000 sites as designated under the Birds and Habitats Directives, irrespective of their size, location, condition and protection regime. There are presently (June 2011), 26,106 Natura 2000 sites in the EU, covering a total of 949,910 square kilometres. Terrestrial Natura 2000 sites cover 751,150 square kilometres, or 17.5 per cent of Europe's land area, whilst marine sites cover 198,760 square kilometres (European Commission, 2011). However, it is also important to point out that other sites should be regarded as core areas where they hold significant populations of targeted species of conservation concern or areas of threatened habitat. Thus core areas should include areas that are of national or regional for such habitats and species, irrespective of their current protection status. For example, all sites that are listed as being Important Bird Areas in Europe (Heath and Evans, 2000) should normally be considered worthy of inclusion in core areas in green infrastructure initiatives.

In England a recent review of the wildlife site network (Lawton et al, 2010) concluded that three tiers of sites that are important for wildlife can be recognised (see Box 5.1). Of these Tier 1 and 2 sites could probably be considered to constitute core areas in the sense of green infrastructure because they are of particular biodiversity importance. But Tier 3 sites such as those designated for the beauty of their landscapes may also play an important role in supporting viable populations of species and habitats, and enhancing connectivity between core sites. This illustrates the difficulty of distinguishing between core sites and other green infrastructure elements, such as sustainable use areas and small sites that might act as natural connectivity features (eg stepping stones).

Box 5.1: The network of wildlife sites in England (after Lawton et al, 2010)

In England, Sites of Special Scientific Interest (SSSI) comprise the backbone of the protected area series, covering 810,314 hectares, or 6.1 per cent of the country's terrestrial area. The entire extent of Special Protected Areas (SPAs), designated under the Birds Directive (Council Directive 79/409/EEC), Special Areas of Conservation (SACs) designated under the Habitats Directive (Council Directive 92/43/EEC) and sites designated under the Ramsar Convention on Wetlands of International Importance are also designated as SSSIs (Lawton et al, 2010). These sites, along with National Nature Reserves, almost all of which have also been designated as SSSIs, and Local Nature Reserves, of which 40 per cent are SSSIs, can be described as 'Tier 1' protected sites, meaning that they enjoy a high level of protection.

In contrast, 'Tier 2' sites within England do not receive full statutory protection but can nonetheless act as significant core areas within ecological networks. As an example, there are 42,000 Local Wildlife Sites across the country, covering 690,000 hectares. These sites are designated to represent the most distinctive, rare and threatened species in a sub-national context and may play an extremely important role in regions where SSSI representation is low. In practice, whether particular classifications of sites can be considered as stand-alone 'core' sites or as 'stepping stones' is largely context dependent (Hodgson et al, 2009).

'Tier 3' sites in England comprise those which have not been designated primarily for the purpose of nature conservation but for recreation, landscape or cultural purposes. Wildlife conservation nonetheless forms part of their statutory purpose. Such sites include Areas of Outstanding Natural Beauty (AONB), of which 12 per cent is also designated as SSSI and National Parks, 24 per cent of the total area of which is SSSI. These percentages include SSSIs designated for geological, rather than biological purposes.

5.2.2 To what extent do core areas potentially protect biodiversity?

For a portfolio, or collection of sites, an important measure of effectiveness is how well the sites represent the full range and examples of a particular feature regionally or nationally (Gaston et al, 2006). Published data on the coverage of threatened habitats and species populations by protected areas is not available at a European scale. However, the Habitats Directive requires Member States to designate sufficient Natura 2000 areas to maintain or restore the favourable conservation status of habitats and species of Community interest. The network should therefore in theory provide adequate coverage to provide substantial biodiversity benefits.

The likely coverage benefits of the Natura 2000 sites, and other protected areas in Europe, is also supported by some national studies. For example, in Estonia Vellak et al, (2009) examined the past and present effectiveness of protected areas in Estonia for the conservation of rare plant species, and found that the adoption of the Estonian Nature Protection Law in 1960 was effective in improving the coverage of species within protected areas needing grassland and forest management. The creation of larger nature reserves covering many habitats may have been the vehicle to allow this. The implementation of the Natura 2000 network since the beginning of the 21st Century has increased the coverage of rare plant species within Estonian protected areas, reaching the 60 per cent target under the Global Strategy for Plant Conservation (2002 – 2010).[11]

Lawton et al (2010) conclude that together Tier 1, 2 and 3 sites (see Box 5.1) provide significant protection for threatened species in England. Together these sites encompass 96 per cent of threatened plant species, 98 per cent of threatened bryophytes and 100 per cent of butterflies listed as a priority under the Biodiversity Action Plan (BAP). Similarly, Jackson et al (2009) found that 88 per cent of 371 Red List vascular plant species of conservation concern were represented within the SSSI network. However, given the continuing loss of species from England (Maclean, 2010; Natural England, 2010), SSSIs have proven to be necessary but not sufficient as conservation tools. This highlights the need for core areas to be seen and managed as part of an integrated ecological network, with adequate areas of habitat that are suitable and sufficiently ecologically connected to maintain ecosystem processes and species in the wider environment.

The importance of connectivity amongst core sites

Although cores sites should be seen as part of a network, a recent review of published evidence (Hodgson et al, 2011) suggests that the quantity and quality of habitat patches is more important than the spatial arrangement of these habitats in supporting multi-generational range shifts in terrestrial species. High quality habitat leads to increased population growth and a greater number of dispersing organisms. The aggregation of habitats (their arrangement in the ecological network) increases the chance of a migrating

[11] Convention on Biological Diversity (2011) *Global Strategy*. http://www.cbd.int/gspc/strategy.shtml. Accessed 23.11.11

individual finding themselves in a suitable habitat but the authors argue that this can only compensate a little for overall deficiencies in the quality and quantity of habitat. A recent review of England's protected area network likewise concludes that better management of existing core sites and increasing the size of these, should take precedence over the creation of further sites and the development of connections between them (Lawton et al, 2010).

The effects of site area

As discussed in Chapter 4 it is well accepted within ecological theory that there is a positive relationship between the size of an area and species richness (number of species) (MacArthur & Wilson, 1967). It is almost always the case that larger sites will support more species than smaller sites, as larger sites are more likely to be physically heterogeneous, allowing niche specialisation and support larger populations less vulnerable to fluctuation and to the effect of random events (Connor and McCoy, 1979). Small populations in small patches of isolated habitat are also more likely to go extinct (see Box 5.2). A study of 16 nature reserves in Hungary found habitat heterogeneity, rather than size *per se*, to be the most important factor in determining the density of arthropod species (Báldi, 2008).

Box 5.2: Impact of patch size on selected butterfly species

Local extinction is most frequently observed in populations of Silver-studded Blue (*Plebeius argus*) and Silver-spotted Skipper (*Hesperia comma*) butterflies found on small patches (Thomas and Harrison, 1992; Thomas and Jones, 1993). Thomas et al (1992) found that as patch size increased and the distance to the nearest occupied patch decreased, habitat patches were more likely to be found to be occupied by four butterfly species under study. However, extinction can hit habitats of any size if there is a significant deterioration in quality: local extinction rates in the Heath Fritillary (*Melitaea athalia*) and Black Hairstreak (*Satyrium pruni*) depend more on time since habitat creation than patch size, as these species depend for their survival on particular successional stages of woodland (Thomas et al, 1992).

In this context, it can be noted that 68 per cent of Natura 2000 sites are smaller than 10 square kilometres, whilst 11.4 per cent are smaller than 10 hectares[12]. Ninety per cent of protected areas designated in Europe are smaller than 1000 hectares (Zisenis et al, 2010). Seventy seven per cent of the SSSIs and 98 per cent of Local Wildlife Sites in England cover an area of less than 100 hectares, whilst several areas classified as 'priority habitats' under the UK Biodiversity Action Plan (BAP) have a median patch size of less than 2 hectares (Lawton et al, 2010). Globally, more than 70 per cent of protected areas cover an area less than 10 square kilometres (Cantú-Salazar and Gaston, 2010).

The margins of small protected areas form a greater proportion of the whole than on larger sites, abutting habitat managed less sensitively and which may be a hostile environment for many species. This leads to so-called 'edge effects', where the functional extent of the protected site is reduced for many species (Ries et al, 2004). The species-area relationship predicts that the loss of 90 per cent of habitat will lead to the extinction of 50 per cent of the species in that habitat (Diamond and May, 1976 cited in; Lawton et al, 2010), partly caused by edge effects and to inbreeding depression, where species breed less successfully at lower densities (Courchamp et al, 2009 cited in; Lawton et al, 2010).

[12] EEA (2011) *Natura 2000 data – the European network of protected sites.* March 2011 dataset. Note that these figures exclude Austria. http://www.eea.europa.eu/data-and-maps/data/natura-1. Accessed 23.11.11

Evidence from 49 randomly selected broadleaf temperate forest reserves in Sweden (mean size of 1.6 hectares) suggested that despite the disadvantages faced by small sites, they can however act as important components of reserve networks in highly fragmented landscapes. Large trees and dead wood were found at higher densities on smaller sites, perhaps as trees were more frequently cleared from larger reserves as recreation was a more important driver here than in smaller areas, or because small patches were unsuitable for forest clearing machinery. Large trees and dead wood are generally correlated with value for biodiversity (eg invertebrates, birds and mammals), with old and dead trees particularly important for forest species with limited dispersal capabilities. A literature review led the study authors to conclude that smaller forest patches do not contain impoverished communities of vascular plants, birds and beetles (Götmark and Thorell, 2003).

A further study from Spain demonstrates the potential value of small sites. Eight years after the establishment of a network of small (2 – 20 hectare) sites to protect endangered, rare and endemic flora in eastern Spain, these 'micro- reserves' had become an important and effective conservation tool (Laguna et al, 2004). Despite this and the example above, ecological theory suggests that larger sites are preferable to smaller in the longer term.

5.2.3 What is the evidence that core areas as part of protected area networks have contributed to biodiversity and ecosystem resilience?

Perhaps the ultimate measure of the effectiveness of individual protected areas is how well the biodiversity features for which the site was originally designated are being maintained. In this respect there is good evidence that the designation of Special Protected Areas (SPAs) under the Birds Directive has had a significant positive impact on populations of Annex 1 bird species found within the original 15 Member States of the European Union (EU15) (Donald et al, 2007). Between 1970 and 1990, no significant difference was recorded in the status and trends of the Annex 1 species between the countries of the EU15 and countries outside this bloc. During this time, Annex 1 species were more likely to be assigned to a lower population class than non-Annex 1 species. Between 1990 and 2000, Annex 1 species inside the EU15 were significantly more likely than the same species recorded outside these countries to be found in a higher population trend band. The authors found that this trend was almost entirely due to the most positive effects on those species listed for the longest under the Directive.

The designation of SPAs was found to be beneficial for both target (Annex 1) and non-target species. Donald et al (2007) conclude that for every additional 1 per cent of a country's land area designated as an SPA, the odds of a positive trend in a population of European breeding bird increase by 4 per cent for non-Annex 1 species and 7 per cent for Annex 1 species. There is a positive association across the EU15 between the mean species trend and the proportion of land designated as SPAs; clear evidence for a causal link between the policy intervention and conservation benefit for European breeding bird populations.

A recent study of the effectiveness of protected area management, making use of academic and grey literature, statistical analysis of data from evaluations and feedback from delegates at workshops, found that protected areas in Europe are regarded as an important resource. The 'conservation of values' for which the site was designated was rated highly in the majority (seven out of 15) reports reviewed evaluating management effectiveness. This result indicates that protected areas are generally considered by those involved in assessments to be maintaining their values despite facing high levels of threats and insufficient resourcing (Nolte et al, 2011).

The documented current poor condition of habitats and species of Community interest (EEA, 2010) suggests that Natura sites are not effectively maintaining biodiversity, even though they may be faring better than areas outside the network. However, this is likely to be often due to ineffective protection and management, rather than inadequate coverage or a more fundamental problem. This is illustrated by a recent initiative in England where concerted government driven efforts improved the protection and management of SSSIs. This resulted in a considerable increase in the total area of habitats that are considered to be in 'favourable' or 'recovering' condition; from 73 per cent in 2003 to 95 per cent in 2010, which resulted in the achievement of the government's target (Kirby, 2010). Similarly, key habitats and species were found to be improving in 52 per cent of the protected areas assessed by a recent study in Catalonia (Mallarach, 2008 cited in; Nolte et al, 2011).

5.3 Restoration Zones

Ecological restoration is gaining an increasingly central role in European nature conservation, appearing in the headline target of the EU biodiversity strategy to 2020 and a specific target to restore 'at least 15 per cent of degraded ecosystems' (EC, 2011). Restored habitats can form important components of green infrastructure, often creating habitat patches or corridors within otherwise inhospitable landscapes. Restoration can be 'passive', in which damaging activity is ceased and the area is allowed to regenerate by colonisation and succession, or 'active' which involves targeted actions such as planting vegetation or reintroducing lapsed management regimes. The effectiveness of either approach in restoring habitats and biodiversity to a favourable state has been the subject of recent debate and can vary between habitat types and individual projects.

Rey Banayas et al (2009) conducted a review of 89 restoration projects across a range of ecosystem types globally, evaluating the degree to which biodiversity and ecosystem services were enhanced by restorative actions. In all cases, across different biomes and restoration types, measures of biodiversity were higher in restored habitats compared to degraded systems (Rey-Benayas et al, 2009). However, full restoration of habitats to the state they were in prior to degradation is rarely possible (TEEB, 2011) and biodiversity measures[13] for restored habitats were on average only 86 per cent of the values for undamaged systems which, although much higher than the 51 per cent for non-restored ecosystems, does not represent full rehabilitation. In many cases, ecosystems are degraded to the extent that they cannot be feasibly restored (TEEB, 2011) and the prevention of environmental degradation by designating protected areas and maintaining appropriate management is therefore critical.

A comparable review focussing on the EU is lacking and detailed evidence for the biodiversity impacts of individual European restoration projects is generally scarce. Very few projects include the use of performance indicators or monitoring programmes (Rey-Benayas

[13] Biodiversity measures were the abundance, species richness, diversity, growth or biomass of organisms present. All of the studies reviewed compared restored, degraded and reference (undamaged) ecosystems within the same assessment (Rey-Benayas et al, 2009).

et al, 2009) and consequently, most literature reports only broad descriptive statements of biodiversity outcomes, which are often anecdotal or interpreted from proxy measures with no supporting quantitative evidence. There is a need for greater use of pre-defined objectives and more comprehensive follow-up monitoring for restoration projects so that the relative biodiversity benefits of different approaches can be evaluated. Nevertheless, some evidence for biodiversity impacts of restoration was found for some habitat types and this is outlined below.

5.3.1 Bog and fen habitats

Overall, restoration projects on blanket bogs and similar fen habitats are relatively well detailed in the literature. The accepted restoration approach in these systems is for artificial drainage channels installed to dry out the land to be blocked using sluice gates or earth and vegetation plugs, and for trees and invading scrub to be removed. For example, as pasrt o a LIFE project restoring active blanket bog in Berwyn and Migneint SACs in Wales (LIFE06 NAT/UK/000134), 485km of drainage channels were blocked, which resulted in the re-wetting of 8,740ha of uplands. This led to general indications of improved bog habitat health - and subsequent recovery of specialist vegetation species including sphagnum moss (RSPB et al, 2011; Wilson et al, 2011). Similarly, anecdotal evidence reports that bog restoration at Pumlumon has resulted in an expansion of peat-forming moss species (see Annex I in-depth case analysis on Multifuncitonal use of Farmland and Forests). Providing there are populations remaining in the nearby area, other species associated with the habitat should recolonise the area and recreate characteristic blanket bog ecological communities.

5.3.2 Grassland habitats

The restoration of grassland habitats on areas of former agricultural land is also fairly well documented, often in relation to agri-environment schemes and frequently comparing the relative efficacy of different management options. Pywell et al (2006) review the biodiversity impacts of various methods to restore flower-rich grassland in arable fields. Simply removing land from agricultural management and encouraging succession (‘passive’ restoration) is found to be relatively ineffective for improving biodiversity whereas sowing pollen and nectar mixes increased flower species richness 300 per cent and bumblebee numbers by a factor of 540 (Pywell et al, 2006). The biggest constraint to natural regeneration is impoverished natural seed sources. High residual soil fertility can also limit biodiversity recovery, encouraging the growth of a few competitive grasses and weed species rather than a diversity of species more typical of semi-natural swards, even when sites are adjacent to natural seed sources (Walker et al, 2004). Agri-environment schemes to restore more natural habitats on former agricultural land have also been shown to enahnce plant and invertebrate diversity in Germany, Spain and Switzerland. However, in the Netherlands, plant species richness was not significantly restored and across all countries, there was no significant benefit for bird species (Kleijn et al, 2006).

5.3.3 River and wetland habitats

River restoration involves the re-establishment of a more natural flow regime to recreate habitat features in and around the river channel which favour a diversity of characteristic species. There are numerous methods for river restoration but, as with other habitats, systematic monitoring to assess the effectiveness of different projects is patchy[14]. One example of a project with well recorded biodiversity impacts is the rehabilitation of the channelized Gelsa stream in Denmark. This involved the re-creation of meanders, riffles and pools, and reestablished a more natural flooding regime for the riparian zone. Two years after restoration, the abundance and species richness of macroinvetebrates was 30 per cent higher in the re-meandered section compared to the unrestored section. This was partly due to regeneration of a greater diversity of chracteristic riverine vegetation with 30 species compared to 22 in channelized sections, including water crowfoot (*Batrachium sp.*) which provides good habitat for a wide range of invertebrate species (Ministry of Environment and Energy, 2011).

Similarly, the River Danube was straightened to allow navigation and the banks were raised to reduce flooding. As a result, habitat diversity within the channel was reduced and floodplains were isolated from the flood regime - 75 per cent of the typical floodplain habitat in the Danube River basin has been lost over the last 150 years. Restoration work in the lower Danube basin has restored 4,430ha of floodplain, reconnecting isolated lakes and creating a mosaic of wetland habitats. There are indications that fish and bird populations have recovered signifcantly (Pittock, 2008), for example, at Katlabuh Lake the number of resident breeding bird species increased from 34 to 72 following restoration (The World Bank, 2010) and bird communities elsewhere in the river basin have shown increases in size and species richness (European Bird Census Council, 2007). A particularly successful and well-documented wetland restoration project in the UK is outlined in Box 5.3 below.

Box 5.3: Example of wetland habitat restoration

Restoring fenland habitat on former arable land at Lakenheath Fen, UK
The RSPB led an ambitious programme of restoration to re-create wetland fen habitats at Lakenheath near Suffolk. The land was previously drained for agricultural use and reed beds became degraded by the expansion of dry-land plant species, as well as direct conversion for cultivation. After purchasing 455 ha of land, the RSPB installed recirculation pumps to return water to the area from a specially constructed channel and the nearby river. A bund was also built to retain water levels and volunteer groups were brought in to replant over 300,000 reeds. The result was the restoration of approximately 187ha of wetland habitat. By 2010, reedbeds had recovered to almost the maximum possible extent and 82 hydrophytic plant species were recorded, compared to a total of 33 plant species before restoration. Water vole populations were found to have increased from occupying 17 % of the 242 1ha squares in 2004 to occupying 30% in 2006. One of the priorities of the project was to restore bird populations and three key species – Bittern (Botaurus stellaris), Marsh harrier (Circus aeruginosus) and Bearded Tit (Panurus biarmicus) – were the subject of specific targets in the management plan. These targets were all successfully met by 2010; the objectives of 5 Bittern nests and 100 – 120 breeding pairs of Bearded Tit were achieved and the aim for 8 Marsh Harrier nests was exceeded with 12 nests.

5.3.4 Woodland habitats

Woodland habitats are often damaged due to deforestation and the establishment of commercial plantations. Elsewhere, forests are degraded by the abandonment of traditional management practices. Restoration of woodlands involves the reestablishment of

[14] As an example, in a review of more than 37,000 river restoration projects in the US, Bernhardt et al found only 10% of project reports documented any form of monitoring and little if any of this information was appropriate for assessing ecological effectiveness of restoration activities (Bernhardt et al, 2005).

characteristic tree and shrub species. This is sometimes achieved through passive restoration in which natural regeneration is encouraged. However, this is a very slow process and may be constrained by a lack of seed availability, unfavourable abiotic conditions or competition from other plants or grazing animals. Consequently, active planting is often more effective for restoration of woodland ecosystems. As an example, Rey Banayas et al (2008) restored oak woodland on arable land in Toledo, Spain through active planting of seedlings. After 13 years, 87 per cent of seedlings had survived within restoration areas and ground flora diversity had significantly increased with 38 per cent more herb species than in control plots. In areas left to naturally recover, only 8 woody species had established and vegetation diversity was much lower (Rey Benayas et al, 2008).

Restoration through natural regeneration can occur in some circumstances. For example, to restore plantations on ancient woodland sites in the UK, the Forestry Commission carried out thinning of conifer trees which resulted in an increase in the establishment of broadleaved seedlings and a change in ground flora composition to create a more typical historic woodland community. However there was some dominance by bramble (*Rubus* species), demonstrating the complexity of successful woodland restoration (Harmer and Kiewitt, 2006).

The biodiversity benefits of woodland restoration can also be limited when it is undertaken for objectives other than ecological conservation such as timber production, carbon off-setting or recreation. In these cases, simple mono-species plantations may be established which offer limited habitat diversity for woodland species (Stanturf and Madsen, 2002). In all cases, restoration is rarely likely to reflect the former historic composition of woodlands, particularly in the case of natural or ancient semi-natural woodlands.

5.4 Sustainable use/ ecosystem service zones

5.4.1 Agricultural management

There is clear and widespread evidence that measures that reduce pressures on biodiversity in the wider environment, eg by reducing landuse intensity, will improve habitat quality and thereby increases species richness and the abundance of some populations. For example, organic farming systems differ significantly and consistently from conventional improved grasslands and especially intensively cultivated arable and permanent crops, particularly in their avoidance of artificial fertilisers and very limited use of pesticides. To maintain soil fertility such systems use livestock manure and/or crop rotations (creating high habitat diversity) that often incorporate green manure crops (ie nitrogen-fixing crops such as legumes). Although the botanical diversity of some organic grasslands is reduced by the use of high amounts of slurry as fertiliser, they benefit from generally being older permanent grasslands that are not affected by herbicides. Stocking levels also tend to be lower (to help avoid disease build-up and transmission) and traditional breeds are often used, sometimes in rotation between species. Organic crops are generally protected from weeds and invertebrate pests by rotations (which help prevent the build up of weed and pest populations), biological methods which maintain populations of parasites and predators of pests, and mechanical operations. Such techniques help to maintain the biological condition of soils and, although it is not normally their intention, non-crop plants and invertebrate abundance in crops tend to be higher than in conventional crops. Non-farmed features such as hedges, grass strips and ditches also tend to be kept as shelter / barriers for crops and livestock and as over-winter habitat for predators of pests, such as in so called 'beetle banks'.

There is now good evidence that the combined habitat characteristics of organic farms generally lead to higher within-farm and within-field species richness, and in some cases higher abundance, across most taxa. The main exception to this is for some species in taxa groups such as bees, butterflies and birds that are highly influenced by landscape-scale habitat properties and population dynamics. Thus an important limitation to the potential benefits of organic farming seems to be that in locations where organic farms are surrounded by less biodiverse conventional farmland, benefits may be constrained by a lack of source populations for colonisation of otherwise suitable habitat.

It has also been postulated that increasing the general quality of the landscape can also help increasing connectivity amongst core sites, by increasing g the permeability of the intervening habitat matrix. 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 simplistic because in reality the distinctions between habitat patches and the surrounding matrix are often unclear (Donald and Evans 2006). It is now recognised that the structure of the surrounding matrix affects many factors such as movement between patches (Ricketts 2001), colonisation rate (Bender & Fahrig 2005), edge effects (reviewed in Ewers & Didham 2006), breeding success (Lahti 2001), as well as species composition, abundance and persistence (Tubelis et al. 2004). In terms of matrix structure, both the permeability of the patches themselves and the permeability of the boundaries between patches will determine the degree of impact the matrix has on species (Stevens et al. 2004).

In the EU the most important measures by far for maintaining and enhancing ecological conditions in the wider environment are agri-environment measures under the CAP (see Chapter 3). Donald and Evans (2006) have therefore suggested that such schemes provide the most important approach that can be used to 'soften' or improve the permeability of the agricultural matrix to species. Indeed there is ample evidence that such schemes provide widespread biodiversity benefits, especially where their design is based on thorough research of ecological needs of target species and they are tailored and focused on key target species or habitats. However the monitoring of such schemes tends to be incomplete and often broad (Sutherland) and therefore evidence of the impacts of agri-measures on habitat permeability is currently lacking.

5.4.2 Forestry

The improved sustainable use of forests provides a considerable opportunity for the enhancement of biodiversity and ecosystems in the EU. Thirty-three per cent of the land area of the 39 countries represented by the EEA is forested; equivalent to 185 million hectares. Seventy-five per cent of this forest is available for wood supply, with the harvest of timber restricted in 25 per cent due to strict biodiversity protection (EEA, 2008). Forestry practices have intensified and conflicts between biodiversity protection and forest management can be linked to changes in harvesting practice, amongst other factors. Crop rotation times, the removal of dead wood, the use of fertilisers and plantation forestry using exotic species can all result in the degradation of forest habitats and loss of species (Young et al, 2005). There is therefore a need to balance competing pressures on forests, including their role in biodiversity conservation, within a framework of multi-functional forest management.

Eighty-seven per cent of forests within countries of the EEA region (and collaborating nations) are subject to some degree of human management. These semi-natural forests are exploited in accordance with sustainable forest management principles adopted by the Ministerial Conference on the Protection of Forests in Europe (MCPFE), generally complemented by national or regional programmes focusing on sustainable use of forested areas (EEA, 2008).

Alongside management for timber and wood pulp, the management of forests for hunting can contribute substantially to the economy of some European countries. In Germany for example, €750 million turnover is generated annually through hunting. The sale of collection permits for mushrooms, including truffles, in Italy, generates greater revenue than from wood production (Pettenella et al, 2005; Pettenella et al, 2006; Pettenella and Kloehn, 2007; cited in EEA, 2008). Forests may also be managed strategically to sequester carbon, although the disturbances and dynamics necessary to maintain woodland biodiversity may conflict with the stability needed to sequester carbon in some cases (EEA, 2008).

In addition, 20 million hectares, or 10 per cent of the total area, of forests in EEA member and collaborating countries, provides a 'protective function'; whether from avalanches in alpine areas or against wind and soil erosion in coastal locations. In Austria, 'Protection Forests' comprise 20 per cent of the total forested area and are designated through the Austrian Forestry Act. Biodiversity is a secondary consideration within the forests, which are primarily designated and managed to provide natural hazard control. Particular silvicultural measures are put in place as a result of the designation and timber production is limited.[15]

There are numerous other examples of forestry initiatives across Europe concerned with balancing biodiversity and the sustainable use of forest products. A LIFE project in the Southern Black Forest, in Baden-Würtenberg, Germany, integrated the needs of the forestry, hunting, tourism and conservation sectors to develop management practices compatible with the ecological requirements of the Capercaillie (*Tetrao urogallus*) and Hazel Grouse (*Bonasa bonasia*). This has resulted in a small increase in the grouse populations and commitment amongst foresters to continuing to manage woodland using means compatible with grouse conservation (EC, 2006; cited in EEA, 2008).

In Ireland, the BIOFOREST initiative resulted in new plantations of Sitka Spruce (*Picea sitchensis*) being located away from species-rich farmland habitats, with site selection taking into account the results of assessments on a large number of biodiversity taxa. In Sweden, time-limited (50 year) nature conservation agreements between landowners and the Swedish Forest Agency result in restrictions in/ adaptations of forest practices in return for a payment to the landowner (Iremonger et al, 2006; cited in EEA, 2008). In Finland, biodiversity must be taken into account in forestry operations and 10 'key habitats' within

[15] See In-Depth Case Analysis, Theme 2: Multi-functional Use of Farmland and Forests.

forests must be set aside whenever they are encountered (Virkkala and Toivonen, 1999; cited in Young et al, 2005). Landscape Ecological Plans (LEP) have formed an integral part of the management of forests in Finland since 2000, with conservation goals such as the creation of ecological networks aligned with different forms of forest use.[16]

In the UK, one of the least forested nations in Europe, many forests are multi-functional, managed for commercial purposes, recreation and biodiversity: 150,000 hectares are designated as Natura 2000 sites and a total of 600,000 hectares has some form of landscape or nature protection (Kretschemer et al, 2011). Many forests in the UK lack active management and the sustainable use of such woodlands for the production of biomass could provide significant biodiversity benefits, if new woodlands are dominated by native species and located on land with low ecological and agricultural value (Kretschemer et al, 2011). A project by Estover Energy to build three to five Combined Heat and Power (CHP) plants in Southern and Northern England and Scotland demonstrates how woodland management could be revitalised through the provision of profitable markets for woodchips. The feedstock would be sourced within a 40 mile radius of the plants, with each plant therefore affecting the management of 15,000 – 25,000 hectares of certified forest (Kretschemer et al, 2011). Although certified forests do not necessarily have high biodiversity value, certification opens up possibilities for more biodiversity-oriented management (EEA, 2008).

5.5 Green urban areas

In comparisons with wilderness and rural environments urban areas support a considerably impoverished biodiversity and comparatively few species of high conservation importance. Nevertheless, significant biodiversity occurs in all cities and according to the EEA its value is often underestimated[17]. Many species, including mammals, birds, invertebrates and plants, have adapted to the ecological niches that urban areas support (Erz and Klausnitzer, 1998; Wittig, 2005; Werner and Zahner, 2009; all cited in Georgi et al, 2010). These tend to be generalist species (due to the high levels of disturbance, nutrient and other pollutant levels, fragmentation and knock-on effects of the low levels of species diversity within urban ecosystems). But there is a growing awareness of the value of even common urban habitats and species to local people for educational, recreational, cultural, health and spiritual reasons (see Chapter 6 for further discussion of broader ecosystem service and human welfare benefits).

Biodiversity levels with cities tend to be highly dependent on the amount, type and diversity of habitats that are present. For example, urban wetlands, abandoned industrial sites, roadside verges, vacant lots and derelict lands, ruins, allotment gardens and cemeteries are increasingly recognised as potential reservoirs of urban biodiversity — together with arboreta, residential gardens and villas, botanic gardens and individual balconies (Heywood, 1996). Although there does not seem to be documented evidence that urban green infrastructure initiatives boost biodiversity levels, this can be reliably inferred, where increases in habitat quality and quantity occur.

[16] See In-Depth Case Analysis, Theme 2: Multi-functional Use of Farmland and Forests.

[17] http://www.eea.europa.eu/publications/10-messages-for-2010-urban-ecosystems

The most important types of urban habitat in biodiversity terms are often some types of post-industrial sites (eg ash heaps or mineral extraction sites) that that have very low nutrient levels, are frequently disturbed, highly acidic or alkaline, or have high levels of heavy metals. Such sites hold few species, but they can have species or communities that are naturally found in habitats such as hot springs or on bare mineral deposits, which are now very rare. Such urban / industrial sites therefore mimic natural sites and may now be the last remaining refuge for some species. The extreme conditions of cities can also give rise to novel species communities and there are documented examples of genetic changes and the evolution of new taxa (Zerbe et al., 2003).

Consequently, although most species are of low nature conservation value, cities can play an important role in hosting certain threatened species and habitats, including some European importance. For example, as a result, some 97 Natura 2000 sites exist in 32 major cities in Europe, sixteen of which are capitals (Sundseth and Raeymaekers, 2006).

5.6 Natural connectivity features

5.6.1 Habitat corridors

A habitat corridor can be defined as a linear habitat embedded in a dissimilar matrix that connects two or more larger blocks of habitat and that has been proposed for conservation on the grounds that it will enhance or maintain the viability of specific wildlife populations in these blocks (Beier and Noss, 1998). The evidence for the conservation benefits of habitat corridors is equivocal, with some studies demonstrating that the movement of species between patches of habitats have been enhanced and others that the corridors have had little or no affect (Davies and Pullin, 2007; Gilbert-Norton et al, 2010; Tewksbury et al, 2002). The results of studies have often been confounded by a failure to account for the additional habitat area which the corridor represents and which may be responsible for the beneficial effect independent of any function as a conduit for movement (Tewksbury et al, 2002).

In their review of studies assessing the utility of corridors as conservation tools, Beier and Noss (1998) conclude that evidence from well-designed studies generally supports the use of corridors. A recent meta-analysis by Gilbert-Norton et al (2010) found that corridors increased the movement of a diverse range of species between habitat patches by approximately 50 per cent compared to movement between unconnected patches. Corridors were found to be most important for invertebrates, non-avian vertebrates and plants than for birds. Natural corridors, existing in the landscape prior to their inclusion in particular scientific studies, increased species movement through the landscape to a greater extent than manipulated corridors.

Beier and Noss (1998) found that only 10 of the studies they analysed provided persuasive evidence that corridors offered sufficient connectivity to improve the viability of the populations connected by them. However, almost all of the studies assessed by the authors suggest that corridors provide some benefits to wildlife or that they are used by animals. The evidence suggests that it might be prudent to adopt a precautionary approach towards the maintenance and creation of corridors (Beier & Noss, 1998; Gilbert-Norton et al, 2010), but equally, in the absence of conclusive evidence, the costs of establishing corridors should be compared critically with the costs and benefits of alternative conservation options (Simberloff et al, 1992; cited in Kettunen et al, 2007).

A recent study undertaken for the European Commission as part of a project by the IEEP and Alterra (2010) examining nine ecological network initiatives in depth, found that of those networks implemented none had put in place ecological monitoring to assess the effect of habitat corridors or network as a whole on biodiversity. The absence of measurable aims and targets and of ecological baseline monitoring constrains the ability of policy-makers to draw conclusions about the efficacy of, often expensive, corridor creation projects (IEEP & Alterra, 2010).

A review of the development of the National Ecological Network in the Netherlands suggests that although limited scientific evidence existed to suggest that target species depended on the creation of habitat corridors for dispersal, the development of these corridors was nonetheless desirable from the point of view of conservation policy (Van Der Windt and Swart, 2008). The authors conclude that the ecological evidence for the ecological corridor concept remains uncertain, despite the existence of a 'Handbook for Robust Corridors' in the Netherlands, but that nonetheless this concept has been a political success.

5.6.2 Hedgerows

Hedges consist of lines of shrubs and/or trees, planted by man, which demarcate the boundaries of fields. 'Hedges' and 'hedgerows' are often used interchangeably (McCollin, 2000). Hedgerows are important habitats which provide bird species with nesting, roosting and foraging sites and act as refugia for small mammals on arable land post-harvest. In addition, they may often provide the only element of biodiversity and structure in a landscape otherwise impoverished through intensive agriculture (Burel, 1996; cited in Davies & Pullin, 2007) Under the Hedgerow Regulations (1997) in the UK, it is illegal to remove or destroy important hedgerows without permission from a local authority. Planning authorities must evaluate hedgerows using a variety of biological, ecological and historical criteria, to determine which hedgerows are worthy of protection (McCollin, 2000).

In addition to their function as habitats, hedgerows are often considered to act as biological corridors, allowing the movement of organisms through otherwise fragmented landscapes (Simberloff et al, 1992). The preservation and creation of hedgerows is thought to be one means of mitigating the effects of fragmentation of woodland, by enabling the persistence of forest species by enhancing migration between populations (cited in Davies & Pullin, 2007; eg Peterken, 2000; Sitzia, 2007; cited in Stacey et al, 1997).

There are a number of examples in the scientific literature of hedgerows facilitating the dispersal of species. For example, hedgerow presence has been shown to increase the dispersal rates of the Eastern Chipmunk (*Tamias striatus*) in farmland in Ottawa, Canada (Bennett et al, 1994). Hedgerows may also serve as corridors between two types of habitat essential for amphibian life history: two species of newt were recording using hedgerows to move between breeding ponds and woodland at a greater frequency than expected based on the availability of hedgerows in the landscape (Jehle and Arntzen, 2000; cited in Davies and Pullin, 2007).

A study on the Po Plain in Italy examined the occurrence of woodland plant species in three hedge types, found at varying distances from a wood. Species composition in the two types of hedges nearest to the woodland ('remnant attached' and 'regenerated attached') showed a strong affinity with that of the woodland, in contrast to isolated hedgerows, indicating that the woodland was acting as a source of propagules. From this study it was possible to infer that the regenerated attached hedgerows were performing a corridor function in the dispersal of woodland plant species. Those species dispersed by ants showed a similar distribution based on distance from the woodland, but there was no significant trend with distance for those plant species dispersed by vertebrates (Sitzia, 2007).

Mortelliti (2011) found that the structural connectivity represented by a network of hedgerows was very important to the distribution of the Hazel Dormouse (*Muscardinus avellanarius*) in a heterogeneous landscape central Italy. The mice were found even in highly subdivided habitat if these were connected by hedgerows. Hedgerows were not significant for the distribution of Red Squirrel (*Sciurus vulgaris*), which can more easily cross open ground. In both cases, the amount of suitable habitat available in the landscape was more significant than the availability of hedgerows to the distribution of the species. The authors therefore recommend the preservation and restoration of existing habitat as a conservation priority.

Overall however, the evidence on the effectiveness of hedgerows as a conservation tool to increase connectivity may be insufficient to draw conclusions about their effectiveness in enhancing population viability (Davies & Pullin, 2007). None of the studies included within the systematic review by Davies and Pullin (2007) demonstrated either a positive or a negative effect of hedgerows on the long-term persistence of populations. Despite this, the authors did find evidence of the effects of hedgerows on local populations in the short-term and of the movement of species through hedgerows between habitat patches. On the basis of the evidence within the review, the authors could not reject the hypothesis that continuous and heterogeneous hedgerows are most likely to foster movement as corridors. In addition, they suggest that as many hedgerows are neglected, the utility of hedgerows as corridors for species' movement could be significantly enhanced under appropriate management regimes.

5.6.3 Riparian Zones

Riparian zones exist as interfaces between terrestrial and aquatic systems. They occupy the stream channel and the portion of the terrestrial environment from the high water mark towards the uplands. Here, vegetation may be influenced by elevated water tables or flooding and by the ability of soils to hold water (Naiman et al, 1993). Riparian vegetation regulates the light and temperature, provides nourishment to aquatic and terrestrial biota, regulates the flow of water and nutrients from the uplands to the stream environment and maintains biodiversity by providing a diverse array of habitats (Naiman et al, 1993).

Riparian zones are often referred to as 'riparian buffers' or 'riparian corridors', depending on the primary function for which they are managed. Riparian buffers are intended to maintain and/or improve water quality by trapping and removing contaminants such as herbicides, pesticides, nutrients from fertilisers and sediments from upland soils (Fischer and Fischenich, 2000). Buffer strips may be herbaceous, grassed or forested. A riparian corridor connects two or more areas of larger habitat and may be managed primarily for conservation purposes.

Riparian zones provide beneficial habitats for a large range of species. Particular species that may benefit from the creation and management of riparian buffer areas in the UK include Water Vole (*Arvicola amphibius*), Otter (*Lutra lutra*), Pipistrelle Bat (*Pipistrellus pipistrellus*), Marsh Fritillary (*Euphydryas aurinia*) and Freshwater Pearl Mussel (*Margaritifera margaritifera*) (all priority species under the UK Biodiversity Action Plan)[18]. Nearly 70 per cent of vertebrate species in a region will use riparian corridors in some significant way during their life cycle (Raedeke, 1989; cited in Naiman et al, 1993). Riparian zones can make a large contribution to maintaining indigenous species in otherwise modified landscapes, but generalists, rather than specialist species may be more likely to persist here (Bennett, 2003).

Most research into the value of corridors to facilitate the movement of species between habitats has been conducted in agricultural and forested landscapes and evidence of the efficacy of riparian strips in this respect is sparse (Fischer & Fischenich, 2000). Evidence has been found that riparian corridors enhanced the movement of juvenile and maintained the movement of adult songbirds between forest reserves in Alberta, Canada (Machtans et al, 1996). An experiment in Costa Rica found that Barred Antshrikes (*Thamnophilus doliatus)* returned to their home territories from areas to which they had been translocated with greater success through riparian corridors than through living fencerows or open pasture (Gillies and Cassady St Clair, 2008). A further study found that mammalian predators were 11 times more likely to be detected in riparian corridors than in surrounding vineyards in California, that more native mammalian predators were found in wide than narrow riparian strips and that native predators were most active in corridors closest to core areas (Hilty and Merenlender, 2004). An extensive search for the purposes of this literature review failed to find any studies from Europe explicitly analysing the role of riparian corridors in facilitating species dispersal or enhancing population viability.

5.7 Artificial connectivity features

A comprehensive description of grey infrastructure and what this term comprises can be found in the in-depth case analysis of grey infrastructure mitigation (case-study six). Broadly, grey infrastructure can be understood to encompass: transport infrastructure; commercial infrastructure; utilities and distribution of services (such as sewage treatment and energy generation) and; social infrastructure (such as schools, hospitals, coastal defences and flood control)[19]. The analysis below focuses on the mitigation of transport infrastructure development (roads) and energy generation (hydroelectric power generation and the installation of dams).

[18] Scottish Government (2011) *Water Margins and Enhanced Riparian Buffer Areas*. http://www.scotland.gov.uk/Topics/farmingrural/SRDP/RuralPriorities/Packages/Wetlands/watermargins. Accessed 18.11.11

[19] See In-depth case-study on 'Grey Infrastructure Mitigation', Annex I

5.7.1 Wildlife Crossings

Wildlife crossings are designed to link critical habitats, straddling a matrix of inhospitable habitats, providing for the safe movement of animals across busy roads (Clevenger and Wierzchowski, 2006). As per in-depth case-study six, on grey infrastructure mitigation, the term 'wildlife crossings' is used here to refer to elements specifically put in place for wildlife migration, (for example green bridges). Crossings can be installed in relation to other linear structures, such as railways, but their use is more common with respect to roads (Corlatti et al, 2009).

- *Overpasses*

Wildlife overpasses can be defined as all bridge-like structures designed for use by fauna or for dual use by wildlife and farm vehicles, planted with grass, shrubs and trees (Corlatti et al, 2009): these overpasses also encompass viaducts (also known as 'ecoducts') (Bank et al, 2002).

- *Underpasses*

An underpass allows the passage of animals below the major linear infrastructure (van der Ree et al, 2007). Underpasses range from culvert systems of pipes and small tunnels, with supplementary trenches, to facilitate the movement of small animals, including amphibians and small mammals, to structures designed for use by medium and large mammals. Heights of 3 metres to 5 metres have proven successful in facilitating the use of structures by medium to large mammals, with underpasses of 5 - 12 metres wide used by smaller species and widths of up to 25 metres necessary for larger species. Rocks, stumps and debris may be placed in and around smaller structures to enhance their use by animals (Bank et al, 2002).

The use of underpasses and other structures such as culverts seems to have been studied to a greater extent than overpasses (Corlatti et al, 2009). A literature review by van der Ree et al (2007) found that the majority of structures reported on were underpasses (83 per cent), specifically culverts (40 per cent), reflecting the relative proportions of underpasses and overpasses in existence.

- *Evaluating the effectiveness of wildlife crossings*

The four main effects of roads and traffic on animal populations are: that they decrease the extent and quality of available habitat; they enhance mortality due to collisions between animals and vehicles; they prevent access to resources on the other side of the road and they subdivide animal populations into smaller, more vulnerable fractions (EEA and FOEN, 2011b). The most severe of these impacts is thought to be the creation of isolated pockets of habitat that cannot support viable populations of organisms in the long-term (Fahrig, 2003); cited in Corlatti et al, 2009). Other impacts may include run-off from the road affecting aquatic communities and emissions, litter, noise and other disturbances, including the spread of pest species by vehicles and along verges, altering species composition, hydrological impacts and erosion (Forman and Alexander, 1998; Spellerberg, 1998).

Forman et al (2003) suggest a set of six criteria against which to assess the effectiveness of crossing structures for wildlife: reducing the rate of road kill; maintaining habitat connectivity; maintaining genetic exchange; ensuring that a species' biological requirements are met; allowing dispersal and recolonisation and; maintaining meta-population processes and ecosystem services.

Despite these recommendations and the high cost of implementing wildlife crossings, few studies have actually evaluated the efficacy of crossings, with a lack of pre and post-construction tests and monitoring, with the results of most studies therefore based on anecdotal evidence and observations (Bennett et al, 2011; Clevenger & Wierzchowski, 2006; Corlatti et al, 2009). Many studies have not explicitly recorded in the literature the timing of the study relative to the construction of the road. In addition, a 'before-after' comparison approach, recording rates of road kill before and after mitigation was apparent in only 15 of the 122 studies assessed in a review by van der Ree et al (2007).

The majority of wildlife crossings have been focused on the level of individuals, rather than examining the benefits or otherwise of these structures at the population level. Studies have focused on the use of structures by animals, but this does not necessarily translate to conservation gain (Ng et al, 2004; cited in van der Ree et al, 2007). van der Ree et al (2007) found that only five publications out of those examined reported on a population-level study and an additional 23 studies implied or alluded to population-level effects, such as increased population viability of prevention of a population sink. There is a need to augment Forman's (2003) criteria of the effectiveness of crossings and assessments that focus only on the degree of usage of structures, with assessments of the extent to which wildlife crossings enhance the viability of local populations (Clevenger & Wierzchowski, 2006; van der Ree et al, 2007; van der Ree et al, 2009).

5.7.2 Artificial connectivity measures and the delivery of ecosystem services

As noted in Chapter 2 of this report, only a limited amount of information emerged from the in-depth case-study on grey infrastructure mitigation (See Annex I case-study six) concerning the contribution of artificial connectivity features to ecosystem service delivery. The socio-economic benefits of these features have so far been captured by examining the reduced costs of collisions between animals and vehicles resulting from grey infrastructure mitigation measures.

- *Evaluating the effectiveness of overpasses*

A recent study (Bank et al, 2002) stated that 125 overpasses could be found in France (1991 figures), 32 in Germany, with additional structures planned, 20 in Switzerland and four overpasses in the Netherlands. The authors of this study suggest that, along with viaducts, overpasses are best suited to the widest range of organisms.

The scientific literature indicates that vertebrates use wildlife overpasses. Studies from France show that Roe Deer (*Capreolus capreolus*), Red Deer (*Cervus elaphus*), Wild Boar (*Sus scrofa*), Eurasian Badger (*Meles meles*) and Red Fox (*Vulpes vulpes*) have used overpasses (Ballon, 1985; van Wieren and Worm, 2001; Vassant and Brandt, 1998; cited in Corlatti et al, 2009). There is evidence for the use of overpasses by Red Fox (*Vulpes vulpes*), European Hare (*Lepus europaeus*) and domestic cat (*Felis catus*) in Germany, and by Roe Deer (*Capreolus capreolus*), Eurasian Badger (*Meles meles*), Wild Boar (*Sus scofa*), Stone Marten (*Martes foina*), Red Fox (*Vulpes vulpes*) and European Hare (*Lepus europaeus*) in Switzerland (De Vries, 1994; cited in van Wieren and Worm, 2001). Moose (*Alces alces*) and Roe Deer (*Caprelous capreolus*) have been shown to use an overpass in Sweden during nocturnal hours, with this use decreasing with increased traffic volume (Olsson et al, 2008; cited in Corlatti et al, 2009). Wood Mouse (*Apodemus sylvaticus*), Common Vole (*Microtus arvalis*) and Common Shrew (*Sorex araneus*) have been shown to use an overpass in the Netherlands, in addition to larger mammals (van Wieren and Worm, 2001). Studies in Northwest Spain have shown that Wild Boar (*Sus scrofa*) use only overpasses, whilst Red Deer (*Cervus elaphus*), lacertids, small mammals and Red Fox (*Vulpes vulpes*) use both overpasses and overpasses. Red Deer (*Cervus elaphus*) only used under and overpasses in this study if they were wide (Mata et al, 2003; Mata et al, 2005; Mata et al, 2007; cited in Corlatti et al, 2009).

There is evidence that wider structures are more frequently used than narrower by dispersing organisms. Swiss studies have shown that structures at least 60 metres wide are more effective than those narrower than 50 metres for larger mammals in particular (Evink, 2002); cited in Corlotti et al, 2009), whilst a study of the 'Terlet' overpass across a motorway in the Netherlands showed that the effectiveness of the structure was related to its width (van Wieren and Worm, 2001). In Croatia, the ratio of larger mammals crossing highways on overpasses 100 metres wide was three to six times higher than on narrower structures.

Despite the literature demonstrating the use of overpasses by a variety of organisms, very few studies have been undertaken to compare the dispersal rates of species before and after the construction of the road and the overpass, making their effectiveness in this respect difficult to assess (Corlotti et al, 2009). van Wieren and Worm (2001) compared the dispersal of large mammals across an overpass in the Netherlands in 1994 and 1995 with data collected in 1989, when the overpass was newly constructed. They found an increase in the total number of passages by species in this time, ascribing this mainly to a three-fold increase in the number of crossings by Red Deer (*Cervus elaphus*). Although this could be evidence that the organisms had become habituated to the overpass, this conclusion is confounded by the increase in supplementary feeding on one side of the passage which could have encouraged the dispersal of Red Deer (*Cervus elaphus*) and Wild Boar (*Sus scrofa).*

Despite the lack of comparative and long-term studies into the use of overpasses by species, Corlotti et al (2009) suggest that overpasses may be a useful tool in avoiding the genetic isolation of species sub-populations, although this will vary on a species-by-species basis depending on use of the structure by the minimum number of individuals required to maintain gene flow. Corlotti et al (2009) also suggest that the effectiveness of overpasses may be linked to the use of fences, which channel species towards the structures.

Kaden et al (1993; cited in Bank et al, 2002) recommend that the size, location, design and habitat used in the construction of wildlife overpasses takes into consideration the needs of the target species in the area under study.

- *Evaluating the effectiveness of underpasses*

Mata et al (2007) found that underpasses, culverts and wildlife-adapted box culverts beneath a Spanish motorway were used by a diversity of animals, although culverts were used less frequently than the other types of underpass. Wildlife passages and adapted culverts facilitated the passage of Wild Boar (*Sus scrofa*), Roe Deer (*Capreolus capreolus*) and Eurasian Badger (*Meles meles*), species which did not tend to cross the road elsewhere.

As with the majority of other similar studies, no information was available from this research regarding the long-term viability of populations affected by the motorway and how the wildlife crossings may influence this.

As discussed elsewhere in this section, assessments of how wildlife crossings increase the viability of local populations of species, aside from whether such structures are used, are sparse (Clevenger & Wierzchowski, 2006; Corlatti et al, 2009; van der Ree et al, 2009). One of the only studies identified through a literature search, on the Mountain Pygmy-Possum (*Burramys parvus*) in Australia, found that population viability modelling supported the assertion that tunnels beneath a motorway restored habitat continuity and population processes (van der Ree et al, 2009). Modelling based on the rates of birth, death and migration before and after the construction of the road and associated mitigation measures showed that the tunnels did reduce the barrier effect of the road to the dispersal of the possum but that there remained a 15 per cent reduction in the median population size of females at the site with the mitigation measure, compared to a site without a road. The authors suggest that this could be due to an insufficient number of tunnels crossing the road; mortality from vehicular collisions or natural fluctuation in the population. Although in this case the mitigation measures did successfully restore population processes in the possum, a decrease of 15 per cent in median population size is a non-trivial issue which may have a larger effect if seen in a rare species (van der Ree et al, 2009).

A further study, by Mansergh and Scotts (1989; cited in Beier and Noss, 1998), found that the viability of a population of Mountain Pygmy-Possum (*Burramys parvus*) in a ski resort was enhanced by the development of a corridor and two tunnels beneath a road bisecting a breeding area. Prior to the construction of the tunnels, the fragmented population exhibited skewed sex rations. Following the development of the underpass, which allowed the dispersal of males, the population structure and survival rates changed to those observed in an undisturbed population. Beier and Noss (1998) caution against making inferences about the utility of such corridors in general for enhancing the viability of fragmented populations on the basis of this study, but allow that this demonstrates very well the value of the particular tunnel under test.

5.7.3 Fish Passes

Connectivity in streams can be disrupted partially or wholly by natural barriers, such as waterfalls, or by man-made barriers such as dams, barrages, sluices, pumping and hydropower stations. Dams have generally resulted in negative impacts on riverine fisheries worldwide (Kroes et al, 2006).

A number of studies of salmonid populations show significant effects on genetic diversity through natural and artificial barriers to upstream fish movement (Neville et al, 2006). Responses to genetic isolation include reduced population viability due to the effects of inbreeding and genetic drift, increased susceptibility to disease, reduced ability to adapt to changing pressures and reduced breeding success (reduced effective population size). Conservation success therefore depends on mitigating the negative effects caused by grey-infrastructure development in watercourses.

Fish passes (also known as ‘fish ways’) are often the only means for fish to circumnavigate obstacles that block their journey and so are key elements for the ecological improvement of running waters. Removing weirs and dams which are no longer needed should however take preference over installing a fish pass where the aim is to restore connectivity in waterways (FAO, 2002).

The Salmon and Freshwater Fisheries Act (1975), requires that new obstructions in watercourses in the UK, or those rebuilt for more than half of their width, must include a fish pass.[20] The Environment Agency holds responsibility for approving the design of fish passes in this country. Figures from 2003 suggest that there are upwards of 380 passes in England and Wales; more than 500 in France, built or retrofitted in response to legislation passed in the early 1980's, covering migratory rivers; passes in Germany, Austria, Portugal, Spain, in Denmark and Norway, a country which has a long tradition of fish ways (Aaerstrup et al, 2003; Larinier and Marmulla, 2003).

Fish passes must be suitable for the fish species and size for which the pass is being built, and should be positioned at the natural point where fish congregate. There are several types of fish pass. Pool and weir passes consist of a series of pools, controlling the flow of a large volume of water by division into several smaller waterfalls. Baffled passes use a series of precisely positioned barriers which reduce the velocity of rapidly flowing water. Fish locks and lifts are used in relation to very large obstructions, such as hydroelectric dams. Fish are drawn into a collection area by a flow of water and then discharged downstream periodically, when the water level in the collection area equalises, through the use of gates or sluices, to that upstream. Pre-barrages consist of a series of smaller weirs downstream of the main obstruction, reducing the height to be traversed. Finally, artificial river channels can extend from below the obstruction to upstream, at a relatively gentle gradient, making them suitable for use by juvenile and smaller coarse fish which are difficult to accommodate through other fish pass designs.[21]

The objective of a fish pass designed for species such as salmon (diadromous species, which migrate over their lifespan between salt and freshwater), located downstream of spawning grounds, is that the whole migratory population traverse the pass and in the minimum amount of time possible, to allow them to reach their reproductive grounds. In the case of a species migrating over a local or regional distance (a potamodromous species) the objective of the pass is to avoid dividing the population.

The pass is generally considered effective if a significant proportion of individuals, relative to the population downstream of the obstacle, traverse this structure (Larinier & Marmulla, 2003). Although there is no official guidance on fish pass efficiency, it is considered that efficiencies should be 90 - 100 per cent for adult salmonids ascending a river to spawn (Lucas and Baras, 2001; cited in Aaerstrup et al, 2003). A search of the literature for this section of the report could find no studies which evaluated the effectiveness of fish passes based on the long-term viability of fish populations traversing them; data were available only on the use of fish passes and this was also challenging to locate.

[21] Environment Agency (2011). *Fish Passes*. www.environment-agency.gov.uk/business/sectors/32651.aspx. Accessed 17.11.11

Upstream fish passes have been researched to a greater extent than downstream passes. Experience in downstream mitigation is mainly restricted to Germany, France and the UK but even in these countries effective facilities are not yet in place and further research is needed (Kroes et al, 2006). Comparatively little information is available for the effectiveness of either upstream or downstream measures for species other than salmonids (Larinier and Marmulla, 2003).

Upstream fish pass design can be considered fairly well developed in Europe for salmonids and clupieds, and in those countries where fish pass technology is advanced for a small number of species may be considered effective mitigation for obstacles that don't drastically modify upstream habitat conditions (Larinier and Marmulla, 2003).

Other references however suggest that the ability of fish passes and guidance devices to attract and permit the rapid and safe passage of fish varies considerably (Lundqvist et al, 2008) and that the quality of the design and construction of passes does not necessarily mitigate the impact of the many barriers in European rivers to a sufficient degree (Kroes et al, 2006).

The success of fish passes is largely determined by whether the fish will find the passage and whether they will move through it. Aaerestrup et al (Aaerstrup et al, 2003) found that over 90 per cent of tagged upstream Sea Trout (*Salmo trutta morpha trutta*) reached the nature-like bypass in Denmark subjected to study but only 55 per cent of these traversed the pass, possibly caused by the pass being too short and the water flow insufficient.

Assessments of the migration of wild Atlantic Salmon (*Salmo salar*) in the River Umeälven in Denmark showed considerable losses of spawning fish between the estuary and a fish ladder (70 per cent), caused by complex flow patterns created by hydroelectric turbines. Further losses, of 30 per cent, were recorded in the area of a fish ladder located further upstream in the regulated river. The authors suggest that the fish ladder was inadequately designed, as the salmon experienced difficulties in locating this (possibly due to high water levels from the dam) and took too long to traverse the ladder when located. Population models suggested that the abundance of salmon spawners would increase by five fold in 10 years if losses in the regulated area of the river could be reduced (Lundqvist et al, 2008).

Further case studies demonstrate fish passes operating with varying degrees of success (Aaerstrup et al, 2003; cited inJungwirth et al, 1998; Lucas & Baras, 2001). A fish pass built in 2003, in association with the Merikoski hydropower station on the River Oulujoki in Finland, has been used by salmon, trout, Rainbow Trout (*Oncorhynchus mykiss*), whitefish, perch, pike, Burbot (*Lota lota*) and bream. A survey of the stretch of river upstream of the fish pass, between the Meikoski station and the next dam, showed some evidence of salmon spawning (Kroes et al, 2006).

In designing and installing fish passes in European rivers, it would seem that for such devices to contribute to biodiversity conservation, the unique aspect of each site and the needs of the species which use the section of river must be assessed on a case-by-case basis (Kroes et al, 2006; Thierrien and Bourgeois, 2000). The fish passes installed may need to be improved and adapted over time based on the results of monitoring efforts (Kroes et al, 2006).

5.8 Integrated Green Infrastructure initiatives

5.8.1 Ecological networks

Over 250 ecological networks are planned or are being established worldwide, at regional, national or international levels (Lawton et al, 2010). Whilst there are scientific studies of how species use habitats and the impacts of landscape structure on population dynamics, there are few examples in the scientific literature of the efficacy of ecological networks *per se*, primarily because the concept of an ecological network has moved from scientific research to a conservation policy planning tool (Kettunen et al, 2007).

Moving beyond the initial phase of mapping habitats and species and assessing the threats they face, in order to designate an ecological network, may take many years and very few ecological network projects have progressed to a stage where implementation on the ground has made substantial progress. Even those which have been implemented, for example the Dutch National Ecological Network, have not been functional for long enough to demonstrate that they have improved the viability of the populations of target species (Bennett and Mulongoy, 2006).

One example of an international ecological network for which some evidence does exist is the EU-wide Natura 2000 network of protected areas. There is good evidence that the designation of Special Areas of Conservation (SACs) under the Birds Directive has contributed to favourable trends in populations of breeding birds listed under Annex 1 of the Birds Directive and to positive effects on non-target bird species (Donald et al, 2007). Gaps in scientific knowledge mean that the full range of ecosystem services and socio-economic benefits associated with the Natura 2000 network are not yet comprehensively understood. However, the evidence available from case-studies (Gantioler et al, 2010; Kettunen et al, 2011; WWF and IEEP, 2009) indicates the significant environmental benefits the Natura 2000 network is currently providing. Further information on the socio-economic benefits provided by protected area networks, such as Natura 2000, is provided in Chapter 3 of this report.

However, evidence for the efficacy of other specific ecological networks for biodiversity is hard to identify. A recent study undertaken by the IEEP and Alterra (2010) shows that ecological network projects may not identify target species around which to focus the creation of habitat corridors, often do not have measurable, specific ecological aims and targets and fail to carry out baseline monitoring against which to assess the contribution of the network to biodiversity conservation.

The evidence discussed earlier in this chapter with respect to the efficacy of different components of ecological networks (core areas, natural and artificial connectivity features) should provide an indication of the likely value of ecological networks as a whole, provided that particular principles for the creation of networks in Europe are met (Kettunen et al, 2007).

6 ECOSYSTEM SERVICES AND BENEFITS SUSTAINED BY GREEN INFRASTRUCTURE AND ITS COST-EFFECTIVENESS

6.1 Introduction

This chapter assesses the ecosystem services and benefits of green infrastructure and highlights the cost effectiveness of different green infrastructure elements as well as the added value of an integrated approach to green infrastructure. In doing this, it takes both the ecosystem services and socio-economic benefits described in this chapter as well as its contribution to biodiversity conservation and resilience as described in chapter 5 into account. The chapter starts with separate general introductions on functions, ecosystem services and benefits sustained by green infrastructure on one side and on the costs and cost effectiveness associated with green infrastructure implementation on the other side. It continues with a discussion on both benefits and cost effectiveness for every individual green infrastructure element, and concludes with outlining the potential cost-effectiveness of integrated approaches.

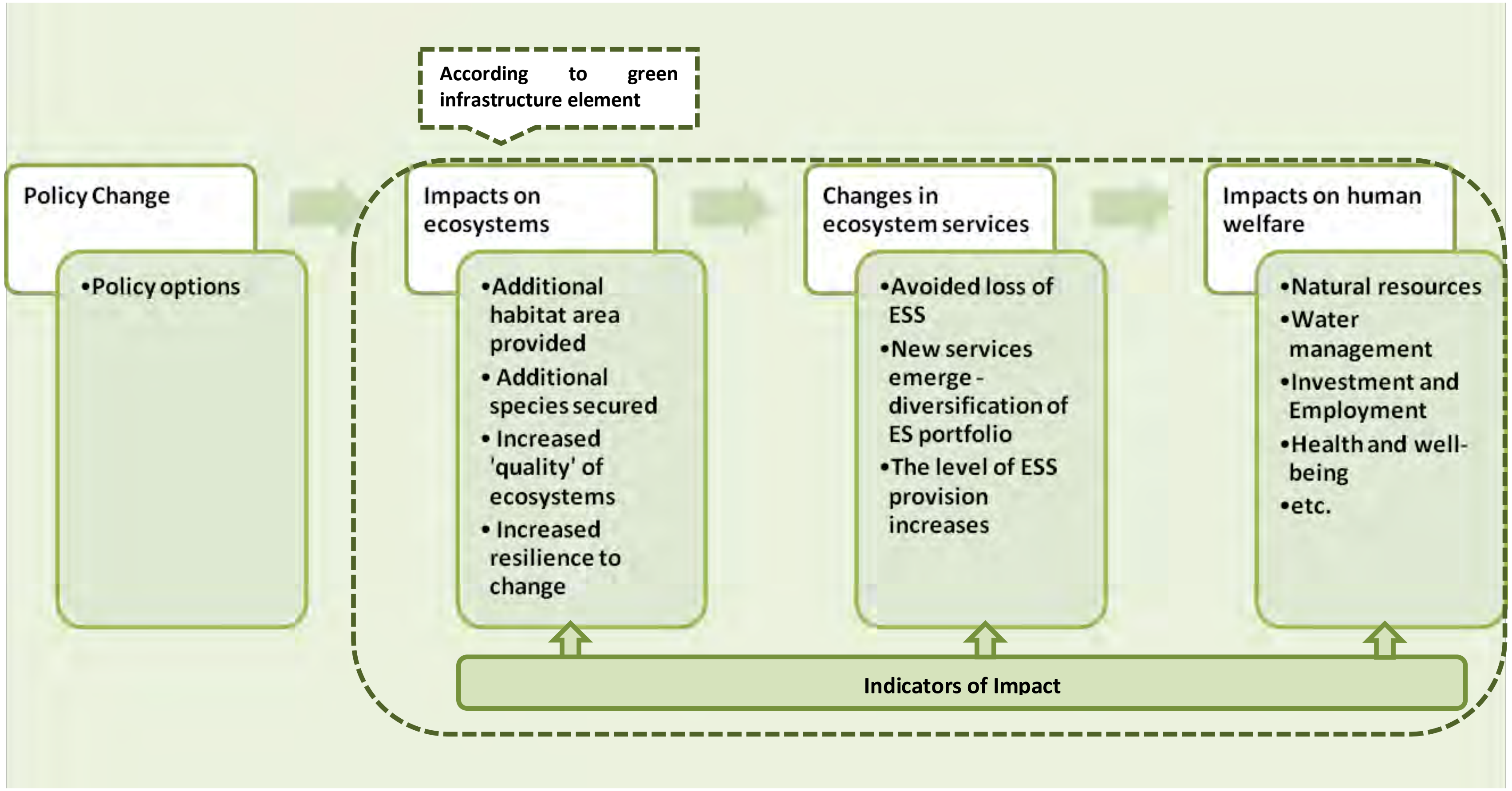
6.1.1 Functions, ecosystem services and benefits sustained by green infrastructure

Conservation of biodiversity is important not only for its intrinsic value, but also for the benefits that it provides to the economy and society. These benefits mainly result from the provision of ecosystem services as outlined in the introduction to this report. The quality and quantity of delivery is influenced by the ecosystem composition and dynamics, and determined by the diversity and structure of habitats, species and genetic resources (EASAC, 2009). The loss or degradation of components can lead to changes in the capacity of an ecosystem to supply a range of functions. The conservation and restoration of biological diversity on the other hand can insure that a sufficient portfolio of components (eg species) for the provision of different functions continues to be provided, also in face of disturbances. Such healthy ecosystems thus play a central role in guaranteeing that a stream of benefits is provided to society now and in the future.

Policy changes can influence the portfolio of services differently depending on how the agreed measures affect different habitat categories (eg grasslands, forests) and which green infrastructure elements it promotes (eg, increase of core areas and/or sustainable use zones). However, it can generally be assumed that policy changes supporting the conservation and restoration of green infrastructure will impact the health of ecosystems by providing additional habitat area, securing the protection of additional species, increasing the 'quality' of ecosystems both inside and outside core natural areas (eg positively influencing the conservation status or conserving and restoring ecosystem functions), including through increased connectivity and coherence. This on the other hand will influence the range of ecosystem services provided, either as 1) new services emerge, 2) the level of provision of some ecosystem services increases, or 3) the degradation of ecosystem services is avoided. In addition, a differentiated portfolio of ecosystem services will also be essential to guarantee the resilience of ecosystems to provide these services in the future.

Figure 6.1 provides an overview of the general logical framework developed in the context of this project for assessing the benefits of green infrastructure policy initiatives, based on the assumptions above. The framework should support the development of a 'storyline' that describes the various stages of impacts of policy change on the final benefits provision.

Figure 6.1: Understanding the impacts of policy change on the benefits provided by Green Infrastructure

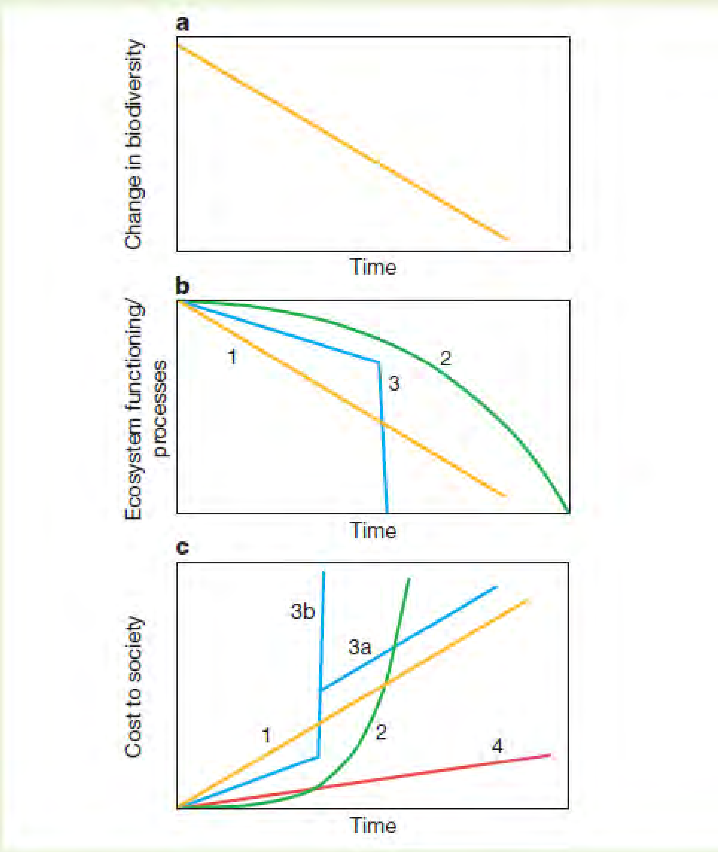


Within the scope of this study, the description of the benefits of green infrastructure had to heavily rely on existing qualitative, quantitative and monetary evidence. The information is scattered and includes a range of gaps due to

- the relative recent development of the concept of green infrastructure and related elements (eg information on extent of artificial connectivity features),
- information gaps and challenges linked to the measurement of ecosystem services provision (eg linkages between biodiversity, ecosystem services and benefits), and
- information gaps and challenges linked valuation (eg limited amount of valuation studies at regional or national level and across range of services).

Ideally, an analysis of the impacts of policy initiatives on ecosystems and their related services would allow determining what, for example, the impact of increasing forest area would be on carbon stores and water quality, or what impact an increase in area of wetlands would have on flood protection. To answer such questions it would be necessary to know the functional relationship between ecosystem properties (eg area, 'quality') and processes and ecosystem services. However, although we have reasonable knowledge of the direction of impacts (eg lost forest areas reduces carbon stores) we often have poor knowledge of the exact shape of the relationship, particularly where they are non-linear as illustrated in Figure 6.2 and are rarely able to quantify impacts. This problem was clearly illustrated in the Scoping the Science study (Balmford et al, 2008) that supported the TEEB initiative.

Figure 6.2: Ecosystem and societal consequences of changes in biodiversity.



Note: **a**, A linear change in biodiversity through time. **b**, This change might (1) induce a linear response in ecosystem processes, (2) have increasingly large impacts on ecosystem functioning, yielding exponential ecosystem change through time, or (3) exhibit abrupt thresholds owing to the loss of a keystone species, the loss of the last member of a key functional group, or the addition of a new species trait. **c**, Even if ecosystem response to diversity changes is linear, associated societal costs through time may respond nonlinearly. Departures from a linear increase (1) in societal costs over time might include larger cost increases (2) associated with each additional unit of change in ecosystem processes, yielding an exponential cost curve through time. Reductions of resource supply below threshold levels may induce step increases in societal costs (3a), such as reductions in water supply below the point where all consumers have access to enough for desired uses. If changes in resource supply or ecosystem processes exceed thresholds for supporting large segments of society, stepwise cost increases may be unmeasurable or essentially infinite (3b). The perceived ecological changes and societal costs of diversity change may be small (4). Actual, unrecognized costs may be far higher (lines 1, 2 and 3) and discovered only later as lost option values. Conservation of biodiversity can help avoid such negative ecological and economic 'surprises'. *Source: Chapin III et al (2000)*

It needs to be recognised that impacts on ecosystem services and the benefits provided are interrelated and context specific. Many of the complex interactions between ecosystems and the services they provide are not yet well understood. The conservation and restoration measures undertaken as part of policy initiatives might have 'ecological' multiplying effects across services which are not yet recognised and valued, due to the potential non-linearity between supporting services and other services.

In addition, the value of a service does not necessarily linearly increase with the level of physical provision, as it will be influenced by the responsiveness of demand, ie the needs of beneficiaries, and supply. There will therefore be many gaps in our understanding of the effects of specific policy initiatives on specific ecosystem services and their value.

In order to get a more conclusive picture of the potential environmental, economic and social benefits of policy change, this chapter focuses on describing the logical chain to the extent possible, ie providing an overview of the existing evidence base and describing causal relationships according to the framework provided above.

6.1.2 Costs and Cost-effectiveness of green infrastructure

Biodiversity conservation has traditionally been paid for through public financing by governments at the national or regional, and to some extent, at EU level (eg co-financing of the Natura 2000 network). An increasing move towards the valuation of ecosystem services provided by biodiversity conservation and a closer examination of the direct and indirect beneficiaries of such services has opened up possibilities for a wider range of funders. Although the business sector's funding of nature has to date primarily been via payments for restoring ecosystems degraded by their activities, the sector has become increasingly involved in the funding of nature conservation in order to secure the long-term provision of services at rates more economical than conventional measures (eg water purification), and to ensure potential new opportunities of investment (eg biomimicry). These developments, as well as the advent of a period of reduced public spending, create a greater need to understand the costs of nature conservation in relation to the benefits it provides and to highlight in particular the cost-effectiveness of specific measures to deliver the desired outcomes.

The evaluation of the ecological, social and economic impacts of green infrastructure initiatives is essential for assessing their efficiency and effectiveness in achieving outcomes, thus supporting a more effective allocation of limited financial resources. Numerous studies have suggested that the explicit consideration of the cost of conservation within programmes can significantly increase the rate of return on investment (eg Carwardine et al, 2008). Nonetheless, a comprehensive evaluation of the social rate of return on investment provided by conservation programmes, for example, is rarely provided (Ferraro and Pattanayak, 2006). As outlined in the previous section introducing the benefits of green infrastructure and in Gantioler et al (2010), this is largely related due to the still apparent lack of quantitative/monetary and well-documented information on the socio-economic benefits of biodiversity conservation.

The terms 'cost-effectiveness' and efficiency are used throughout the literature to describe conservation/ecosystem service returns per unit of investment. Laycock et al (2009), who reviewed the cost-effectiveness of the UK Biodiversity Action Plan, define "effectiveness" in a conservation context as the measure of total conservation gains, while "efficiency" is the maximisation of efficiency gains per unit cost. Efficiency can therefore be increased through either minimising costs or maximising benefits (see Murdoch et al, 2010). (2009) describe efficiency as 'the maximum biodiversity represented at the lowest cost, often measured as the fewest number of sites'.

Establishing the effectiveness and efficiency of green infrastructure and its components is being aided by a growing literature on evaluation the economic benefits of the services that ecosystems provide. However, certain goods and services can be more easily given a monetary value, particularly provisioning services; other services, in particular those that reflect societal values, are not reflected in market prices. In these cases often approaches are required involving the analysis of stated or revealed preferences of stakeholders to determine 'willingness-to-pay'. Broader welfare benefits may still not be captured in monetary terms. In this regard, a measure may be relatively efficient in terms of increasing biodiversity (compared to competing approaches), but may have a negative cost-benefit ratio, particularly if considering the current lack of information on the monetary benefits.

In this study, the term 'cost-effectiveness' has been used in place of 'efficiency' to describe the return on green infrastructure initiatives for both biodiversity and ecosystem services. This is primarily thought to facilitate the communication of the results and better reflect the exercise which was carried out in the context of this study.

6.1.3 Chapter's structure

To allow for a structured discussion of the ecosystem services and benefits of green infrastructure and its cost-effectiveness, following structure was adopted in this chapter:

Section 0 of provides a general introduction into the linkages between green infrastructure and ecosystem services provision, and an outline of the potential **ecosystem functions and services sustained by different green infrastructure elements**. This includes case examples on quantitative and monetary benefits where relevant to determine their cost-effectiveness, but focuses particularly on qualitative evidence. **Section 0** then provides insights into the **cost-effectiveness of each of the green infrastructure elements.** A literature review was carried out to determine the extent to which detailed cost-benefit analysis of the green infrastructure elements already exist at the EU or Member State level. This is supplemented with data from outside the EU in cases where such studies do not exist at this level. Annex III provides an overview of the costs of the 98 initiatives review in the course of this study.

Section 6.3 provides evidence on the potential **quantitative and monetary impact of integrated green infrastructure** on human well-being in terms of benefits provided. This very often refers to information on the benefits supported by ecosystems in general as proxy for the value of green infrastructure and a collection of evidence which cannot be directly linked to individual green infrastructure elements. It distinguishes between 10 key benefits groups, their underlying functions and physical services, and their potential quantitative and monetary description. **Section 6.3** then also examines the likely cost-effectiveness of identified green infrastructure initiatives and integrated approaches.

Section 6.4 on conclusions includes a final **qualitative assessment** of the estimated impact of green infrastructure elements on benefits provided, setting in relation evidence from sections 0 and 6.3, and at the same time providing a short analysis of what the overall impact of different elements combined might be (policy initiative level). **Section 6.4** then also includes a final **qualitative assessment** of the cost-effectiveness of green infrastructure.

An analysis of the cost data collated through the initiatives identified in the country analysis described in section 3.1, also distinguishing different types of costs, is included in Annex III.

6.2 The benefits and cost-effectiveness of green infrastructure elements

Functions and services sustained by green infrastructure elements

The designation of areas to conserve and restore key habitats and species has been identified as essential means to halt further loss of biodiversity. In this regard, the Natura 2000 network forms the foundation for biodiversity conservation in the EU, supported by the designation of additional protected areas and national parks at the national level. The **socio-economic benefits** of the network and of protected areas are linked to the avoided degradation of ecosystems due to the designation and the implementation of management measures which can affect the quantity and quality of ecosystem services provided. Differently to many national protection systems, Natura 2000 represents a network of conservation and restoration areas with varying degrees of protection and therefore varying degrees of activities allowed within and in the near proximity of the sites, depending on the land use type. This can lead to a wider range of benefits potentially provided compared to national designation schemes (Gantioler et al, 2010).

However, the designation of protected areas covering core species and habitats might not be sufficient in securing healthy ecosystems. Activities outside the boundaries of the areas can affect the functions of ecosystems within, potentially leading to unstable states and affecting the provision of a range of ecosystem services. The isolation of areas might therefore also limit the level of benefits provided due to a disruption of important ecosystem functions and connectivity.

EC (2010; adapted from Foley et al., 2005) provides an overview of the ways different types of land use might exemplarily and figuratively affect the provision of ecosystem services. Natural ecosystems for example can provide a very high level of different benefits, but usually provide only limited quantities of food or fibre. Intensive agriculture, on the other hand, can lead to a very high amount of crop production (at least on the short term), but to the detriment of other services, which in the end will likely also affect the provision of this one service in the long-term. Extensive forms of farming might not achieve the same level of ecosystem services as natural areas (eg, water flow regulation), but they can complement the portfolio of services delivered.

The portfolio of benefits will be influenced differently depending on the habitat category (eg, grasslands, woodlands). However, it can generally be assumed that ecosystems can be strengthened outside and within sites and the provision of benefits enhanced by integrating new elements with core areas of habitat. The degree to which 1) new services emerge (eg, crop production), 2) the level of provision of some ecosystem services increases (eg. increased genetic resources due to species migration), or 3) the resilience of ecosystems to provide those services in the future is affected will be influenced by the following two main factors:

- Additional area provided
- Quality of ecosystems both inside and outside core natural areas.

It is the understanding of the authors that 'quality' is not only determined by the conservation status of species and habitats inside and outside core areas, but is also affected by the degree of connectivity and coherence and reduced levels of fragmentation. It is expected that a targeted provision of green infrastructure outside core areas is able to enhance ecosystem functioning by affecting the diversity of species and habitats covered. The term 'quality' thus also refers to aspects such as integrity, connectivity and critical mass.

In order to be able to assess the socio-economic benefits that the green infrastructure elements provide it will be important to determine how they relate to the factors described above. This also includes defining appropriate indicators to describe the quality impact (eg conservation status of key habitats and species, status of common species) of the different elements (see chapter **Error! Reference source not found.**).

For example, an artificial connectivity feature such as a green bridge may mainly consist of additional grassland, which *per se* does not provide many additional ecosystem service benefits (eg hay production). However, it might substantially affect the 'quality' of ecosystems between two protected areas, by improving the conservation status of certain species, which may result in an increased level of ecosystem service provision.

An assessment of key ecosystem services provided by the different green infrastructure elements is outlined below. It needs to be noted that they are likely many overlaps across the different elements, given also the difficulty of clearly separating them (eg role of Natura 2000 network in providing core areas, sustainable use and restoration zones). However, the following analysis should help to determine what key role certain elements can play.

6.2.1 Core areas

Ecosystem services and benefits

As core areas can encompass a variety of habitat types, a wide range of ecosystem services are potentially associated with this green infrastructure element. While the designation itself is not responsible for the existence of services provided by an ecosystem found within a core area, designation is important to avoid its degradation and the loss of a wider range of ecosystem services. In addition, it affects their quantity, quality and composure, depending to a significant degree on the management measures implemented and the activities that are permitted or prohibited within the area (Gantioler et al, 2010).

As noted with regard to the Natura 2000 network, in the absence of any designation or conservation measure, the flow of benefits risks being unbalanced (eg, in favour of provisioning services), with some services becoming eroded (eg regulating services, cultural services) or even completely lost in extreme cases where the site faces strong environmental pressures or conversion to other land-use types (Gantioler et al, 2010). Overall, protected areas prevent the degradation of ecosystems within their boundaries, thereby maintaining or even enhancing the provision of services (TEEB, 2011). In other cases, designation and the associated measures can also create additional services (eg recreational and tourism services, products branding). Some interesting examples on key services supported by core areas, as identified in existing studies, are detailed below.

Although food provision is not likely to be a major service for many protected areas (at least in terms of level of production), they are considered important reservoirs of plant genetic resources, including endemic and threatened crop wild relatives (Mulongoy and Gidda, 2008; Stolton et al, 2006). Crop wild relatives may be important sources of novel traits for resistance to pathogens and drought, and tolerance to extreme temperatures and salinity (Mulongoy&Gidda, 2008). European temperate grasslands are not only extremely rich in species, but also display high genetic variability within species (Prentice et al. 2006, in Vandewalle et al, 2010). Numerous protected areas throughout the world provide natural water filtration and provision systems for municipal water supplies (Mulongoy and Gidda, 2008; Dudley and Stolton, 2003); (Getzner, 2009). For example, Berlin's water supply is provided entirely by groundwater from nine waterworks surrounded by protected zones. A total area of 230 km^2 is protected specifically for the purpose of maintaining water quality (Berliner Wasserbetriebe, 2011).

Dudley et al. (2010) also underlines that protected areas are the most effective management strategy to avoid conversion to other types of land-use, thereby preventing the release of carbon that is already present in vegetation and soils. In addition to the above mitigation services, protected areas can play an important role in ecosystem-based adaptation to climate change. They provide a range of ecosystem services that directly address some of the likely impacts of climate change on human well-being (Dudley et al., 2010). These include preventing or reducing the effects of natural disasters, providing a secure drinkable water supply, addressing climate-related health issues and maintaining food supplies such as wild foods, fisheries and crop wild relatives (Dudley et al., 2010). As vulnerability to extreme weather events is predicted to increase with climate change, protected ecosystems, particularly forests and wetlands, can act as barriers or buffer zones against floods, tidal storms, coastal erosion and landslides (Mulongoy and Gidda, 2008). Protection status also helps reduce grazing pressure and maintain watersheds and water retention in soil, preventing droughts and desertification (Dudley et al., 2010; TEEB, 2011).

Core areas are also known to provide a range of cultural services, such as spiritual values and opportunities for nature-based tourism. The WWF/ARC report Beyond Belief: Linking faiths and protected areas to support biodiversity conservation (Dudley et al., 2006) explored the interactions between faiths and biodiversity conservation and included a survey of one hundred protected areas around the world which provide important spiritual values. Species, open spaces, natural landscapes and scenic views are an important driver of tourism, with substantial economic benefits (TEEB, 2011). For example, the annual profits associated with tourism in the Bayerischer Wald, Berchtesgarden and Mueritz national parks in Germany amount to almost €14 million/year (Job and Metzler, 2005, in Gantioler et al., 2010). A national level assessment of the economic impacts of nature tourism and nature-related recreation activities in Finland found that total annual revenue linked with visitor spending in national parks was €70.1 million and supported local employment by creating 893 person-years (Metsahallitus, 2009, in Gantioler et al., 2010). The forest rehabilitation project in Krkonose and Sumava National Parks in the Czech Republic is thought to have brought about numerous benefits, particularly related to climate adaptation but also to soil erosion or air quality. In particular, it has been estimated that alongside other broad socio-economic benefits project lead to an estimated 9.8 million tonnes of sequestered carbon. In total, the project's costs were estimated at around € 22 million for the period 1992 - 2007 (for further details see Ecologic Institute and ECI, 2011 forthcoming).

Box 6.1: Examples of socio-economic benefits provided by core areas

Benefits of marine protected areas

An ex ante estimation of the benefits arising from implementation of the proposed network of marine conservation zones in the UK found that marine protected areas would have a high positive impact on services such as nutrient cycling, climate regulation, bioremediation of waste, and habitat provision compared to the situation prevailing in the absence of designation (Hussain et al, 2010). For instance, mainly using a benefit transfer technique, the study estimated an increase in food provision worth **£885 million** and an increase of benefits associated with leisure and recreation worth about **£1.4–£3.4 billion**, resulting from the full implementation of the network. In terms of provisioning services, a review of 112 studies on 80 marine protected areas found that fish populations, size and biomass increased significantly inside reserves, allowing spillover to nearby fishing grounds (Halpern, 2003, cited in TEEB, 2011). A field survey of 12 marine protected areas in Southern Europe reported significant economic gains from commercial fishing, recreational fishing and diving activities in the areas. However, it is difficult to distinguish the effects attributable to a site's reserve status from the level of benefits that would have been delivered in the absence of protection (Roncin et al, 2008).

Overall socio-economic benefits associated with Natura 2000

According to IEEP et al (2011, forthcoming), a first estimate of the benefits of the (terrestrial) Natura 2000 network suggests that these could amount to **€200-300 billion per year** at present. The values were obtained by scaling up from existing site based studies that looked into a broader range of ecosystem services associated with the network. The estimate is based on a relatively small number of studies from a small number of authors and scaled up to the EU level using the benefits transfer method. **The** value of**€200-300 billion per year** relates to a range of services from the protected area network, and should be seen as 'gross benefits' delivered by sites, rather than the net benefits of the Natura 2000 designation and associated conservation measures. With regard carbon, for example, **it is estimated that the Natura 2000 network currently stores around 9.6 billion tonnes of carbon, equivalent to 35 billion tonnes of CO_2, which is estimated to be worth between €607 billion and €1,130 billion (stock value in 2010)**, depending on the price attached to a tonne of carbon.

The contribution of Natura 2000 to climate regulation

In addition to the side-based calculations above, IEEP et al (2011, forthcoming) undertook an ecosystem services based approach. According to authors, the entire Natura 2000 network currently sequesters approximately 9.6 giga tons of carbon. Forests and other woodland represent the most important sink within the network, accounting for 52per cent of the total carbon stocks, followed by dryland ecosystems (17per cent) and marine/coastal ecosystems (15per cent). The total carbon value of Natura 2000 sites ranges between **€607.2 and 1129.6 billion** in 2010, depending on the choice of carbon prices. In 2020, the total value would be **€1376.7 to 1976.8 billion**. The study also evaluates the potential economic gains compared to this baseline value under two policy scenarios. Improving the current conservation status or quality of forest, grassland and cropland habitats would increase the value of carbon sequestration in the network by 1.71per cent in 2020. Increasing Natura 2000 forest cover by 10per cent via conversion of some cropland and grassland ecosystems yields a value increase of 3.74per cent in 2020. These economic gains can also be interpreted as lower-bound estimates of the costs of policy inaction.

The contribution of Natura 2000 to recreation and tourism

According to a study undertaken by BIO Intelligence Service (2011, forthcoming) to complement work by IEEP et al (2011, forthcoming), expenditure supported by roughly 1.7 million billion visitor days to Natura 2000 sites amounts to € 50-85 billion/year (2006 price levels). Only a share of the visitors is explicitly attracted by the Natura 2000 designation, according to the authors. Most are likely simply attracted to the site for its aesthetic and landscape value. If only visitors who have affinity for Natura 2000 designation are taken into account (230-520,000 million visitor days), the expenditure decreases to €9-20 billion/year. Based on a meta-analysis of published estimates from protected areas in Europe, the value of recreational benefits was estimated at € 5- 9 billion per annum.

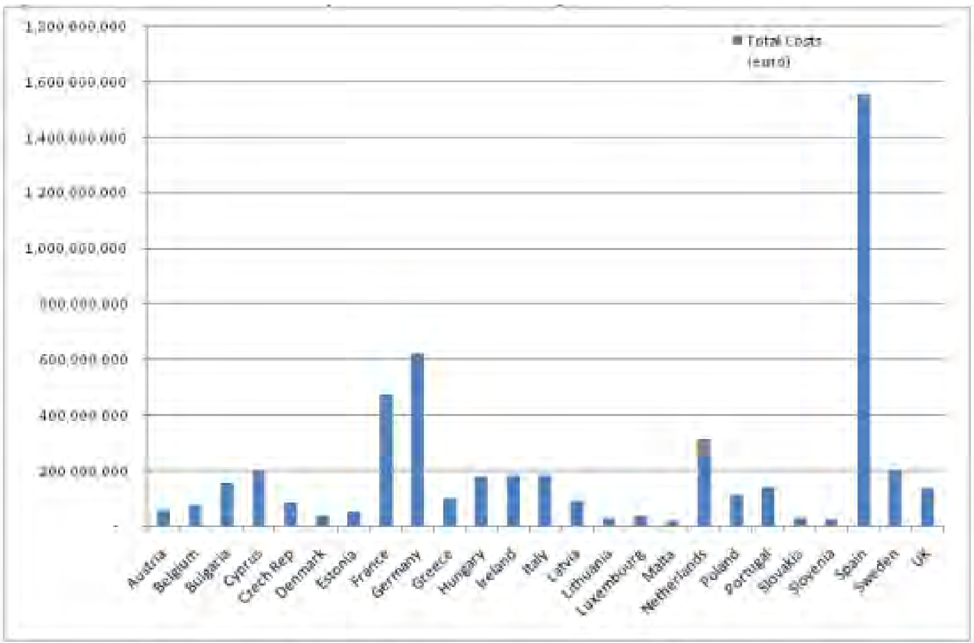
The benefits of SSSIs in the UK
According to a study by GHK et al. (2011), currently there are roughly 5,000 Sites of Specific Scientific Interest (SSSIs) in England and Wales, which include a wide range of habitats (mainly semi-natural) and geological features and provide a range of benefits to society. SSSIs cover around 8% of the land area of England and 12% of Wales, and a rather small and fragmented and do not constitute a network. However, more than 96% of SSSI area in England was in favourable or recovering condition by the end of 2010. Public expenditure on SSSIs has thus grown to further build on this achievement and now totals **£101** million annually in England and **£10 million** annually in Wales. At the same time, the authors estimate that the public is willing to pay **£827million** for the benefits currently provided by SSSIs in England and **£128million** for those provided by sites in Wales. The benefits of increasing funding to enable all sites to reach favourable condition are estimated at **£666 million** in England and **£103 million** in Wales. This significantly exceeds the annual public cost of the policy. The choice experiment focused on certain major ecosystem services only, not the full range of services potentially delivered by SSSIs, and also due to other methodological challenges the figures above represent estimates only.

Costs and cost-effectiveness

Protected areas vary substantially in their cost-effectiveness in achieving biodiversity conservation or the provision of ecosystem services (Wiersma and Nudds, 2009; and references therein). The factors affecting cost-effectiveness are disputed. Fuller et al (2010), for example, suggest that many protected areas are based on a historical rather than conservation basis and that conservation performance of protected areas could be radically improved, without an increase in spending, by replacing underperforming sites with new ones that provide greater representation of species. Dobson et al (1997) suggest that the existence of aggregated geographic distributions of species in the United States, as a result of endemism and anthropogenic pressures, cost-effectiveness could be greatly increased by expanding conservation efforts and expenditure within the most important areas, thus limiting transaction costs. Similarly, Armsworth et al (2011) in the UK, in an examination of costs associated with small protected areas, find that site area is the most determinant of management costs noting that the implementation of management conservation on an additional hectare of land in a large protected site incurs a lower cost than doing the same in a smaller protected area. Ando et al (1998) argue nonetheless that a better determinant of cost-effectiveness of protected areas may be the examination of land prices as land purchases in regions of high land prices can easily exhaust resources otherwise used for biodiversity conservation. Land prices can also be indicative of higher opportunity costs, where conservation is delivered through regulation or landowner agreements. An important consideration in the cost-effectiveness of core areas is the cost of protection per area.

An overall assessment of the cost-benefit analysis of core or protected areas at the European scale is incomplete. A number of studies have attempted to estimate the costs associated with the management of the Natura 2000 network. The Commission's own first estimate of the costs across the EU-25 Member States of managing the Natura 2000 indicated that €6.1 billion per year was required, based on own Markland Report (Markland, 2002), at an annual cost of €107/ha. This estimate was updated by Gantioler et al (2010) who provided a revised estimated of €5.8 billion per annum extrapolated to the EU-27 based on the average cost of €63/ha per annum, lower than previous estimates. Furthermore, a study by BirdLife (2009) indicates the likely costs of managing the Natura network are €128/ha per year, based on estimates from six Member States provided by their partners.

Figure 6.3: Estimated total costs of managing Natura 2000 by Member States



Source: Gantioler et al (2010)

The low estimates provided in Gantioler et al (2010) reflect discrepancies in the manner in which Member States (on whose responses the estimates are based) interpreted the question. As a result, in most Member States, the estimates reflect the expenditure required to maintain Natura 2000 sites in their current condition rather than achieve favourable conservation status (FCS) as directed under the Habitats Directive. Spain was the only Member State to provide an estimate of both current expenditure and that required to meet FCS, with the latter 60 per cent higher than current spending. Therefore the estimate is potentially a significant underestimate. However, it is also assumed that factors such as level of income, the size of the sites, accessibility / proximity of the sites to urban areas, levels of income and maturity of the network have a high impact on cost levels and as such can strongly influence the cot-effectiveness of the network.

A review by the EU ALTER-Net network analysed the cost-effectiveness of the implementation of the Natura 2000 network, in Finland, Germany, Poland and the Netherlands (Wätzold et al, 2010). They found the following factors will have an important impact on the cost-effectiveness of the Natura 2000 network:

- Augmenting the societal benefits associated with conservation management.
- Careful consideration of the trade-offs associated with stakeholder involvement; engagement will involve higher costs but lower risk of costly conflicts.
- Greater investment is required in implementing management plans than planning them, as this provides greater conservation benefit.
- The guarantee of funding over the long-term produces greater certainty and improved investment decisions.

With regards to benefits, a comparison of the results of a forth-coming study (ten Brink et al, forthcoming) suggests that benefits are significantly larger than the costs, with the total carbon value alone of the network between €607 and €1,129 billion in 2010 (see). While not all of this value can be attributed to its designation (as much of the carbon may be held in these sites without inclusion in the network), the designation and subsequent management provides greater assurance as to its long-term protection.

Similarly, analysis of case studies from the Natura network suggest that a potential for benefits to significantly exceed the costs. According to a study in Ireland, the aggregate benefits provided by the Burren's limestone pavement and grasslands amounted to €4,420/ha per year using choice experiment approaches, providing a return on government investment of about 235 per cent (Van Rensburg et al, 2009).

At the Member State level, the UK has recently completed a review of the benefits associated with their Sites of Special Scientific Interest (SSSI) network (see Box 6.2). The study estimates a cost-benefit ratio of 1:8.6 at current conservation status, with significant increases expected if condition were to improve (GHK Consulting et al, 2011).

Box 6.2: Cost effectiveness of UK Biodiversity Action Plan Habitats and Marine Protected Areas

Christie et al (2011) undertook an evaluation of the impact the investment in BAP habitats in the UK has on the ecosystem services and biodiversity they provide and support. Under the current annual spend of £469 million on BAP habitats, the value of ecosystem services attributable to BAP conservation activities was estimated to be £1,336 million per year, primarily from water and climate regulation, representing a **benefit-cost ratio of 2.91** and net benefit of £897 million per year.

Source: (Christie et al, 2011)

As outlined already in Box 6.1, Marine Protected Areas can provide a range of ecosystem services including the provision of sheltered habitat in which fish biomass and population size increase significantly, boosting catch volumes in adjacent fishing areas (Roberts et al, 2001). In an evaluation of existing MPAs globally, Cullis-Suzuki and Pauly (2010) estimate that the combined benefits of these protected areas to fish stocks would be the **equivalent of a subsidy to fisheries of £870 million** a year compared to the total current subsidies, which are considered harmful and unsustainable, of approximately $30-34billion a year.

Source: (Cullis-Suzuki and Pauly, 2010)

6.2.2 Restoration zones

Ecosystem services and benefits

Aronson et al. (2007) emphasize the socio-economic benefits of restoration by referring to the "restoration of natural capital", defined as "any activity that integrates investment in and replenishment of natural capital stocks to improve the flows of ecosystem goods and services, while enhancing all aspects of human well-being."

Restoration zones can provide multiple ecosystem services, depending on the type of ecosystem restored and the specific measures undertaken. A meta-analysis of 89 published scientific evaluations of the outcomes of restoration actions undertaken in a variety of ecosystems across the world found that ecological restoration increased provision of biodiversity and ecosystem services by 44 and 25 per cent, respectively. Increases in biodiversity and ecosystem service measures after restoration were found to be positively correlated (Benayas et al, 2009).

Grassland restoration, for example, may contribute to **water flow regulation** and increase the ecosystem's **carbon sequestration** potential (MDTP, 2008, cited in TEEB, 2011).

Reforestation along coastal plains has been shown to enhance buffering capacity, providing protection against **natural hazards**. Restored wetlands can provide agricultural and urban water supply, flood control services, habitat for wildlife, new recreation opportunities, increased fishery yields and agricultural productivity (WWF, 2008). Restored ecosystems may sometimes act as direct **substitutes** for conventional 'grey infrastructure'; for instance, the restoration of watersheds may substantially increase the amount of clean water available, eliminating the need for man-made filtration facilities, as in the case of the Catskills restoration project in the state of New York (Elliman and Berry, 2007). The renaturalisation of riverbeds to optimize microbial activity has been shown to improve water quality at lower costs than filtration through water-treatment plants (TEEB, 2011).

Box 6.3: Examples of socio-economic benefits provided by ecosystem restoration zones

Along the lower **Danube River**, **restoration of floodplains** by decommissioning under-performing flood protection infrastructure has improved natural capacity to retain and release floodwaters and remove pollutants, enhanced biodiversity, and strengthened local economies through the diversification of livelihoods based on natural resources. Implementation of this project is estimated to **cost €183 million**, which can be compared to likely annual **revenues of €85.6 million** and also to flood saving costs of **€396 million** (Hulea et al, 2009). Similarly, wetland restoration was found to be the most cost-efficient measure to reduce nitrogen pollution in the Stockholm archipelago – providing a **SEK 20/KG nitrogen abatement cost**, in contrast to the next cheapest measure of **SEK 25/kg** (Gren, 1995b).

In **France**, the programme related to "Innovative measures to ensure enhanced/continued ecosystem service delivery from freshwater ecosystems" involves the removal of orphaned pieces of infrastructure to restore or improve the **ecological continuity in rivers**, which is essential for fish migration and the achievement of good ecological status of surface waters. In addition, restoration of wetlands contributes to flood and drought control, water quality, erosion, provision of drinking water and preservation of biodiversity (see in depth case study on freshwater and wetlands in Annex I).

The proposed **restoration of riparian forest habitats** (510 ha) along the Mesta River in Bulgaria would increase the sites' carbon sequestration capacity by 200 tonnes per year, to at least **1,036 t C per year or 3,797 t CO2 per year** (EUCC, 2010). In both case studies, carbon sequestration is only a co-benefit of habitat restoration, alongside other ecological and socio-economic benefits.

Similarly, the **peatlands restoration strategy** formulated by the state of **Mecklenburg-Vorpommern, Germany** in 2000 has been shown to yield significant greenhouse gas regulation benefits (Förster, 2010). By 2008, an area of 29,764 ha (about 10per cent of the area of drained peatlands in Mecklenburg-Vorpommern) had been restored, resulting in avoided emissions of about **300,000 tCO2-equivalents** every year. Assuming a marginal cost of damage caused by carbon emissions of 70 € per tCO2, the value of peatlands restoration in the area amounts to **€21.7 million every year, or €728 per ha**. To reduce the opportunity costs of foregoing conventional agriculture on restored peatlands, it has been suggested to implement alternative land uses that can generate income while sustaining carbon storage. These include extensive grazing, the production of reed or sphagnum mosses and the growth of alder forests (Förster, 2010).

Restoration of peatlands in Belarus is estimated to have led to a reduction in GHGs emissions totalling around **100,000 tonnes of CO_2** emissions equivalents avoided annually, while at the same time significantly contributing to peat fire prevention or climate adaptation in general. The results from associated nation-wide cost-benefit analysis showed that from the economic point of view the commercial exploitation of peat deposits of the peat land ecosystems in Belarus is not competitive with the conservation and sustainable use of the ecosystems (for further details please consult Ecologic Institute and ECI, 2011 forthcoming).

Costs and cost-effectiveness

Restoration, particularly 'active' restoration, often involves considerable investment and therefore creates a significant challenge for restoration projects to cover their costs.

Establishing the cost-effectiveness of restoration initiatives requires detailed monitoring and reporting of the biodiversity and socio-economic outcomes of initiatives along with information on the costs. Yet rarely is there an assessment of the costs and achievements of projects to allow the cost-effectiveness of different restoration techniques to be evaluated. In a review of over 20,000 restoration cases studies for the TEEB report, only 96 were found to provide meaningful cost data (TEEB, 2011). Additionally, approaches to costing are variable with some studies reporting only capital and labour costs whilst others report a single overall cost for the project (Bullock et al, 2011). This lack of reporting in peer-reviewed literature extends to records of ecosystem service provision. Aronson et al (2010) reviewed 1,582 peer-reviewed papers dealing with ecological restoration and found that the majority of restoration practitioners fail to report on links between ecological restoration, socio-economic aspects and links to policy, resulting in an underselling of the benefits to society of investing in restoration initiatives. Detailed cost-benefit studies that do exist are more common on the global scale than in the EU.

The effectiveness of ecological restoration is often evaluated against a reference, commonly taken to be the re-establishment of the characteristics of ecosystem (such as biodiversity or ecosystem function) that were prevalent before degradation. A meta-analysis of 89 global restoration assessments over a wide range of ecosystems indicates that median response ratios of restored systems were substantially higher than those of degraded ecosystems; 44 and 25 per cent for biodiversity and ecosystem services respectively (Rey-Benayas et al, 2009, see also section 5.2 on biodiversity benefits). Increases in biodiversity and ecosystem were particularly evident in tropical terrestrial biomes, while aquatic temperate biomes showed significant effects of restoration only on biodiversity. Values of both nonetheless remained lower in restored systems than reference ecosystems, achieving only 86 and 80 per cent median response ratios respectively compared to that of reference systems. Therefore, while individual restoration projects achieve a high level of success, ecological restoration on the whole fails to fully restore biodiversity or ecosystem services to those of reference values (Bullock et al, 2011).

Meta-analysis studies of the cost-benefits of ecological restoration at the EU or European level appears to be lacking. This makes an overview of its likely cost-effectiveness more difficult. Nonetheless, a certain indication of the direction of the cost-benefit can be drawn from selection studies and green infrastructure initiatives identified as part of this study (see also Box 6.3 on benefits).

It is evident that active restoration undertakings in an EU context often require significant investment. In many cases, it is somewhat premature to ascertain cost-effectiveness as many of the initiatives are at early stages of development and the full benefits will be properly determined in the medium to long-term. Specific cases appear to suggest that large benefits may be accrued from restoration projects. For example, Credoc (Credoc, 2008) estimated the net benefit value of improved water quality and recreation opportunities created by restoring a section of the Gardon, a river in southern France, to come to €36 million, demonstrating the potentially high rate of return possible from restoration. The overall cost-effectiveness of restoration schemes is however likely to be heavily site specific and dependent on successful implementation by users (see Box 6.4).

Box 6.4 Examples of the cost-effectiveness of restoration zones

Investment in green infrastructure: Sigmaplan II in the Scheldt Estuary, Belgium

The updated Sigmaplan II refers to a long term strategy and list of projects to increase flood protection and promote nature restoration of the Scheldt Estuary in Belgium. It includes projects in the short and longer term (2006-2030) to restore floodplains, estuarine nature areas and wetlands along the Scheldt and its tributaries, leading to over 5,000 ha of extra natural areas. The size of the program is small with relatively high costs, compared to, for example, the Lower Danube restoration programme, due partly to the specific site conditions of creating estuarine habitat along a tidal river. The costs of the project up to 2030 are projected to be approximately €869 million, of which €247 million are attributable to nature restoration, and a further €100-€200/ha/year for ongoing nature management practices. It is expected to provide flood protection benefits €740 million (over 2010 to 2100), additional ecosystem benefits (erosion protection, water retention, water purification, nutrient cycling, and carbon sequestration) worth €130 million and recreational values estimated at €22 million. The flood protection benefits can be higher for specific cases, for example in areas at high flood risk and if initiatives are considered very effective to protect cities and industrialised areas.

Source: In-depth case analysis on Freshwater and Wetlands Restoration and Management – Annex I

Freshwater wetland restoration initiative in Denmark

In 1998, the national programme for restoration of freshwater wetlands across Denmark was initiated to reduce nitrogen load from agricultural areas and to enhance natural value in newly restored sites. The initiative aimed to reclaim 8,000ha of land from agricultural uses within five years. The initiative suffered initially from unrealistically low compensatory offers to farmers and significant more time was required for the engagement of landowners than was originally foreseen. Nonetheless, by 2005, 3,060ha had been restored and a further 3,769ha approved for restoration. An initial budget of €67 million was allocated to the initiative (20% for planning, administration and monitoring; 80% for compensation and construction works), with an average cost per hectare expected to be €8,375/ha. The mean nitrogen removal rate was estimated to be 259 kg N/ha/year which was above the minimum objective set of 200 kg N/ha/year but below the target of 350 kg N/ha/year. The results range from 39 to 372 kg N/ha/year showing the very wide range of performance as a result of variations in site conditions and implementation.

Source: (Hoffmann and Baattrup-Pedersen, 2007)

Costs and Benefits of the Mersey Forest Project

The Mersey Forest project, funded through ERDF, involved investments of £7 million (€7.8 million) in more than 100 projects in the Merseyside area of North West England. This resulted in a total of 418 hectares of habitat being managed and/or improved. The benefits of these investments were estimated by Regeneris (2009) to total €2.2 million per annum, after allowing for displacement of benefits from other areas. This gives a present value of benefits of €79 million over 50 years, suggesting an overall benefit: cost ratio of more than 10:1. Regeneris estimated that each £1 invested in the project gave overall benefits of £10.20, of which £2.30 represented an increase in gross value added, £0.70 comprised social cost savings, while non-market benefits (in terms of enhanced wellbeing) amounted to £7.20. Landscape, recreation and tourism benefits accounted for the majority of the total, though provisioning services and regulation of air quality and climate were also important. The estimates were based largely on the transfer of values from other studies.

Summary of the Estimated Benefits of the Mersey Forest Project

Benefit	Annual Value (€m)	Present Value over 50 years (€ million)
Carbon sequestration	[illegible]8	1,553
Biodiversity	43	1,538[illegible]
Products from the land	1[illegible]	[illegible]6,6[illegible]3

Landscape – views from home	461	16,784
Landscape – views while travelling	590	21,475
Recreation	453	16,508
Tourism	283	10,293
Health and well being (cost savings and contribution to GVA)	37	1,338
Air pollution absorption	130	3,040
Total benefits	**2,196**	**79,217**

Source: Ecologic and GHK (2011)

Cost and benefits of restoration activities in the coastal and marine environment: Wallasea Island

Wallasea Island was re-claimed from the ocean over 400 years ago and converted to agricultural land. 'Grey' infrastructure flood defences were constructed, but have recently been found to no longer be economically viable. This makes continued public expenditures unlikely and puts the surrounding 12,100 ha floodplain at risk. The aim of the project is thus to combat the threats from climate change and coastal flooding by restoring the wetland landscape of mudflats and saltmarsh, lagoons and pasture. It will also help to offset the historical losses of such coastal habitats elsewhere in England and address the ongoing regional flood risks.

The vast majority of the costs are incurred at the beginning of the project (modelling, planning, permissions, land purchasing etc). Financial costs of the project related to management and administration activities are estimated to be on the order of £190,000 per year (excluding staff costs). Costs related to ecosystem maintenance and/or restoration include over £5 million of land purchase and physical implementation works of around £17.5 million, mainly involving deposition of material on Wallasea Island, and managed realignment through controlled breaches of the existing sea wall. The project also involves opportunity costs, eg the loss of farmland in the area, and potential negative impacts on recreational yachting and oyster fisheries (cf. eftec, 2008). It was determined, however, that these negative impacts would have been more significant in the (inevitable) event of an unmanaged breach. In sum, none of the above land-use restrictions has lead to reductions in land values.

On the benefits side, it was estimated that intertidal habitat is capable of capturing up to 2.2 tonnes of carbon per hectare per year, while the same land used for farming would be a net source of carbon. The primary benefits of the project are environmental (habitat creation), but secondary benefits also include waterborne nutrient processing and provision of fish feedings and nursery habitats. The benefits generated from carbon sequestration are valued at £ 1.7 million over the next 50 years (eftec, 2008). In addition, society benefits from avoided flood defence infrastructure expenditure of £5 – £10 million and avoided loss of built assets on Wallasea worth £3.1 million under moderate flood event scenarios.

Sources: Eftec (2008), Ecologic and ECI Oxford (2011)

Payments for ecosystem restoration have been typically borne by the public sector in the public interest, or by businesses restoring areas damaged by their activities (Bullock et al, 2010). The advent of Payments for Ecosystem Services provides an opportunity for financing from willing buyers of a service for individuals or communities to maintain or increase the provision of services, including via restoration. Nevertheless, as many of the returns are in the realms of public goods and will only be realised over the long-term, direct government investment is likely to needed in many circumstances (TEEB, 2011).

6.2.3 Sustainable use / ecosystem service zones

Ecosystem services and benefits

By definition, sustainable use areas ensure the sustainable provision of a range of ecosystem services. Protected areas corresponding to IUCN management category V fall under this category. They are sites "where the interaction of people and nature over time has produced an area of distinct character with significant ecological, biological, cultural and scenic value". Their objective is to protect and sustain the values created by this interaction, but also to provide opportunities for enjoyment and socio-economic activity through recreation and tourism and to provide natural products and environmental services (Dudley, 2008). Protected areas under category VI have as their primary objective to "protect natural ecosystems and use natural resources sustainably, when conservation and sustainable use can be mutually beneficial". Such areas aim to conserve ecosystems and habitats, together with associated cultural values and natural resource management systems (Dudley, 2008). In addition, given also the limited availability of information specifically assessing the socio-economic benefits of protected areas falling under these categories, sustainable land management more broadly is taken into as a proxy for the assessment of benefits of sustainable use zones.

Sustainable management practices can protect or enhance a range of services associated with agricultural or forest ecosystems. High Nature Value (HNV) farming for instance is a low-input farming system associated with the preservation of high biodiversity values. According to different estimations, the share of HNV farmland varies between 32 and 43 per cent of agricultural land in the EU (EEA, 2010a). HNV farmland is characterised by having a high proportion of semi-natural vegetation, a mosaic of low intensity agriculture and semi-natural structural elements, including field margins, hedgerows, stone walls, patches of woodland or scrub, and small rivers, or supporting rare species whose numbers may represent a high proportion of the European or world populations (EEA, 2010a). It is known that the Natura 2000 network is protecting a significant portion of HNV farming area, especially parts that are of recognised biodiversity quality (for further information see Paracchini et al., 2008). Conversely, HNV farming directly benefits conservation of Natura 2000 farmland habitats, being either within actual sites or in the wider countryside. However, it also needs to be mentioned that there is no formal HNV farmland designation and that disputes on the exact definition are still on-going. As such it not necessarily falls under the definition of green infrastructure as applied for this report. Nevertheless, independent from the current lack of an exact definition, it can be agreed that the concept generally addresses extensive farming measures with high biodiversity impacts and as such can be seen as representative of sustainable use zones.

Given the extensive character of most HNV farming systems, such farmland can support a variety of ecosystem services, in addition to its conservation benefits. For instance, HNV farming systems are not only important for maintaining many of Europe's threatened habitats and species, but also contribute to soil carbon storage, the protection of water resources and fire prevention (RSPB, 2011). Such systems also underpin an active rural population and often sustain a unique way of life in some of Europe's most economically fragile areas (RSPB, 2011). More generally, low input farming systems aim to enhance biological soil fertility and the agro-ecosystem's natural capacity to reduce negative effects on agricultural production, such as disease and climate change (Biala et al., 2008). Such systems provide a wider portfolio of ecosystem services than intensive systems, by maintaining and enhancing biodiversity and the landscape, and thanks to the associated practices that promote good soil and water management (Cooper et al., 2010).Carbon losses from agricultural ecosystems can be reduced through the adoption of farming practices which increase organic matter inputs to the soil and/or reduce soil disturbance, such as reduced and zero tillage, set-aside, perennial crops and deep rooting crops, more efficient use of organic amendments, organic farming, extensification, and conversion of arable land to grassland or woodland (Smith, 2004).

Forest management and conservation practices influence the provision of ecosystem services in managed forests and may involve trade-offs between different benefits. In recent years, the scope of sustainable forest management has broadened from sustained timber management to sustained management of all forest functions, including amenity, recreation, soil protection, carbon sequestration, biodiversity, and water production (Baskent and Keles, 2008). Management aimed at enhancing forests' carbon sequestration potential has received growing attention. Forest management practices such as control of fire by thinning and removal of undergrowth can bring mitigation benefits (Campbell et al., 2009). In 2011, 24 European countries reported soil protection as a main policy objective of protective forest management, with particular focus on preventing and controlling soil erosion and degradation. Other countries highlighted policies on water management and protection, in particular, the role of forests in regulating natural water cycles, maintaining water reservoirs and preventing flooding (Forest Europe et al., 2011).

Box 6.5 provides some examples of the potential benefits of sustainable use zones. Given the current difficulty in separating those zones from general sustainable land management, related benefits have been mainly covered in the next section on benefits from integrated green infrastructure and ecosystems in general.

Box 6.5: Examples of on socio-economic benefits provided by sustainable use zones

An ex ante study of the benefits of the proposed network of **marine conservation zones** in the UK estimates the present value of the climate regulation service provided by the initiative at **£7.4 to 18.1 billion**, depending on network size and the level of protection (Hussain et al, 2010). The value of climate regulation in the scenario with the most extensive network and the most restrictive management regime is almost £10 billion higher than the value of this service in 2007 (no-designation scenario).

More than 20 per cent of Europe's forests are '**protective forests'**, ie having 'protective function' for soil, water and other ecosystem services as the main management objective. Austria's protection forests, for example, are important buffers against natural hazards such as avalanches and rock slides; in the absence of this ecosystem service, **€ 600 million** would have to be invested annually in technical solutions to achieve an equivalent level of protection (see In-depth case analysis on Farmland and Forests - Annex I).

National Forest Creation, West/East Midlands, UK
Evaluating the costs and benefits resulting from the public funds invested in long term woodland creation project in central England over the period 1990 to 2100, it has been estimated that the net present benefits of the project have a **total present value** of **£909 million** (€1017 million) with associated **costs of £188** million (€210 million) (Eftec, 2010 as in Naumann et al., 2011).

Biosphere reserves include a variety of natural and human-influenced ecosystems with the main goal of bringing together biodiversity conservation and socio-economic development for the well-being of the ecosystems and communities living in such areas (Persic et al, 2008). Biosphere reserves provide goods such as organically-produced agricultural products and medicinal herbs, cultural services such as nature-based tourism, as well as climate regulation and water purification services (Persic et al, 2008).

Costs and cost-effectiveness

Sustainable use zones, as described above, are likely to perform an active role in improving ecosystem resilience through improved permeability of the landscape. Primary provision of services nonetheless is likely to via sectoral land use (agriculture or forestry) or the designation of land to provide a specific ecosystem service (eg flood protection). The extent to which this element has been recognised and utilised to date for this purpose is debatable. While agricultural land has received a sustained level of support from the public in the EU over the last 50 years, in part justified by the understanding that the sector provides (or has the potential to provide) a wide range of public goods highly valued by society, only a small proportion of payments are targeted at specific environmental outcomes. As sustainable use zones will almost exclusively fall within private ownership, participation within any scheme to deliver public goods would most likely be on a voluntary basis, therefore requiring any incentive scheme to be sufficiently attractive to achieve the level of uptake required (Hart et al, 2011a).

While there are no full cost-benefit studies of these areas at the EU scale, Hart et al (2011b) examined the costs associated with meeting the full range of environmental issues, such as biodiversity, but including climate change mitigation, water quality, soil conservation and landscape protection, on agricultural and forested land, considering the need to reverse environmental decline and to fully mitigate pressures faced. They estimate the costs of undertaking environmentally beneficial land management on agricultural and forested land by 2020 to be in the region of €34 billion per year. Over 50 per cent (€18 billion/year) of these costs associated with bringing 40-50 per cent of arable land under one or more relevant farm management practices with a further €10 billion/year associated with grassland management (with organic management and maintaining stubble over the winter accounting for 22 per cent each of this). The maintenance of 100 per cent of the landscape/structural features on farms in comparison appears to be a relatively low cost option; this accounts for only 4.6 per cent of the cost but significant environmental benefits, although excludes the costs of restoring features removed in many areas (Hart et al, 2011b).

Table 6.1 Cost Estimates Associated with Different Land Uses

Land Use	Cost Estimate for Environmental Management needed (€ billion)	Proportion of cost estimate (%)
Arable	17.6	51.5
Grassland	10.1	29.5
Permanent Crops	1.5	4.4
Rice	0.1	0.3
Wetland Habitats (including, grazing marsh, peatland etc)	1.5	4.4
Forest and Woodland	3.4	9.9
Total	**34.2**	**100**

Source: Hart et al, 2011b

At the Member State level, one study (Cao et al, 2009) carries out a similar study examining the costs of meeting priorities associated with environmental land management requirements in the UK. It estimates the total costs of meeting the UK's environmental targets in relation to agricultural and forestry land management at €2.5 billion per year over approximately 16.2 million hectares (ie €154/ha).

In addition, Hart et al (2011b) estimated the cost of maintaining HNV over the EU-27 in the range of €16.9 – 23.1 billion per annum. This was calculated by combining the estimated funding requirements of HNV through the decoupled payments of Pillar 1, and the Less Favoured Area (LFA) and agri-environment payments under Pillar 2. The range of estimates is due to different assumptions on the proportion of HNV requiring agri-environment support. On the other side, however the monetary benefits provided by those areas have not been assessed in any detail and as such a comparison of the costs in relation to the benefits is not possible.

6.2.4 Green urban areas

Ecosystem Services and benefits

Studies on the benefits of urban green infrastructure have primarily focused on the contribution of parks, gardens, urban trees and green roofs to micro-climate control, air quality and water management.

Urban green areas play a major role in moderating the ‘urban heat island’ effect by direct shading and evapotranspiration. Increasing tree cover by 25per cent was estimated to reduce afternoon air temperatures by 5 to 10^{o}C (Zipperer et al., 1997). In town centres and high density residential areas, green roofs have been shown to provide an effective means to reduce surface temperatures and enhance the thermal efficiency of buildings (Carter and Butler, 2008; Handley and Carter, 2006); (Goode, 2006). By shading the roof surface and through evapotranspiration, plants have a cooling effect and transport water back into the atmosphere. Research by Gaffin et al. (2005, 2006, cited in Oberndorfer et al., 2007) indicates that evapotranspiration may be the most important mechanism by which green roofs reduce the amount of heat transferred through the roof. Further research is needed to assess the relative impact of different types of greening interventions on air temperatures, and the impact of greenspace abundance and distribution on the magnitude of the cooling effect (Bowler et al., 2010). A meta-analysis of empirical data on the effects of urban greening on temperature shows that, on average, an urban park could be 1°C cooler than a non-green site (Bowler et al, 2010). The cooling effect of parks may extend to the wider surrounding area (Green Infrastructure North West, 2011). For example, a long-term study of three parks in Göteburg showed the effect could reach as far as 1 km from the park boundary, for the largest park considered (156 ha) (Upmanis et al, 1998). Modelling by Gill et al (2007)in Greater Manchester suggests that increasing the current area of green infrastructure by 10 per cent in areas with little or no green cover would cool the surface temperature by 2.5°C under the high emissions scenario based on the UK Climate Impacts Programme predictions. McPherson et al (1994) modelled the impact of tree planting on temperatures in Chicago and showed that, at local scale, large numbers of trees and green spaces could reduce local air temperatures by 0.5°C. At city scale, increasing Chicago’s urban tree cover by 10 per cent was estimated to reduce average air temperatures by 1°C, which would translate into 5-10 per cent reductions in total heating and cooling energy use. Similar modelling with regard to green roofs in the US indicates reductions in electricity consumption of 2 to 6 per cent compared to conventional roofs (Foster et al, 2011). However, energy-related figures cannot be readily transferred to Europe, where domestic air conditioning is less common than in the US. The green infrastructure valuation toolkit developed by Green Infrastructure North West (2011) applies a rate of 3 per cent energy savings for residential buildings and of 8 per cent for commercial properties located within 10 metres from trees.

A vast literature has explored the role of trees and urban greenspace in regulating air quality. Trees and woodlands can absorb significant quantities of gaseous pollutants from the atmosphere, such as sulphur dioxide and NO_x gases. Their absorbing capacity depends on a number of factors including tree species, canopy stomatal conductance, and environmental conditions (Broadmeadow and Freer-Smith, 1996, cited in Forest Research, 2010). Vegetation also reduces the amount of suspended particles in the atmosphere, through accumulation on the surface of leaves and bark. The deposition of polycyclic aromatic hydrocarbons on soil beneath trees can result in the degradation of particles by bacteria in the rhizosphere (Spriggs et al., 2005, cited in Forest Research, 2010). Reduced concentrations of pollutants in air benefit human health by reducing respiratory diseases and may reduce the adverse impacts of pollution on ecosystems (eg acid rain, eutrophication).

Urban areas are generally dominated by hard, nonporous surfaces that encourage heavy runoff. In addition to exacerbating flooding, erosion and sedimentation, urban runoff is high in pollutants such as pesticides and oil residues, which can degrade wildlife habitats and contaminate drinking supplies (Oberndorfer et al, 2007). The hydrological benefits of green infrastructure are particularly important in this regard. Green urban areas provide natural drainage services and contribute to improved water quality (Forest Research, 2010). Research by Gill et al. (2007) suggests that increasing tree cover and greenspace by 10 per cent in urban areas could reduce surface water runoff by almost 6 per cent and 5 per cent, respectively. Sustainable Urban Drainage Systems (SUDS) that encourage green space in urban areas have received increased attention in recent years. Techniques include controlling flow rates at source using permeable surfaces, filter drains, green roofs, swales and basins, wetlands and balancing ponds, which help to minimise surface water runoff (Forest Research, 2010). Green roofs have been shown to increase rainfall interception and water storage. A review of the literature on green roofs concluded that their water retention capacity depends on substrate depths, climatic conditions and amounts of precipitation (Mentens et al, 2006). Green roofs also reduce noise pollution by absorbing sound waves outside buildings and preventing inward transmission (Dunnett and Kingsbury, 2004, cited in Oberndorfer et al., 2007). Several studies have documented invertebrate and avian communities on a variety of green roof types (Brenneisen, 2006a). Rare plants and lichens often establish spontaneously on older roofs (Oberndorfer et al, 2007).

Green infrastructure has been shown to enhance neighbourhood attractiveness, with effects on property values, investment and employment opportunities (ECOTEC, 2008). Urban green spaces offer opportunities for increased physical activity, with positive effects on individuals' health and can contribute to reducing stress and restoring cognitive function and capacity to deal with the demands of life (O'Brien et al, 2010). Urban green spaces can also play a role in enhancing mental well-being by providing a setting for social interaction (Forest Research, 2010). Estimations of the recreational value of urban green spaces were provided in the UK based on a meta-analysis of studies of urban green (including hedonic pricing and stated preferences), separate from eg amenity values for inhabitants (Bateman et al, 2011). Results show an average value of £ 128/inhabitant/year in the baseline scenario. This value would increase by 20 per cent (to £ 152) in a "Green and pleasant land" scenario.

A few studies also point to the 'disservices' of urban green infrastructure; such elements are prone to establishment of invasive species that may threaten native vegetation, and can facilitate unwanted incursions of native wildlife into urban areas (Forest Research, 2010).

Box 6.6: Examples of socio-economic benefits provided by green urban areas

Basel: Building regulations and incentive programmes for green roofs (Switzerland)
In Basel, Switzerland, the use of green roofs has been promoted through a combination of financial incentives and building regulations. The city's Building and Construction Law (2002) requires all new and renovated flat roofs to be greened. A first incentive programme providing subsidies for green roof installation ran from 1996 to 1997, followed by a second programme in 2005-2006 which incorporated design specifications into the green roof guidelines. One million CHF were invested in each programme. Energy savings amounted to 4 giga watt-hours per year from the first incentive programme and 3.1 giga watt-hours per year from the second. In 2007, the estimated surface of green roofs was around 700,000 m^2, making Basel the city with the highest per-capita area of green roof in the world (Kazmierczak and Carter, 2010).

Copenhagen's mandatory green roof policy (Denmark)
As part of its strategy to become a carbon-neutral city by 2025, the city of Copenhagen introduced in 2010 mandatory greening of all new flat roofs. The surface of green roofs is expected to increase to 325,000 m^2 by 2015. According to calculations by COWI (2010), this would result in annual CO_2 emission savings of **218 tons**.

Toronto (Canada)
A study on the environmental benefits of green roofs in Toronto (Banting et al, 2005) shows that greening 5,000 hectares of roof (the maximum feasible city-wide) would reduce local ambient air temperatures by 0.5 to 2°C, depending on the time of the year. The annual cost savings attributable to a reduction of the Urban Heat Island effect and building energy savings amount to C$12.32 million and C$21.56 million respectively.

Sustainable urban drainage in Manchester (UK)
Sustainable urban drainage systems (SUDS) support green infrastructure in urban areas by managing water levels and flows through trees and vegetation, green roofs, infiltration trenches and filter drains, swales and basins, ponds and wetlands. A case study in Manchester indicates that increasing green areas by 10 per cent would reduce runoff with around 5 per cent (Gill et al.,2007).

Although the information is still very limited, a case study in Scotland indicates that the overall costs of SUDS are lower compared to traditional drainage solutions (Duffy et al., 2008).

Some additional quantitative and monetary values of air quality regulation by urban trees in Europe are presented in Box 6.7.

Box 6.7: The value of urban trees

McDonald et al (2007) used an atmospheric transport model to simulate the transport and deposition of PM_{10} across the West Midlands and Glasgow under different tree planting scenarios. In the West Midlands, increasing total tree cover from 3.7per cent to 16.5per cent was found to reduce average primary PM_{10} concentrations by 10per cent, removing 110 tonnes per year of primary PM_{10} from the atmosphere. Increasing tree cover to a theoretical maximum of 54per cent would result in a 26per cent reduction, removing 200 tonnes of primary PM_{10} per year. In Glasgow, increasing tree cover from 3.6per cent to 8per cent would reduce primary PM_{10} concentrations by 2per cent, removing 4 tonnes of primary PM_{10} per year. Increasing tree cover to 21per cent would reduce primary PM_{10} air concentrations by 7per cent, removing 13 tonnes of primary PM_{10} per year.

Powe and Willis(2002) estimate that the net health benefits attributable to the absorption of PM_{10} and SO_2 by woodland in the UK (compared to other land uses) amount to 45-62 hospital omissions and 65-89 less deaths brought forward by air pollution. This is equivalent to cost savings of £0.07-4.21/ha/year and a total of £222,308 - 11,213,276 across the UK (in 2002 prices). This is likely to be an underestimate given that pollution absorption in this study was modelled at spatial scales of only 1 km^2 and woodland can be expected to have an impact on pollution levels at larger distances.

Tiwary et al (2009) used an integrated modelling approach using air dispersion (ADMS-Urban) and particulate interception (UFORE) models to predict PM_{10} concentrations both before and after greenspace establishment, taking a 547 ha area of the East London Green Grid (ELGG) as a case study. The ELGG is a proposed network of interlinked, multi-functional and high quality open spaces that connect with town centres, public transport nodes, the countryside in the urban fringe, the Thames and major employment and residential areas. The study reports PM_{10} reductions for the ELGG within the study area of 17.99 t/ year (0.03 t/ha/ year) under 100per cent grassland, 60.49 t/yr (0.11 t ha/$^{/}$yr) under 100per cent *A. pseudoplatanus* (sycamore), 1277.13 t/yr (2.33 t/ha/yr) under 100per cent *P. menziesii* (Douglas fir). When the more realistic planting scenario of 75per cent grassland, 20per cent sycamore and 5per cent Douglas fir is used, the PM_{10} removal is 90.41 t/yr (0.17 t ha/yr), corresponding to 2 deaths and 2 hospital admissions averted per year.

Ruijgrok et al (2006) calculate the value of air quality regulation by different ecosystems in the Netherlands using the costs arising from diseases caused by particulate matter, SO_x and NO_x. The annual values are as high as €9,800 - €61,400 per hectare for deciduous forest, €17,500 – €118,400 per hectare for coniferous forest, €4,200 – €16,200 per hectare for heathland, and €770 – €3,120 per hectare for reedbed and scrub.

Costs and cost-effectiveness

As the previous section has shown, green urban areas have a demonstrable potential to create positive ecosystem service benefits, partly due to high densities of people in urban areas, who therefore have greater access to these places. Cost data on the implementation and operation of green urban areas are nonetheless rare and the cost-effectiveness of green infrastructure features in urban areas will require greater examination through cost-benefit models and greater comparison with alternative options to determine if they are the most effective technology for a particular service. A number of features of green urban areas are looked at in more detail, where data are available.

Urban Greenspace/Public parks

There is a strong body of evidence of the benefits provided by green spaces in urban areas (see above), and yet the economic valuations of public green spaces can vary considerably (UK NEA, 2011a), with few studies investigating the associated costs of park creation and management. It is evident, nonetheless, that the existence of quality green spaces within dense urban areas inevitably creates a tension between the high value of land for development and the greater demand for these spaces due to the higher numbers of people, fewer domestic gardens and fewer, smaller parks. Regulatory instruments curtailing development in urban areas will likely result in higher opportunity costs of foregone development than in rural settings; costs borne by the construction industry and users of new homes. Nonetheless, those subject to full or partial planning restrictions will lose value, those located near the existing green spaces will increase in value due to improved local environment and often better leisure facilities and/or sports, as acknowledged in the SEA for the Viimsi *Green Network and Valuable Surroundings* (Estonia). Indeed, there will be many different beneficiaries, from the city government, property owners, communities and direct use values to citizens (see Box 6.8 for an example**Error! Reference source not found.**), recognition of which could have important implications for payments of upkeep and maintenance.

The effectiveness of these spaces to deliver cultural services depends on investment and on-going maintenance; continuous budgets cuts to public parks over several decades in England have been shown to lead to a significant decline in their quality and value to society (DTLGR, 2002). However, justification for the continuing investment is undermined by the absence of systematic accounting of the value of the parks; in the UK, local authority registers often list urban parks as having no financial value (in many cases denoted with a notional value of £1) (CABE, 2009). The undervaluing of the authorities' assets in this manner can lead to poor choices in the investment of ever diminishing local authority budgets. A study of the parks and recreation system in Philadelphia demonstrated a possible return on investment in parks at 100:1, of which over 80 per cent is comprised of direct use values or increased property value (see Box 6.8).

Box 6.8 Expected annual value of the Philadelphia parks

A study in Philadelphia, endorsed by the Mayor, demonstrates the expected distribution of benefits delivered by the city's park and recreation system. While there are significant regulating ecosystem service benefits from storm-water and air pollution mitigation (circa $6.5 million), the most significant beneficiaries are citizens through direct use values (based on 'willingness to pay' studies) and property owners through increased property values ($1 billion and $688 million respectively). Health values to citizens are the estimated to provide significantly higher values than regulating services (a total of $69 million per year). The report states that the value derived from the parks is circa 100 times city-wide expenditure on parks (ie circa $10 -20 million per year).

Source: Trust for Public Land (2008)

Green roofs

These features have been shown to provide a range of benefits, from reducing storm-water run-off to energy savings and biodiversity protection. They can be divided into two general types: intensive (characterised by soil deeper than 15cm and diverse plant palate) and extensive (thin growing medium 5-15cm, supporting drought tolerant plants). The latter constitute 80 per cent of the green roofs in Germany and are expected to be the most cost-effective due to lower investment costs (Harzman, 2002). Thinner growing mediums can, however, exacerbate the challenging conditions for plants and animals on green roofs and reduce the biodiversity value (Brenneisen, 2006b).

The cost-effectiveness of this feature is dependent to a degree on costs outside the scope of green infrastructure. A study that applied life cycle cost-benefit analysis to extensive vegetated roofs to a specific urban catchment in the United States (Athens, Georgia) found that the feature has a higher Net Present Value (ie lower cost-effectiveness) than traditional roofs under the existing conditions, due particularly to high investment costs (Carter and Keeler, 2008). However, green roofs may become cost-effective under reasonable assumptions of reduced construction costs, higher energy prices or different watershed specific characteristics. Specialisation and direct production of the technology, such as in Germany, has led to lower production costs relative to the United States, and maturation of the market in the US can be expected to have a similar impact (Carter & Keeler, 2008). In Switzerland, average costs of installation of green roofs have decreased substantially since the 1990s, from €82/m^2 to €16/m^2 which has been an important factor in the increased uptake of the practice (see in-depth case analysis on Urban Green Infrastructure – Annex I) and increasing the likelihood of a favourable cost-benefit analysis, although bespoke studies in Europe were not found.

Green urban areas initiatives

Two urban ecological networks with cost estimates were identified in the context of this study (Madrid Ecological Network, and Fingal Ecological Network) which provide an insight to the differences in cost data throughout the EU.

Box 6.9 Examination of costs related to two European urban ecological networks

The **Fingal Ecological Network** (a county in the Dublin region), which is to be implemented between 2010 and 2015, will form a cornerstone of the council's forthcoming green infrastructure strategy. The network includes an area of 13,120ha of privately owned land, covering core areas, buffer zones, nature development areas and ecological corridors. Nature development areas, which constitute over half of the network, are areas where nature conservation is combined with existing land uses such as quarries, farmland, recreation areas, etc selected on the basis of existing or potential wildlife value. The budget for the network is €750,000 over 5 years delivered through a small grant scheme and the development of markets for products. The outcomes are expected to deliver reduced flood risk through improved urban drainage, enhanced biodiversity, wetlands to provide greater protection from pollutants entering watercourses and cultural and amenity services through improved public spaces and recreation areas.

The costs of the projected **Network of Ecological Corridors of Madrid** are on a markedly different scale. It is projected to cost €48.8 million over five years, at an average rate of €319/ha. The project has as its focus improving the connectivity of habitats by improving the quality of the core areas (82% of budget) and linking the parks by interconnecting corridors. However, it recognizes and plans for the utilization of the green spaces by society.

Source: Fingal County Council (2010) and In-depth case analysis on Urban Green Infrastructure – Annex I

The discrepancies in budget size (see Box 6.9) are partly due to the differences in area covered; more importantly, perhaps, it also reflects the fact that cost figures for Fingal are based on real fund allocations while the costs in Madrid represent proposals for funding which attempt to describe the funding requirements. In Madrid, the majority of the one-off costs (82 per cent, or €33 million) are envisaged to be spent on restoration of priority areas.

These features also have the capacity to generate widespread savings by replacing or negating the need for investment in grey infrastructure. New York City Government, for instance, plan to reduce volumes of water discharged to the storm and sewer system at a cost of $1.5 billion lower (over 20 years) than the all-grey infrastructure strategy currently being contemplated, achieved through capturing 1 inch of precipitation over 10 per cent of impervious surfaces through detention or infiltration techniques *(2010).*

6.2.5 Natural connectivity features

Ecosystem Services and benefits

Ecological connectivity is essential not only for certain species, but also for the maintenance of many ecosystem processes (Bennett & Mulongoy, 2006). For example, inland water systems depend for their functioning on physical connections between their upper and lower catchments, and disruptions to their flows can impact the entire ecosystem (Bennett and Mulongoy, 2006). Connectivity helps to secure the delivery of ecosystem services via its effect on ecosystem resilience. The long-term survival of many species is strongly dependent on the dispersal and migration of individuals between different habitat patches. The movement of individuals is necessary to ensure genetic exchange between different populations and secure the capacity of a species and its populations to adapt to changing environmental conditions. By enabling movement within landscapes, connectivity features of high ecological quality therefore help to reduce the negative impacts of fragmentation and contribute to the maintenance of biodiversity. See discussion in Chapter 5 of the types of connectivity features that provide ecological benefits.

Natural connectivity features also provide a range of other services, including hydrologic services, habitat provision, pollination and biological control. Riparian vegetation contributes to hydrologic regulation and water quality, by forming a buffer zone between land and streams and mediating the exchange of water, nutrients, sediments and energy between the two ecosystems (Bennett, 2003). Riparian vegetation traps and filters sediments and sediment-bound pollutants before they reach aquatic ecosystems, therefore reducing their negative impacts, such as the potential for eutrophication. Riparian woodland buffer areas have been shown to effectively protect streams and groundwater sources from pesticide applications on adjacent land, both by intercepting aerial drift of pesticides and by trapping pesticides bound to sediment in runoff (Lowrance et al., 1984). The filtration efficiency of riparian vegetation increases with gentle slopes, wide strips, and a high density of vegetation and litter cover at ground level (Binford and Buchenau, 1993, in Bennett, 2003).

Unfarmed features in agricultural landscapes, including hedgerows, stone walls, field margins, buffer strips and small areas of woodland, can help protect soil quality by reducing erosion and improve water quality by reducing siltation and run-off (Farmer et al., 2008).The role of field margins and hedgerows in the biological control of agricultural pests has also been documented in Europe. Such features may provide refuge for beneficial predatory invertebrates, such as beetles and spiders (Thomas et al., 1991; Dennis et al., 1994, in Bennett, 2003).Ecological corridors and stepping stones in grazing landscapes play a key role in maintaining genetic exchange between plant populations, as they are used by seed-dispersing bats and birds (Galindo-Gonzalez et al., 2000; Cascante et al., 2002, cited in Fischer et al., 2006). More natural river banks and riparian natural areas improve the amenity and recreational value of rivers (Liekens et al., 2010; Bateman et al., 2010; Ruijgrok, 2004). Green infrastructure elements on agricultural land in present cultural heritage landscapes, such as hedgerows and tree rows improve amenity and recreational value of these landscapes (Kantelhardt et al., 2003; Pulido-Santacruz P et al., 2011). Hedgerows can contribute to prevent soil erosion (Pulido-Santacruz et al., 2011), resulting into market benefits for the agricultural sector but also to costs savings for other sectors, due to sediment control in rivers and reduced flood damages.

Box 6.10: Examples of socio-economic benefits provided by natural connectivity features

A study for Canterbury province of New Zealand estimates a net benefit of hedge rows (shelterbelts) on agricultural output of up to 35 per cent, accounting for beneficial impacts from reduced wind speed, minimising soil erosion, improving microclimate with higher levels of soil moisture, provision of shelter and pollen/nectar to pollinators and to natural enemies that perform biological control of pests and diseases. The total value of these benefits is estimated at 200 US $/ha for conventional farming and at 880 US $/ha for organic farming (Sandhu et al., 2007).

GI elements such as hedgerows or tree rows can improve the recreational and amenity value of semi-cultivated landscapes. This value is confirmed in studies for France, Germany and Portugal in the Mutagri project (Madureira et al, 2007). Inhabitants of the studied regions are willing to pay from € 18 to 34/household/year for policy scenario’s that protect or improve hedgerows in rural landscapes. Also tourists are willing to pay for these amenity improvements (€1/day).

Costs and cost-effectiveness

Debate on the effectiveness of ecological corridors has for some time focussed on the relatively high costs and lack of scientific evidence on their efficacy (Simberloff et al, 1992). Cost data on the establishment of connectivity features as part of green infrastructure initiatives is nevertheless difficult to obtain. In a review of nine European ecological networks from across the EU, no initiative provided information on the costs of managing or protecting corridors (IEEP and Alterra, 2010).

Aside from the cost of creation, the management of ecological corridors may also be more expensive per hectare than core sites (Good, 1998). Farmer et al (2008) examine payments delivered through agri-environment schemes for the creation and management of hedgerows in the EU (see Table 6.2). The study identifies differences between Member States in the manner of payments are made and how action is incentivised. France, for example, establishes a set payment per metre of hedge created, while in Denmark, payments for planting hedges are made on the basis of reimbursing a percentage of costs incurred by farmers. Additional costs associated with these features include their identification of and delineation within spatial plans, which may ultimately amount to a significant proportion of an available budget. In the Czech ecological network, circa €10 million was spent attempting to delineate features of the network.

There is a distinction between the scales at which corridors are planned. A review of the applicability of corridors in Ireland found that regional corridors were unlikely to have a cost-benefit advantage over options such as site enlargement, site buffering, maintaining hydrological processes and site management, asserting that corridors are relatively high cost, high risk and of limited applicability compared to these other measures (Good, 1998). While corridors should be considered on a site-by-site basis as part of an integrated dispersal management approach, it states that local corridors within sites are more likely to be successful than regional corridors. Lawton et al (2010) suggest that it may be more cost-effective to promote and enhance the existing network of green corridors and stepping stones, through management and widening, than it is to establish new corridors.

In certain cases, structural connectivity and habitat loss have additive impacts on species distribution (see section 5.5). For example, Mortelliti et al (2011) find that improving structural connectivity for two forest dependent arboreal rodents (Hazel Dormice and Red Squirrel) will be ineffective if the amount of forest cover in the landscape is less than 5-10 per cent. They therefore recommend that resources not be invested into landscape linkages before their efficacy for a given percentage of habitat cover has been assessed.

Table 6.2 Agri-environment payments for planting and managing hedgerows

One-off payments for planting hedgerows	
Denmark	Farmers can receive refunds of 40% to 60% of the cost for establishing 1 – 7 rowed hedges or woodlots smaller than 0.5 ha. At least 75% of the plantings must be broad-leaved.
Normandy (France)	€1.49 per metre.
Veneto (Italy)	€2.70 per metre for 6m wide hedge and margins. This includes costs of planting and maintenance of hedge and grass strip, plus income foregone and transaction costs.
England (UK)	£5 (€6.3) per metre.
Wales (UK)	£2.40 (€3.0) per metre.

On-going payments for managing hedgerows	
Normandy (France)	€0.43/metre for trimming to €3.32/metre for restoration.
Italy	Payments and the methods for calculating them vary significantly by region and depend on the age of the hedgerow, but average €250-400 per hectare. The overall range is €50-900 per hectare. In Veneto region payments are €0.80 to €1.29 per metre, based on a 6m wide hedge and margins.
Catalonia (Spain)	€110/ha for maintaining a minimum of 100m of hedges on banks per hectare of farmland, including costs of maintenance of hedge and management of native vegetation.
England (UK)	Higher Level Stewardship - £2.70 (€3.4) per metre for maintenance of hedgerows of very high environmental value through; £5 (€6.3) per metre – restoration by laying, coppicing or gapping up; additional supplements available. Entry Level Stewardship – farmers need to earn 30 points per hectare from various practices to gain a payment of £30 (€38) per hectare. Hedgerow management gains 11 - 42 points per 100 metres, with an equivalent value of £1.1 - £4.2 (€1.4 to 5.3) per metre.
Wales (UK)	£2.40 (€3.0) per metre – laying or coppicing.

Source: Farmer et al (2008)

The initiatives identified under this study reveal how connectivity features are being implemented in very different scales very different examples of ways in which. In the original plan for the National Ecological Network, the main priority with regard to reducing fragmentation was to restore the opportunities for dispersal and migration. 267 indicative corridors were proposed for this purpose with the intention that the many small-scale defragmentation measures required, such as tunnels for amphibians and fish ladders, could be realised without purchasing land. However, a 1998 evaluation concluded that the measures taken were not as effective in achieving their objectives as intended. The corridor programme was therefore intensified with the aim of realising 12 so-called "robust corridors" which are substantially larger in scale and have a higher level of protection. The robust corridors are less species-specific than in the original concept and are mainly intended to connect comparable habitats or to traverse environmental gradients in areas of high priority for increased connectivity. They would also require a substantial land acquisition programme. The revised target was to designate a total of 27,000 ha of robust corridors by 2008 (including aquatic linkages). However, many of these corridors have still not been designated, mostly because it is proving more difficult than expected to apply the necessary measures to agricultural land. The government that took office in 2010 has announced that it intends to end its financial support for realising the robust corridors (see in-depth case analysis on Ecological Networks – Annex I). See Box 6.11 for an example of the costs and benefits expected from one such robust corridor.

Box 6.11: The OostvaardersWold corridor initiative, the Netherlands

The OostvaardersWold initiative, begun in 2006, aims to form a robust corridor from the Oostvaadersplassen wetland to the Horsterswold forest, creating an integrated habitat area of 15,000ha as the first step in connecting the wetland to natural areas in Germany. The corridor, which includes six overpasses, is expected to be used by Red Deer as the target species but also Heck cattle, Camarque horses, small mammals, amphibians, reptiles and insects. Since 2007, over 600ha of land have been purchased. A minimum of 70ha of forest will be created. The management of the corridor is also expected to provide water retention and reduce flood risk. The corridor aims to create a high-quality nature recreation resource, covering 85% of the area, and to attract over 300,000 visitors per year. An economic study of the plan concluded that the total turnover from restaurants, transport, commerce and services would vary from €5,510 to €7,660/ha and additional employment would total from 1,482 to 1,687 jobs (Bade et al, 2009). The total budget for the initiative is €403 million, predominately provided by the national and regional governments and state agencies.

Source: Unpublished country file on green infrastructure initiatives in the Netherlands produced in the course of this project.

6.2.6 Artificial connectivity features

Ecosystem Services and benefits

Artificial connectivity features are designed to benefit biodiversity rather than to support the provision of ecosystem services. However, as discussed above, connectivity features, whether natural or artificial, can contribute to improving the conservation status of certain species, which may result in an increased level of ecosystem service provision. In particular, such elements facilitate the dispersal, migration and exchange of genetic material, thus maintaining genetic variability. They can also potentially increase levels of biological control due to the fluctuation of different control agents, including larger carnivores such as wolf or lynx. Or in the case of fish ladders allowing the crossing of artificial infrastructure such as dams could lead to a more diverse portfolio of fish products up- or downstream.

Only a limited amount of information on the contribution of artificial connectivity features to ecosystem service delivery emerged from the in-depth analysis of grey infrastructure mitigation in Annex I policy carried out as part of the study. It is recognised that there is a general difficulty in measuring the 'benefit' to assemblages, communities and ecosystems as compares to the negative impacts and compounding feedback of *not* installing a given measure (van der Ree, 2008). Some examples resulting from the in-depth analysis and additional assessments are presented in Box 6.12 below.

Box 6.12: Examples of socio-economic benefits provided by artificial connectivity features

Socio-economic benefits of grey infrastructure mitigation features so far have mainly be captured by looking at the reduced costs from road accidents, rather than looking at the services from ecosystems they support. According to the Eidgenössische Finanzkontrolle (2007) wildlife crossings are foreseen to reduce the number of auto accidents caused by collisions with red deer and other wildlife species by providing an alternative route to cross the large motorways. As such, the wider financial implications of wildlife accidents need to be considered in cost-benefit calculations for mitigation measures. The estimated social costs of such accidents is approximately €42,375 million per annum (includes material damage, human injuries and human fatalities) in Switzerland and €851,000 per year in Spain. Spain further estimates approximately 5,000 wildlife accidents per year, averaging €2,700/claim. Sweden figures estimate a cost of between €8,325 and 21,853 per moose accident. (Trocmé et al., 2003).

In France, for example, the number of road collisions involving wild boars and other game animals has been significantly augmented. The total costs derived from these collisions were estimated at €150 million, of which 96 million could be attributed only for wild boars, according to the Office National Interministériel de la Sécurité Routière. Management plans and development of green infrastructure to increase the permeability of the landscape for wild boar populations could potentially lead to a significant reduction of these costs (EC, 2011).

Costs and cost-effectiveness

Artificial connectivity features encompass a number of designs that can be employed to mitigate the impacts of transport infrastructure. Alterra (2008) estimated the costs associated with implementing four of these features in a hypothetical scenario in Bulgaria (see Table 6.3). The study omits the cost of fencing to direct towards the features and the costs associated with planning and locating the features.

Table 6.3: Costs associated with different Artificial Connectivity Features

Wildlife passage type	Unit costs (€)	Description
Wildlife overpases	€700,000 - 3,200,000	Overpass to restore connectivity for 'target' animal species; min. Width of 50m.
Large wildlife underpass	€900,000 - 1,500,000	Underpass for the passage of medium-sized and large mammals; min. Width of 20m.
Small wildlife underpasses	€30,000 - 60,000	Underpass for the passage of small animals; min. Width of 1.5m.
Modified bridge or viaduct.	€20,000 - 50,000	Existing infrastructure adapted to provide connectivity.

Source: Alterra (2008)

These cost estimates are broadly supported by case examples; two wildlife overpasses in Austria, for instance, were delivered at a cost of €3m and €2m respectively, omitting costs arising from spatial planning (Eidgenössische Finanzkontrolle, 2007). Similarly, in the Netherlands, the Oostvaarderswold corridor initiative envisages six wildlife overpasses expected to be delivered at a cost of €3 million a piece (unpublished country file on The Netherlands produced for this study). Rosell et al (2002) estimate investments in artificial connectivity features range from 1 to 3.5 per cent of the total working budgets, including direct and indirect costs; the costs of mitigation, compensatory and environmental integration measures were found to usually comprise 5 per cent of the total budget. Costs are expected to be minimised if the features are built during the construction of the transport infrastructure.

The effectiveness of these features can be measured against a set of six objectives, namely: reduce rates of road-kill, maintain habitat connectivity, maintain genetic exchange, ensure biological requirements are met, allow for dispersal and re-colonisation and maintain meta-population processes and ecosystem services (Forman et al, 2002). The greatest return on investment is likely to come from reduced road accidents (see Box 6.12 above). Accepting high and low cost-savings of €2,700 (Spain) and €21,830 (Sweden) per collision and an average cost of €2million per overpass, the feature would have to prevent between 92 and 740 collisions per year to be cost-effective.

The costs associated with defragmentation programmes at a national level have been estimated in a limited number of cases. The Multi-Annual Defragmentation Programme in the Netherlands aims to remove the most important barriers formed by the country's dense road and rail infrastructure. The obstacles in every province have been mapped and prioritised. A total of 208 projects have been approved, including many wildlife crossings.

Box 6.13 The Multi-Annual Defragmentation programme, the Netherlands

In 2004, the national government in the Netherlands adopted the Multi-Annual Defragmentation Programme. It has the status of a policy programme for the period 2005–2018. The goal of the programme is to remove the most important barriers formed by the country's dense road and rail infrastructure. Joint responsibility for the development and implementation of the programme lies with the Ministry of Infrastructure and Environment and the Ministry of Economic Affairs, Agriculture and Innovation. The obstacles in every province have been mapped and prioritised. A total of 208 projects have been approved, including many wildlife crossings.

The total costs of the programme were estimated at €410 million in 2004 for the period of 2005-2018. It does not include costs of additional provincial expenditures. The Ministry of Infrastructure and Environment is providing €250 million, the Ministry of Economic Affairs, Agriculture and Innovation the remaining €160 million for defragmentation measures to the national infrastructure located within the 'Robust Connections'.

The total budget of €410 million is still applicable in 2011. However, no published information is available on exactly how the budget is being spent. An independent evaluation of the programme (Blekemolen et al, 2009) projected that in 2013 46% of the barriers will be resolved but that 58% of the total budget will have been expended, inferring a shortfall of €115 million (in addition to the €410 projected initially) if all the barriers are to be resolved. The report concludes that, in particular, the costs of resolving railway barriers and those in the robust corridors are relatively expensive. It is also expected that completing the National Ecological Network will require more barriers to be resolved than foreseen by the programme.

Source: In-depth case analysis on Grey Infrastructure Mitigation – see Annex I

These features are predominately anticipated to benefit biodiversity, and have limited ecosystem service benefits. Indeed, even the ecological benefits delivered by these features are also contested (for example, see Van Der Windt & Swart, 2008). Efforts to implement these schemes at a national scale entail significant costs, with the costs in the Netherlands, for instance, likely to exceed €500 million in total.

6.3 The benefits and cost-effectiveness associated with an integrated green infrastructure

6.3.1 Socio-economic benefits provided across green infrastructure

The previous section focused on key functions, ecosystem services and benefits sustained by individual green infrastructure elements. However, it needs to be considered that the socio-economic benefits resulting from the promotion of green infrastructure will likely be more than the sum of the benefits of its parts (eg connectivity, coherence, resilience and ecological multiplier effect). In addition, potential trade-offs might arise across different elements if no integrated approach is applied. It is also important to iterate that a large majority of the existing valuation studies were carried out to assess the value of services provided by ecosystems at large. Assessments of the benefits of ecological networks largely focus on assessing their biodiversity value, and yet very limited information is collected on their socio-economic benefits. The new concept of green infrastructure has not yet entered valuation work, and only little evidence exists on the monetary benefits primarily linked to individual green infrastructure elements such as sustainable use zones or artificial connectivity features.

Given the above the authors decided to display separately information on key quantitative and monetary benefits which cannot be clearly attributed to an individual green infrastructure element or which link to integrated initiatives. This is done by presenting these benefits according to ten key groups considered particularly important in relation to green infrastructure. The approach is also considered particularly useful to inform the assessment of policy options part of this study. It should allow to more easily link information on benefits to changes in different policy areas (eg, benefit group 'natural resources' and agriculture, cohesion policy and benefit group 'investment' etc.).

Increasingly, the necessity has been recognised that all different steps, from the importance of biodiversity in securing ecosystem functions to the physical provision of the service and the qualitative, quantitative and monetary description of benefits they deliver, need to be analysed to describe the value of an ecosystem. This is considered important in order to get the most comprehensive picture, first due to many methodological challenges still surrounding economic valuation (and thus questioning its informative and un-biased value) and secondly the fact that currently it is not possible to transform all benefits provided by ecosystems into monetary figures (recognising the value of qualitative and quantitative equal to monetary information). The previous section thus used a wide range of qualitative information on biophysical provision of services and the following section attempts to focus to a large extent on the benefit provision.

Building on approaches used by Genecon LLP (2010) in the development of a green infrastructure valuation toolkit, by Maes et al. (2011) in assessing and mapping Europe's ecosystem services and by the MA's differentiation of services and resulting constituents of well-being (including security, health, social relations and basic material), the study thus decided to distinguish between ten benefit groups considered particularly relevant in the context of this study. These include:

1. Natural Resources
2. Water management
3. Climate regulation and adaptation
4. Health and well-being
5. Investment and Employment
6. Tourism and Recreation
7. Education
8. Land and Property values
9. 'Insurance' value
10. Conservation benefits (non-use values)

The tables presented below for the individual groups include information on the different ecosystem functions and services that are considered to be particularly important in supporting the provision of related benefits, and on the that may be used to measure them. The examples included in the tables are far from extensive and the monetary description of the benefit groups is mainly based on market price methods and cost savings approaches. Only to a limited extent other methods such as revealed (eg, travel cost method) or stated preferences studies (eg, contingent valuation) have been taken into consideration when developing the tables. As the focus of this report is particularly on impacts (eg, economic impacts) the approaches described in the tables are considered particularly useful. The tables are followed by a summary of important evidence that allows capturing some of the values linked to the different groups. Where available, interesting estimates resulting from the application of a wider range of methods have been included (eg contingent valuation).

It is clear that there are numerous uncertainties and limitations associated with the approach of using benefit groups instead of following the classification of ecosystem services. This for instance relates to the fact that many regulating and supporting services can result in more than just one benefit due to their strong relationships. For example, air purification included in the health benefit group can also lead to decreased eutrophication and acidification and as such positively impact tourism and recreation as well as natural resources. In addition, many important supporting services such as nutrient cycling or ecological interactions are not explicitly covered in this section.

It is perceived that by including the two categories 'insurance value' and 'conservation benefits' these limitations are partly counteracted. Particularly the 'insurance value' category should offer the opportunity to emphasise the importance of many regulating (eg, genetic diversity maintenance) and supporting services (eg, nutrient cycling) due to their key role in underpinning and in the end ensuring the provision of many other services.

It also needs to be emphasised that it was beyond the scope of this report to provide an overall economic value for the different benefit groups and as such the issue of double counting played a minor role. However, this needs to be taken into further consideration before aggregating values within or across benefit groups.

(1) Natural Resources

Table 6.4: Natural resources – underlying services/functions and resulting benefits

Benefits Group	Green Infrastructure services/function	Quantitative Benefits	Monetary Benefits
Natural Resources (eg, cereal crops, vegetables, livestock, food, timber, natural medicines. local breed varieties; fruit and juices from orchards)	**Capacity to provide a diversified portfolio of products** • Forests for wood supply • Total area of cropland/grassland suitable for livestock • Total area of low input cropland • Number of edible fish species	• Production in tonnes, m^3 and/or hectares • Quantity of certified products • Number of wild species used as food/ornamental resources etc. • Employment sustained by sectors • Number of crop, livestock and fish varieties in production	• Market value of products
	Maintenance of soil fertility • Soil carbon content • Species composition, aggregated in functional groups (eg, biomass of decomposers, proportion of different trophic groups) as an indicator of process capability	• Increased yield attributable to soil quality	• Market value of contribution to production
	Biological Control • Abundance and species richness of biological control agents (eg, predators, insects, etc.) • Changes in disease burden as a result of changing ecosystems • Range of biological control agents (eg, in km, regular/aggregated/random, per species)	• Increased yield attributable to biological control	• Market value of contribution to production
	Pollination • Abundance and species richness of wild pollinators • Range of wild pollinators (eg, in km, regular/aggregated/random, per species) • Proximity to natural habitat	• Increased yield attributable to pollination	• Market value of contribution to production

With agriculture covering about half of EU land area, Europe's biodiversity is linked inextricably to agricultural practices, creating valuable agro-ecosystems across the whole of Europe. There exist several opportunities to preserve and improve the use of biodiversity in Europe's agricultural areas, while meeting demand for food, fibre, feedstock and bioenergy (EEA, 2010). In addition to sustainable use zones, green infrastructure elements such as hedges, tree rows and agroforestry[22] plots (eg orchards, silvopasture, silvoarable) on agricultural land can offer several services that contribute to a more sustainable supply of food and natural products. Although green infrastructure may have a negative impact on productivity and land-use efficiency compared to intensive agriculture, they can be an important element in a long term sustainable supply of food and timber due to the capacity of providing a diversified portfolio of products.

To the extent the impact of green infrastructure measures on food and timber production can be quantified, it can be further valued in economic terms by using market prices. Some examples are discussed below. It should be noted that this is only a partial analysis, which does not account for differences related to external costs caused by agriculture and which can be substantial for intensive forms (Hartridge and Pearce 2001; Pretty et al, 2000). Furthermore, impacts on crop productivity in the short term and on individual parcels may not give a full picture of the total impacts in the long term (eg, accounting for effects on soil productivity) or at a landscape scale (eg, effects on pollination). Even if agricultural production by low input farming is substantial, it may be in competition with intensive farming for resources and markets.

Although organic farming is not strictly related to green infrastructure, it can be relevant to lower inputs of nutrients and pesticides in sustainable use zones, and can be used as a proxy to determine potential monetary benefits from low input farming associated with green infrastructure. Recent meta-analyses for developed countries for all crops indicate an average organic/conventional yield ratio of 80 to 90 per cent (Badgley et al 2007). However, given external costs of organic farming are likely to be lower compared to those for conventional farming, the difference in total net social costs is likely to be smaller. On the other hand, Sandhu et al (2007) discovered on average a higher food production for organic fields in a case study in Canterbury, New Zeeland (see Table 6.5).

Table 6.5: Summary of mean and range of economic value of ecosystem services in organic and conventional fields for Canterburry area, New Zealand

	Ecosystem services	Economic value (range) in US $ $ha^{-1}yr^{-1}$	
		Organic fields	Conventional fields
1	Biological control of pests	50 (0–100)	0 (0–0)
2	Mineralisation of plant nutrients	260 (26–425)	142 (30–349)
3	Soil formation	6 (0.7–11)	5 (2–9)
4	Food	3990 (1150–18900)	3220 (840–14000)
5	Raw materials	22 (0–224)	38 (0–298)
6	Carbon accumulation	22 (0–210)	20 (0–210)
7	Nitrogen fixation	40 (0–92)	43 (0–92)
8	Soil fertility	68 (53–82)	66 (54–73)
9	Hydrological flow	107 (− 111–190)	54 (− 118–194)
10	Aesthetic	21 (21–21)	21 (21–21)
11	Pollination	62 (0–438)	64 (0–455)

22 Agroferestry refers tot he integration of agriculture and/or farming with forestry so the land can simultaneously be used for more than one purpose (Emmanuel, 2000). It may include silvopasture (mixing trees with pasture/forage), silvo arable – mixing trees and arable or horticultureal crops (www.agroferestry.co.uk)

	Ecosystem services	Economic value (range) in US $ $ha^{-1}yr^{-1}$	
		Organic fields	Conventional fields
12	Shelterbelts (hedgerows)	880 (0–472)	200 (0–617)
	Total economic value of ES	**4600 (1607–19,412)**	**3680 (1263–14,570)**
	Non-market value of ES	**1480 (452–5237)**	**670 (48–1235)**

Source: Sandhu et al, 2007.

In modern agroforestry systems, low final tree densities (30-100 trees/ha) allow crop production to be maintained until tree harvest. The average productivity of silvo-arable systems is higher than the combined productivity of separate tree and crop systems. Productivity increases up to 30 per cent in biomass and 60 per cent in final products have been observed (EU Safe project, Durpaz et al., 2005). The net benefit varied from 19 €/ha in the Netherlands to around 72 €/ha in France and the UK.

Natural areas can produce specific agricultural products and timber and thus further diversify the portfolio of products provided. The total production, for example, of round wood forest products in the EU-27 in 2010 was € 16 billion (€ 120/ha of woodland available for wood supply)(Forest Europe, 2011).The total production of non-wood goods in European forests[23] is estimated at € 2 billion (for the year 2010) of which Christmas trees, fruits, berries and edible nuts and cork are the most important (Forest Europe, 2011). The value of marketed forest services for 16 EU Member States was estimated at € 0.5 billion in 2010 (Forest Europe, 2011), of which game meat (hunting licenses) and wild honey accounted for the most important part. Divided by all forest land, this corresponds to respectively € 3.0/ha[24] for non-wood goods and € 2.0 /ha[25] for marketed services. Other case studies in literature give higher values per ha for these goods and services. For France, it is estimated that a value of € 10/ha to € 15 /ha is a good proxy (Chevassus-au-Louis, 2009). Merlo (2005) produced a value of € 17/ha for Mediterranean Forests (cited in EFIMED, 2008). For the Netherlands, the value of production of raw materials in Natura 2000 areas is estimated at € 317/ha/year (Kuik, 2006; see in depth case study on ecological networks in Annex I).

Natural resource values per ha are relatively low compared to the non-market value of other services. As an example, the UK NEA assessment illustrated that if carbon sequestration was valued at 50 £/ton CO_2, the average value would amount to 239 £/ha. This analysis shows that appropriate accounting of non-market services may be more important than market values for the optimisation of land use decisions and management.

On the other hand, provisioning services from green infrastructure may be particularly relevant for local producers and communities. The Danube wetland case study (see Box 6.3) illustrates that these products can be important at a local scale. Restoration of the pilot polders in Romania resulted in a diversification of livelihood strategies towards fishing,

23 Data for member states of forest Europe without Russian Federation. Data are incomplete.

24 Own calculation, based on all forest and woodlands (655 million ha)

25 Own calculation, based on all forest and woodlands for the states with data for marketed services.

tourism, reed harvesting and livestock grazing on seasonal pasture, activities that produce an average EUR 26 per ha/per year and EUR 9000/year for both polders.

In addition, particular attention should be given to those services that can be considered especially important to ensure the supply of different goods due to their more visible direct impact, such as pollination and biological control. Box 6.14 provides an overview of valuation work undertaken to estimate the monetary benefits linked to pollination.

Box 6.14: Monetary benefits associated with pollination

Pollination represents an essential ecosystem service for human wellbeing, being a key ecological process on which natural and agricultural systems depend (eg, TEEB, 2011; (Millenium Ecosystem Assessment, 2005); (Balmford et al, 2008). It is estimated that insect pollinators are directly responsible for approximately 10 per cent (around €14.2 billion) of the total value of the EU-25 agricultural food production in 2005 (Gallai et al., 2009). Insect pollination is also estimated to increase the yields of 75 per cent globally important crops and is responsible for an estimated 35 per cent of world crop production (Klein et al., 2007).

According to IEEP et al (2011), there are various reasons to expect that the value of wild pollination will rise, mainly due to rising food demand and documented regional declines in pollinators' populations.

However, from the existing evidence on pollination it is very difficult to provide any quantitative or monetary value of the benefits stemming from policy initiatives related to green infrastructure. This is due to the fact that there is generally very sparse evidence on the values of pollination, especially in the context of Europe. Moreover, as the benefits from pollination are mostly connected to agricultural production, the valuation exercise is very site-specific. Meanwhile, the current scientific understanding of different factors influencing pollination and the trends in pollinators' populations is far from complete. This makes the valuation exercise problematic and it creates difficulties to identify the benefits associated with related policy initiatives.

It is also important to note that, beyond its impact on agriculture, pollination's contribution to human wellbeing has a broader scope. Even though currently unknown, pollination value and services to wildflowers and for recreational and other cultural services is expected to be significant (UK NAE, 2011, chapter 14).

Some of the identified valuation studies concentrating on the value of wild pollination:

- Klein et al. (2007) found that the production of 87 out of 115 leading global crops (representing up to 35 per cent of the global food supply) were increased by animal pollination.
- Using the methods of Gallai et al. (2009), the United Kingdom's National Ecosystem Assessment estimated the economic value of biotic pollination as a contribution to crop market value in 2007 at EUR 629 million (England: EUR 532 million, Northern Ireland: EUR 28 million, Scotland: EUR 69 million, Wales: unknown) (UK NEA, 2011).
- Losey& Vaughan (2006) estimated that wild pollinators alone are responsible for about EUR 2.4 billion of fruits and vegetables produced in the United States.

Source: based on IEEP et al (2011, forthcoming)

(2)Water management

Table 6.6: Water management – underlying services/functions and resulting benefits

Benefits Group	Green Infrastructure services/function	Quantitative Benefits	Monetary Benefits
Water management (eg, natural	**Regulation of water flows** • Water infiltration capacity/rate • Water storage capacity in mm/m • Floodplain water storage capacity in mm/m	• Deprived households at risk from flooding • Reduced surface water run-off	• Avoided costs of property damage • Avoided costs of grey infrastructure (eg, dam construction)

drainage, irrigation and drought prevention, water purification)	**Water purification** • Water quality in aquatic ecosystems (sediment, turbidity, phosphorous, nutrients, etc.) • Biological indicators: eg, Index of Biological Integrity, • Nitrogen retention • Nitrogen removal	• Population served by high water quality	• Reduced waste water treatment costs for domestic and commercial users
	Storage of freshwater resources • Groundwater recharge • Total area of inland water bodies and inland wetlands	• Population served by renewable water resource • Total annual freshwater consumption by sector	• Reduced expenses on bottled water

Green infrastructure and integrated water management are closely interlinked. Whereas adequate protection of natural core areas requires good status of water bodies (both in terms of water quality and quantity) other Green infrastructure elements can contribute to or may be essential for the achievement of good status. Green infrastructure is important for water management as it more naturally and likely cost-effectively regulates buffers and mitigates extreme water levels, avoiding damages associated with floods and drought[26]. This is relevant for a wide range of green infrastructure elements, including small ones in an urban context (green roofs or pavements) or rural environments (ditches and marshes) to larger green infrastructure elements (wetlands, core areas).

A first category to describe the impact on human well-being includes benefits in terms of avoided costs of flooding. Green infrastructure can contribute to slow down the drainage of extreme rainfall episodes upstream and store water in natural areas downstream, preventing built-up areas like towns or industrial areas to be flooded. Floods are recognised as a serious and increasing problem in Europe. The current expected annual economic damage[27] for the EU-27 amounts to EUR 6.4 billion, potentially affecting 200,000 inhabitants (EEA, 2010).

The contribution of green infrastructure in flood control is well documented through different case studies, especially for the benefits of temporary water storage in natural areas such as wetlands. The exact value depends on a range of factors and values in literature range between zero and a few thousand €/ha/year (De Groot, 2002). The latest recent meta-analysis of these studies confirms the importance of flood protection as the most important, quantified and monetised benefit from wetlands (Brander et al., 2006; Ghermandi et al., 2008, Brander et al., 2008). The relative importance can best be illustrated by the implementation of the results of the meta-analysis for wetlands in the UK. Morris and Camino (2011) estimate the marginal value for flood protection for an additional ha of wetland in the UK at £ 407/ha/year for inland wetland and at £ 2498 /ha/year for coastal wetlands. The case example on Sigma plan II in Belgium (see in-depth case analysis on freshwater and wetlands management) shows that the flood protection benefits can be much higher for specific cases (€ 740 million Net Present Value (NPV) for the full plan or up to € 20,000/ha/year for controlled flooding areas), in areas at high flood risk and if initiatives are considered very effective to protect cities and industrialised areas. Information on flood control benefits collected in France mainly refers to replacement costs, ie the costs of

[26] This on the other hand can be closely linked to the benefit groups climate regulation and adaptation below.

[27] Considered damages relate to material goods (eg, infrastructure, furniture) and industries. Damages to human health (deaths, injuries, mental stress) or ecosystems are not included.

building a dam to replace the natural water storage of wetlands. Case studies in several French river basins indicate benefits ranging from € 37/ha/year to € 617/ha/year (Schéhérazade et al., 2010). Better flood protection can lead to additional benefits, eg, by supporting the livelihoods of local communities (as illustrated in the case study for the Donau Green corridor). In addition, higher groundwater levels and higher levels in rivers avoid damages to a whole range of sectors, including inland shipping, amenity and recreation, energy production, damages from drought in agriculture, water restrictions to households. There is some evidence about the relative importance of these damages and the willingness to pay to avoid these impacts (eg, expressed per household/year), but these figures cannot be translated directly to the value of the water provision service of green infrastructure (eg, per ha).

Secondly, green infrastructure can contribute to improved water quality and good status of water bodies. The lack of good (ecological) status of many fresh- and groundwaters is an important problem in the EU, and the European Water Framework Directive aims for the achievement of good status, not later than 2027. For wetlands in the UK, the marginal value of this service is estimated at £ 292/ha/year of inland wetlands and £ 1793/ha/year for coastal wetlands (Morris and Camino, 2011). These estimates are based on the meta analysis by Brander et al. (2008). For wetlands along the Scheldt, the benefits for water quality improvement (nutrient recycling, aeration and sedimentation) estimated to range from € 1148/ha/year to €2929 /ha/year (Broekx et al., 2010). These benefits relate to avoided costs for other sectors, eg for dredging or additional waste water treatment.

A choice experiment in Belgium in the context of the EU Aquamoney project illustrates the relative importance of more natural riverbanks. Improvement of the natural status of riverbanks from bad to moderate generates benefits of €23,000/km river/year and an additional € 28,000/km river/year for improvements from moderate to good) (Liekens et al., 2009, De Nocker et al., 2011). This corresponds to approximately 30 per cent of the total benefits of achievement of good status of surface waters. These numbers are derived by dividing the total benefits of improvement of ecological status of rivers for Flanders by the total length of the rivers. The numbers reflect the preferences and willingness to pay of the public for more natural river banks (€57/household/year for the improvement of natural river banks from bad to good) and the relative high population density in Flanders.

The value of this ecosystem service is well recognised in a few cases where cities or producers of bottled water pay upstream land-owners or users for the protection of this service (eg, city of New York and Munich or company Vittel). In these cases this service is valued from $35 ha/year to $1800/ha/year (Schéhérazade et al., 2010). Greiber et al. (2009) list several case studies where forest owners are paid for protection of water quality:

- In Denmark, forest owners are paid up to € 100 per hectare per year for changing forest management practices.
- In Kaufering, Germany, forest owners are paid € 200-300 per hectares per year for forest management practices contributing to the quality of drinking water supply. Funds are obtained from the drinking water price.
- For Bionade, forest owners in Germany are paid € 6800 per hectare to transform coniferous forests to broadleaf forests.

Another category of benefits relates to the provision of water and avoided costs of drought. Water scarcity constitutes an important problem in large parts of the EU, due to different reasons. While many regions in Southern and Eastern Europe are short of water due to physical water limitation, water shortages in many Central European regions mainly reflect high population densities. In Northern Europe, water scarcities may occur in dry years or summers (EEA, 2010). Green infrastructure upstream can slow down rainfall run-off. Whereas generally in urban areas cities up to 60 per cent of rainfall runs off, this only amounts to 5-15 per cent in vegetated areas, making the rest available for filtration (and evaporation) (Bernatzky, 1983). For all forests in France, the value of this service is estimated at € 44-90/ha/year (Schéhérazade et al, 2010; Chevassus-au-Louis et al, 2009). For wetlands in the UK, the marginal value of this service is estimated at £ 1/ha/year of inland wetlands and £ 12/ha/year for coastal wetlands Morris and Camino, 2011). These estimates are based on the meta analysis by Brander et al. (2008).

Several studies have attempted an economic valuation of this service, and some values where provided above. It should however be noted that it is difficult to derive values for water that are generically applicable because the context of water demand and supply varies considerably, both spatially and temporarily. Prices charged for water abstraction in no way reflect the full value of water either in its natural state or in any particular application. While some estimates are available of willingness to pay for water and of its value in use, these tend to be very context specific.

(3) Climate regulation and adaptation

Table 6.7: Climate regulation and adaptation – underlying services/functions and resulting benefits

Benefits Group	Green Infrastructure services/function	Quantitative Benefits	Monetary Benefits
Climate regulation and adaptation	**Carbon storage and sequestration** • Total amount of carbon sequestered / stored =sequestration / storage capacity per hectare x total area (Gt CO2)	• Total amount of carbon removed and contribution to the achievement of climate change targets	• Price of non-traded/traded carbon
	Temperature control • Evapotranspiration rate • Canopy stomatal conductance	• Reduced peak summer surface temperatures • Building energy savings – heating and cooling	• Building cost savings – heating and cooling
	Storm damage control • Wind attenuation potential	• Deprived households at risk from storm damage • Deprived land at risk from storm damage	• Avoided costs of property damage • Avoided costs of damage to natural resource production

Green infrastructure can contribute to climate regulation by protecting existing stores of carbon or reducing the rate of carbon loss, replenishing historically depleted stores by restoring soils and ecosystems, and creating new stores by promoting greater carbon storage/sequestration in areas where this service is currently low (EUCC, 2010).The average annual sequestration of carbon in forest biomass between 2005 and 2010 amounts to 430 million tonnes in the EU-27, corresponding to about 9 per cent of the region's greenhouse gas emissions (Forest Europe et al., 2011). Marine ecosystems, including marine protected areas, also affect climate regulation, due to their effect on biogeochemical cycling and the biological 'pump' that moves carbon from the surface ocean and sequesters it in deep waters and sediments (Díaz et al., 2005).

A recent project by the EUCC demonstrates the possibilities of linking carbon sequestration to biodiversity conservation, with a focus on grassland and wetland ecosystems. For example, the restored wetlands of Dragoman marsh, Bulgaria (a site of 331 ha) have an estimated carbon sequestration rate of 147 $gC/m^2/year$, corresponding to a total of 487 tonnes of carbon annually or 1,782 tonnes of CO_2 annually. The emergent vegetation in the wetland provides an additional carbon storage benefit of approximately 900 tonnes (EUCC, 2010).

A meta-analysis (Conant et al, 2001) of 115 studies from around the world (but with a majority from the UK, New Zealand, Canada, Brazil and the United States) shows that carbon sequestration by grasslands can be strongly influenced by management practices, such as fertilization, improved grazing management, conversion from cultivation and native vegetation, sowing of legumes and grasses, earthworm introduction, and irrigation. Soil carbon increased following management improvements for 76 per cent of studies reporting changes in carbon content and for 65 per cent of studies reporting carbon concentration only. The average increase was of 20 per cent for content data and 29 per cent for concentration data. Conversion from cultivation, the introduction of earthworms, and irrigation resulted in the largest increases.

The Pumlumon project launched in 2007 covers approximately 40,000 ha of upland habitats in the Cambrian Mountains, Wales. The project takes a landscape level approach to biodiversity conservation by increasing habitat quality, size and connectivity, through measures that also improve other ecosystems services and their socio-economic benefits. The value of the increase in climate regulation services (particularly carbon safeguarding) attributable to the project is estimated at £6.2 million over 10 years (Bailey, 2010; see also in-depth case study on farmland and forest in Annex I).

By modifying climate locally, green infrastructure can help areas adapt to rising temperatures, a particularly important aspect in urban areas, which as such has thus largely been addressed in section **Error! Reference source not found.**. Evidence from various countries indicates that temperatures are on average lower in areas with higher percentages of green cover (Potchter et al, 2006; Chang, 2007; Yu, 2006; Bowler et al, 2010). Aspects of climate change adaptation linked to water management have been covered in the previous section.

(4) Health and well-being

Table 6.8: Health and well-being – underlying services/functions and resulting benefits

Benefits Group	Green Infrastructure services/function	Quantitative Benefits	Monetary Benefits
Health and well-being	**Air quality** • Atmospheric cleansing capacity in tonnes of pollutants removed per hectare • Downward pollutant flux, calculated as the product of dry deposition velocity and pollutant concentration	• Total amount of pollutants removed and contribution to air quality targets	• Reduced mortality from reduced respiratory illnesses • Avoided cost of air pollution control measures

	Accessibility for exercise and amenity: • Reduced stress levels and improving mental health • Increased physical activities	• Human health impacts expressed in disability adjusted life years (DALY = years of life lost + years lived with disability)	• Health care savings from eg, reduced obesity, cardiovascular diseases • Avoided indirect costs, such as earnings lost due to inability to work
	Noise regulation Natural sound absorption capacity	• Persons/year where defined threshold in dB is not exceeded due to natural sound absorbers	• Health care savings from eg, reduced cardiovascular diseases

As outlined for green infrastructure in urban areas, ecosystems remove contaminants from air through physical processes such as filtration and biological processes such as decomposition and assimilation (Balmford et al., 2008). Green infrastructure can thus be associated with improvements in air quality, which can translate into fewer incidences of respiratory and cardiovascular diseases and a reduction in hospital admissions. Time-series studies indicate that short-term exposure to carbon monoxide, nitrogen dioxide, sulphur dioxide and ozone correlate with increases in excess risk of mortality (UK NEA, 2011 and references therein). Street trees, for example, can filter out as much as 70 per cent of air pollution (Forest Research, 2010), with the most significant impacts likely to occur during peak traffic densities (Forest Research, 2010). In addition to the direct removal of pollutants, vegetation helps to reduce localised pollution by lowering air temperatures through shading and transpiration (see section (3) on green infrastructure and local climate regulation). It is estimated that up to 12 per cent of air pollution problems in cities are attributable to heat island effects due to the temperature-dependent formation of many pollutants, including volatile organic compounds (VOCs) and ozone, and the dynamics of particulate dispersal (Forest Research, 2010).

As an indication of the value of clean air in general, healthcare spending on respiratory diseases in the EU currently averages €95 per capita per year (HEAL and HCWH, 2010). According to the European Lung Foundation, costs related to respiratory diseases account for approximately €47.3 billion, or 6 per cent, of the total healthcare budgets of EU Member States (HEAL & HCWH, 2010). A study conducted under the EU APHEKOM project calculated that reducing exposure to $PM_{2.5}$ in 25 European cities with 39 million inhabitants to the level recommended by WHO guidelines (10 micrograms per cubic metre) could add up to 22 months to the life expectancy of each citizen currently aged 30 and save €31.5 billion annually in health and related costs (Aphekom, 2011). The study also estimated that exposure to ultrafine particles by living near busy roads could be responsible for 15-30 per cent of all new cases of asthma in children, and of chronic obstructive pulmonary disease and coronary heart disease in adults aged 65 and older. The associated economic burden in the 10 European cities studied could total €300 million every year. In the UK, the health costs incurred due to particulate matter pollution have been estimated at £8.5 to 20.2 billion per annum (Defra, 2007, in UK NEA, 2011). According to calculations by HCWH and HEAL(2010), the total health co-benefits of moving from a 20 per cent to a 30 per cent internal cut in EU27 greenhouse gas emissions by 2020 would be between €10.6 and €30.5 billion per year.

Vegetated habitats can also provide barriers against noise, thereby reducing noise-induced stress and the incidence of other health problems such as hearing impairment, hypertension and ischemic heart disease, and sleep disturbance (UK NEA, 2011; Rowe, 2011). A belt of trees can reduce noise levels by up to 6-8 decibels for every 30 metres width of woodland (Leonard and Parr, 1970, in (ECOTEC, 2008). Similarly, green roofs have been shown to reduce noise pollution by 2-8 decibels (Foster et al, 2011).

Accessibility for exercise and amenity: The mechanisms by which green infrastructure can positively affect an individual's health include inducing physical activity; making physical activity particularly beneficial by providing a greater psychological benefit than physical activity in other settings; ameliorating stress; facilitating social interaction and engagement; and reducing the threats and incidence of pollution and disease vectors via a range of purification and control functions such as local climate regulation, air pollutant removal, and noise reduction (Forest Research, 2010; UK NEA, 2011). In general, the health benefits derived from ecosystems are a function of ecosystem type, ease of access to nature, and frequency of green space use (UK NEA, 2011).

Two studies conducted in the Netherlands found a positive correlation between individuals' self-reported health and the amount of green space present in their neighbourhood, even when controlling for socioeconomic and demographic characteristics (Forest Research, 2010; Maas et al, 2006). On the other hand, Mitchell and Popham(2007) found that although a higher proportion of green space in an area was generally associated with better population health, this association varied according to the combination of area income deprivation and urbanity. There was no significant association between green space and health in higher income suburban and higher income rural areas, while in suburban lower income areas, a higher proportion of green space was associated with worse health, possibly due to the poor quality of green space in such areas.

Green infrastructure can encourage participation in physical activity, which has been shown to reduce the likelihood of developing obesity, type 2 diabetes, osteoporosis, hypertension, and various heart and vascular diseases (Blair and Connelly, 1996; Biddle et al, 2004, cited in UK NEA; Pedersen and Saltin, 2006, in (WHO, 2007), as well as having positive effects on the disease-specific symptoms of the above conditions and of chronic obstructive pulmonary disease, osteoarthritis, fibromyalgia, chronic fatigue syndrome, certain types of cancer and depression (WHO, 2007). There is evidence of a positive relation between proximity to green space and levels of physical activity (Tzoulas et al, 2007); (Cohen et al, 2007; Kaczynski and Henderson, 2007). The direction of causation is, however, difficult to establish, as individuals may choose to live near areas which facilitate activity if they enjoy exercising in green space (UK NEA, 2011b). Research on residents of Bristol, UK (Coombes et al, 2010) found that the reported frequency of green space use declined with increasing distance from the respondents' residence. Respondents living closest to areas classified as Formal parks were more likely to achieve a recommended 30 min or more of moderate activity five times a week and less likely to be overweight or obese. However, the association with being overweight or obese disappeared after controlling for respondent characteristics, area deprivation and characteristics of the neighbourhood environment.

Apart from the promotion of physical activity, several studies suggest that natural environments may enhance health and well-being by allowing restoration from attention fatigue (Kaplan and Kaplan, 1989, in Bowler et al, 2010) and reducing stress levels. Even passive views of the natural environment can induce stress-ameliorating effects (Kaplan, 1995, Ulrich et al, 1991, in Forest Research, 2010). Research based on nine Swedish cities

(Grahn and Stigsdotter, 2003) suggests that the more often an individual visits open green spaces, the less often he or she will report stress-related symptoms, regardless of the informant's age, sex and socio-economic status. The same correlation is observed with regard to the amount of time spent per week in urban green spaces. The data also suggests that the greatest obstacles to frequent use of urban green spaces are time and distance (Grahn & Stigsdotter, 2003).

The health-related benefits of green infrastructure are difficult to monetize given the difficulty of quantifying the link between greening interventions and physical activity, the exact influence of physical activity on health (in the absence of other confounding variables), and the resulting changes in the costs incurred. A growing body of evidence provides, however, an indication of the order of magnitude of such benefits. For instance, it is estimated that physical inactivity accounts for about 3.5 per cent of the disease burden and up to 10 per cent of deaths in Europe (WHO, 2007), and for approximately 2.5 per cent of total national healthcare costs in Western countries (Katzmarzyk et al, 2000, in (Department of Health, 2004). In addition to healthcare costs, the economic consequences of physical inactivity include the value of economic output lost due to illness, work disabilities and premature death (WHO, 2007). In Britain, the cost of physical inactivity to the economy is estimated at £8.2 billion (equivalent to £164,000 per 1,000 people), including £1.7 billion for the National Health Service, £5.4 billion from work absence and £1 billion for early mortality (Department of Health, 2004). Bird(2004)estimates that the potential value of a UK urban park of 8-20 ha, calculated as the avoided cost of inactivity, is between £1.6 million and £8.7 million[28], assuming that 20per cent of the population within 2 km of the park use it to reach an activity target of 30 minutes five days a week.

(5) Investment and Employment

Table 6.9: Investment and Employment – underlying services/functions and resulting benefits

Benefits Group	Green Infrastructure services/function	Quantitative Benefits	Monetary Benefits
Investment and Employment	**Image enhancement** Scenery, amenity, environmental quality	• Perception surveys on the attractiveness of an area for workers/investors • Number of products whose branding relates to cultural identity	• Direct spending on branded local and regional products • Indirect and induced effects resulting from supplier and employee expenditures (GVA)
	Investment and Employment Employment resulting from green infrastructure initiatives	• Temporary employment impacts of green infrastructure provision • On-going employment impacts of maintenance • Summary of employment sustained by sectors (eg, agriculture, forestry, tourism and recreation	• Effects on wider economy (tourism, inward investment – value of investment and expenditure, effect on GVA)
	Labour productivity Scenery, amenity, environmental quality • Amount of workplace individuals benefiting from green infrastructure investment or existing GI	• Impact on worker's effectiveness on the job	• Savings from reduced short-term absenteeism from work

[28] The large value ranges reflect the different population densities examined.

The following section particularly focuses on the issue of employment impacts and as such includes information that potentially can be attributed to individual green infrastructure elements (eg Natura 2000 and jobs). However, given the importance of the subject for integrated approaches and its minor relevance to determine cost-effectiveness of individual green infrastructure elements it is mainly covered under this heading.

Economic impacts of capital investment – As with other forms of infrastructure investment, development and restoration of green infrastructure creates temporary employment and provides business opportunities for suppliers and contractors. For example:

- Mills et al (2010) looked at the employment impacts of implementing Environmental Stewardship schemes in England. They found that much of the income and employment benefits from scheme expenditure are retained locally, supporting 1 FTE job in the local economy for every €1m of initial agri-environment scheme spending. This particularly related to capital works involved in boundary maintenance and restoration. These schemes were also found to under-pin employment for local businesses, including stone walling and hedge restoration contractors, and some farm advisors.
- A green infrastructure initiative involving restoration of riverside areas in Lyon, France, involved 17 enterprises in project works, creating between 60 and 120 temporary jobs (Naumann et al. 2011);

Economic impacts of green infrastructure maintenance – Annual expenditures on maintaining green infrastructure support employment and incomes for land managers. For example:

- The implementation of Natura 2000 network was considered to have positive impacts on GDP in Spain, with an estimated increase in GDP between 0.1 - 0.26 per cent at national level. It was estimated that the network would generate an additional 12,792 jobs to the country (Fernandez et al 2008).
- A study of the economic value of protected areas in Wales concluded that they directly or indirectly support nearly 12 000 jobs.
- It has been estimated that a fully funded Natura 2000 network could support 207,000 jobs and GVA of €5.2 billion across the EU, mostly in rural areas (Rayment et al 2009).

Enhanced opportunities for inward investment and economic development – Especially in urban areas, investing in green infrastructure can improve the living and working environment, enhancing property values, stimulating regeneration and attracting businesses to locate and invest in the area. For example:

- The Glasgow Green project in the UK stimulated the development of 500-750 new residential properties, enhanced average house prices, increased the total value of property transactions (by between £3m and £4.5m), and increased the value of local land from £100,000 to £300,000 per hectare (GEN Consulting 2006). Associated costs of this project has been estimated at average of €321,343 per ha of park restored (Naumann et al., 2011)
- Crewe Business Park, Cheshire, UK, has created a high quality office environment through protection of natural features and community well-being. This has

helped the business park to generate over £4.5 million in capital receipts and create more than 2,800 jobs (Landscape Institute 2009).

Enhanced labour productivity – Green infrastructure enhances physical and mental health – by improving air quality, supporting outdoor recreation and hence reducing the problems of inactivity and obesity, and by improving psychological well-being. This can impact health costs occurring to the public. At the same time, it can enhance labour productivity by positively impacting the effectiveness at work. Though these benefits are difficult to assess, some attempts have been made to estimate them, mainly referring to reduced economic losses due to sickness and absence from work rather than looking at positive effects. For example, the Mersey Forest project in North West England is estimated to have brought net benefits of £20,000 per annum as a result of reduced absenteeism from work, as well as cost savings of £13,000 per annum, as a result of improved health through physical recreation. In addition, the benefits of improved health through absorption of air pollution are estimated at £116,000 annually (Regeneris, 2009). By mainly using information on avoided economic losses due to absence from work, there is risk of overlap with information on health benefits.

Enhanced opportunities for regional branding and marketing – investing in green infrastructure can enhance the image and cultural identity of an area and stimulate new opportunities for marketing both the area itself and its produce. Green infrastructure initiatives often involve planned and co-ordinated investment in natural assets which can contribute to regional identity and brand, thus enhancing economic opportunities. The English National Forest initiative has created or safeguarded 333 forestry related jobs, created 5 forest related businesses and trained 78 people in forest related business activities (Naumann et al, 2011).

(6) Tourism and recreation

Table 6.10: Tourism and recreation – underlying services/functions and resulting benefits

Benefits Group	Green Infrastructure services/function	Quantitative Benefits	Monetary Benefits
Tourism and recreation	**Tourism** Scenery, amenity, environmental quality, products, flagship species and habitats	• Employment supported by tourism • Amount of nature tourism • Number of visitors to protected sites per year	• Tourism expenditure • Expenditures for wildlife watching • Travel costs
	Recreation Exercise, scenery, amenity	• Number of local users for hiking, camping, nature walks jogging, winter sports, water sports, angling, horse riding, hunting, cycling	• License fees for hunting and angling • Indirect and induced effects resulting from expenditure • Willingness to pay/accept access fees (consumer surplus)

This benefit group refers to the use of natural and cultivated landscapes for pleasure, and includes both visits to specific areas by local people (recreation) and by people outside the region and overnight visitors (tourism). It refers to a wide range of activities, from walking and sightseeing to more specific activities like angling or rock climbing. For recreation, most types of green infrastructure are relevant, provided they are accessible to the public. To attract tourists outside the region green infrastructure elements need either to be sufficiently large, part of a larger set of green infrastructure system or have unique characteristics.

The economic values of recreation and tourism is well documented, and include information on both market prices (especially expenditures and profit margins related to tourism), revealed preferences (especially travel cost methods and hedonic pricing) and stated preferences.

The literature provides a wide range of studies documenting the value of specific recreational activities (eg, walking, angling), mostly expressed in €/visit or activity. These data can be based on travel and time costs that reveal (a lower limit) of the value people attach to these activities in an area (eg, forests, coastal areas, mountains, wetlands). They can also be based on stated preferences, eg where people indicate how much they are willing to pay for a protection or improvement of specific natural area. The most detailed and nation wide study of recreational value based on travel costs is made in the UK in the context of the UK NEA Economic Analysis Report (Sen et al, 2011). The average value per visit in the baseline scenario is £ 3.1/visit. Natural areas were considered important and half of the population visit them at least once a week, while 10 per cent visits them on a daily basis. On average, the total recreational value of current natural areas in Great Britain is £10.04 billion/year, which corresponds to on average £181/inhabitant/year (Sen et al, 2011). The analysis of different scenarios illustrates that this value can still increase significantly. It is estimated that by 2060 the recreational value of nature will increase in most scenarios. The increase may vary from £4 billion to £6 billion per year in the 'go with the flow' and 'green and pleasant land scenario', corresponding to in increase of around £60/inhabitant/year. In the 'nature at work' scenario the increase is largest, with £24 billion/year. On the other hand, this recreational value could be reduced by 30 per cent (£800 million/year or £57/inhabitant/year) under a 'world markets' scenario.

The average value per visit is of a similar magnitude as the estimates for forest recreation, based on a metal analysis of European studies. Visits to forest in Europe are valued on average at € 4.52 /visit (Zandersen et al, 2009). It should however be noted that the value of specific areas can vary widely, eg, forest visits in Europe show a range between €0,6/visit to € 112/visit (Zandersen et al, 2009). These differences reflect the variety in local conditions, preferences and ability to pay from citizens, and methods applied.

The recreational value of forests have been estimated for several EU member states (Bartczak, 2008; Guyot, 2009).

- € 90-219 /ha/year for the UK ,
- € 117-140 /ha/year for Denmark,
- € 66-126 /ha/year for France,
- € 250 /ha/year for Ireland
- € 214 /ha/year for Germany
- € 570 /ha/year for Poland

The relative high value for Poland is remarkable, and reflects that values not only depend on GDP but also on preferences and cultural differences. Forest recreation is highly valued in Poland, and both trip frequency and trip values are higher in Poland than in Western Europe. The value is € 7.38 /visit, based on travel costs and in PPP adjusted (Bartczak, 2008).

It has to be noted that the values in Europe are much higher than for eg, Canada or US, which reflects a higher population density (400 to 800 inhabitants per km² forest, compared to 8 or 28 inhabitants/km² forest for Canada and US) (Guyot, 2009). In addition, there is evidence that people with more access to green space participate more in outdoor recreation and enjoy health benefits. People with very good access to attractive and large public open space were 50per cent more likely to have high levels of walking, defined as at least 6 walking sessions per week totalling 180 minutes (GHK Consulting, 2006).

For tourism, values per trip are typically higher than for recreation. The value for tourists (consumer surplus) of the Doñana region (located at the end of the Guadalquivir watershed in Andalusia on the south western coast of Spain) are estimated for different type of tourists (Martin Lopez et al, 2011). The figures show that density of use for recreation plays an important role for the benefits per ha.

- Nature: 36.8 € / year , corresponding to € 199/ha/year
- 'Sun and Beach': 36.8 € / year; corresponding to € 1681 /ha/year
- Cultural : €,14.2 /year; corresponding to € 428/ha/year
- Religious : £ 86.3 /year; corresponding to € 905/ha/year

Protecting and enhancing natural areas and improving access to them helps to stimulate tourism and recreation, bringing new revenues to local economies. This can also support the diversification of the tourism sector and extend the season beyond the summer months. For example, it is estimated that the National Forest, a major green infrastructure initiative in central England, has provided 20 new tourism attractions, and attracts 8.7m visitors annually, bringing tourism revenues of €321 million to the local economy (Naumann et al. 2011). Restoration of the 'Uitkerkse polder', Belgium, has attracted 150,000 visitors per annum to the area, bringing annual tourism revenues estimated at €3.5 million (Gantioler et al, 2010).

The economic value will differ a lot between green infrastructure areas, depending on vegetation type, infrastructure to ease recreation, possibilities for specific recreation, population densities and availability of substitutes. Whether an area has a local or regional importance depends on a number of factors. The guidance of The Greater London Authority (GLA) gives an idea of the importance of site size as regards required distance to attract visitors:

- regional parks of up to 400 hectares in size have a 'catchment area of 3.2 to 8 kilometres
- district parks of up to 20 hectares have a catchment area of 1.2 kilometres
- local parks of 2 hectares serve the local population within 400 metres.

Box 6.15: From coal mines to eco-tourism: the Hoge Kempen National Park (Belgium)

The Hoge Kempen National Park (6000 ha) is set in a rural part of eastern Belgium, a former coal mining area in the Province of Flanders. The objective of the national park is to restore and further develop the natural values of the region to support nature tourism and education. The initiative was taken against the background of closing coal mines in the east of Belgium in the late 1980's and the need to promote economic development. The first steps were inspired by similar initiatives in other countries (Naturpark in Germany, Parcs Naturels Régionaux in France and Areas of Outstanding natural Beauty in the UK; VORL, 2011).

The initiative was successful in terms of bringing a wide range of stakeholders together to protect and promote the area for nature tourism and education. It raised up to € 90 million to invest in the project, and the revenues from sustainable tourism are forecast to reach € 24.5 million per year by 2011.

The natural park is in operation for five years (since 2006) and the results are mainly in terms of infrastructure and capacity:

- Better protection of the core natural area's;
- Building of infrastructure for ecotourism;
- Increased cultural value of the area;
- Increased recreational value: 30 per cent increase of visitors to the area in 2010 (700.000) compared to 2005;
- Increased educational value: 11.000 visitors that used a (paid) service from the natural park rangers (2010).

The authors are not aware of independent or scientific studies on the economic impacts of the natural park. The opening event and project website offers some information on economic impacts from the project, or related to the project.

- In the municipalities participating in the project, overnight tourism has grown by 26 per cent (since 2006), compared to 8 per cent for whole Flanders. Related economic turnover is estimated at € 24 million (€13 million direct turnover, €11 indirect turnover).
- The Related initiative bicycle route network attracted 700.000 cyclists a year, of which 20 per cent sleepover bicycle tourists. Total expenditures of these cyclists were estimated around € 16,5 million for the year 2006, which is an economic return to this region. In 2009, the number of cyclists was almost 900.000 (Marghescu , 2006).

(7) Education

Table 6.11: Education – underlying services/functions and resulting benefits

Benefits Group	Green Infrastructure services/function	Quantitative Benefits	Monetary Benefits
Education	**Research and education** Flagship species and habitats, endemic species, well-functioning, complex ecosystems.	• Total number of visits, specifically related to education or cultural reasons • Total number of educational excursions • Number of TV programmes, studies, books etc. featuring sites and the surrounding area	

Green infrastructure can contribute to education and provide ecological learning experiences for both children and adults. Though the service is clearly recognizable, relatively little information exists on the actual value amount of this service. In addition, it is very often difficult to separate educational trips to natural areas from recreation and tourism, though this is often addressed by targeted surveys to determine the purpose of the visit. Nevertheless, careful attention has to be paid to risks of double-counting.

An attempt to value educational services of green infrastructure was performed in the UK National Ecosystem Assessment (Bateman, 2011a; Church, 2011; Mourato, 2010). The economic valuation of cultural goods conducted for the UK NEA examined two components of ecological knowledge using differing methods. Firstly, an accounting framework was used to examine a portion of the ecological component of school education. The tentative findings produce an estimate of £2.1 billion for the value of the ecological knowledge contained in the education attainment of pupils in 2010 completing GCSE and A2 geography, science and biology. Though the accounting methods are very approximate the findings indicate that the value of ecological knowledge is possibly substantial.

Secondly, two case studies were used to estimate the monetary value of ecological knowledge acquired through outdoor learning by examining the 'cost of investment' associated with these activities. In a first case study the monetary value of outdoor learning was explored through the 'cost of investment' in organised school trips to nature reserves. The analysis estimates that trips to RSPB nature reserves by schools were based on total investment costs of between £850,000 and just over £1.3 million. A second case study was made of the RSPB Big School Birdwatch initiative which involves pupils and teachers counting species of birds visiting school grounds for an hour on any day in a two-week period. The 'cost of investment' approach suggests the value of pupil and teacher time contributing to the Big School Birdwatch is £374,000 or an average of £188 per school.

While none of the above case studies reveals the level or benefit of ecological knowledge acquired, they provide an indication of the financial outlay for an activity which can contribute to the acquisition of ecological knowledge. No evidence was found regarding the acquisition of ecological knowledge among young people and adults outside the formal education system. This is also strongly linked to valuation of services related to tourism and recreation. The study on the economic value of the Doñana region in Spain indicated that the creation of the natural area led to an increase in expenses for research and education in the region. These were accounted for as the benefits for scientific value and education, accounting respectively to € 6.7 /ha/year and € 3 /ha/year (Martin Lopez et al, 2011).

Finally, there is a lot of evidence in the literature which indicate that access and exposure to, and play in, nature can have profound positive effects on children's emotional, physical, and psychological development (Strife, 2009; Church et al, 2010). The positive effects of nature exposure include improved cognitive functioning (including increased concentration, greater attention capacities, and higher academic performance), better motor coordination, reduced stress levels, increased social interaction with adults and other children, and improved social skills. A study in Telemark, Norway showed that children who used a forest as a play setting performed better in motor skills tests than children who used a standard playground (Fjortoft 2001, cited in Strife, 2009) A study in Urban Sweden showed that children attending day care facilities surrounded by natural areas, such as woodlands and orchards, had greater attention capacities and motor coordination skills than did children who attended day care centers surrounded by tall buildings (Grahn et al., 1997, cited in Strife, 2009). A study with children from low income urban families showed that when families were relocated to houses with more nearby nature, they had higher levels of cognitive functioning (Wells, 2000, cited in Strife 2009 and Church, 2010).

(8) Land and Property values

Table 6.12: Land and property values – underlying services/functions and resulting benefits

Benefits Group	Green Infrastructure services/function	Quantitative Benefits	Monetary Benefits
Land and property values	**Land and property** Exercise, scenery, amenity	• Changes in the number of residents	• Residential land and property value uplift (<450m from green space) • Commercial land/property value uplift

There is a lot of evidence that nearby green spaces and water can enhance property values both from local studies and nationwide studies. As people value faster and easier access to green areas they are willing to pay more for houses that offer this feature, which is reflected in higher selling or renting prices. The difference in house prices that can be allocated to the proximity of green areas is an indicator of the value people attach to these characteristics.

A recent, major study in the UK, building on 1 million house transactions in England, Wales and Scotland between 1996-2008, indicates the relative importance of these effects (Maurato et al, 2010; Bateman et al, 2010). The results indicate that a 1 per cent increase of green areas within the local area (1 km around the house) increases house prices with 0.06 per cent to 0.4 per cent. These premiums can also be interpreted as the willingness to pay for 1 extra ha of that green area type in the local area. The degree depends on the type of green area or water, and is biggest for

- Freshwater, openwaters, wetlands and floodplains: 0.4 per cent increase (£ 768)
- Broadleaved mixed and yew woodland: 0.19 per cent increase (£ 377)
- Coniferous wooldland: 0.12 per cent increase (£ 277)
- Enclosed farmland: 0.06 per cent increase (£ 133)

In addition, increasing distance from natural amenities such as rivers, National Parks or National Trust sites is associated with a fall in house prices. This effects is the largest for rivers, and an increase with 1 km leads to a fall of 1 per cent in house price (£ 2400). Similar effects are shown for distance to National Trust owned sites (- 0.7 per cent or £ 1350) and National Parks (- 0.24 per cent or £ 460). In the Netherlands, Brouwer et al used a stated prefence method (choice experiment) to ask people if they would be willing to pay more for a house nearby open water, and for more natural river banks (Brouwer et al, 2006). The study reveals that on average people were willing to pay 3per cent extra for a house nearby a natural river bank (compared to artificial concrete banks) which corresponds to € 10,000 (what corresponds to € 400/year using a 4 per cent discount rate). A nearby river with good ecological status gives a premium of 8 per cent or € 25,000 (what corresponds to € 1,000/year using a 4 per cent discount rate).

A study in Sweden finds a positive relation between green infrastructure elements in rural landscapes nearby a farm (semi natural pastures, mown meadows, riparian strips and wetlands) and the prices for “staying on the farm”. It indicates that visitors are willing to pay for a more natural and heterogenous landscape setting (Liljen stoppe, 2011).

The value of scenic beauty from the property is also reflected in house prices. A study in Finland showed a 4.9 per cent premium for value of houses with forest view (Tyrväinen & Miettinen, 2000). Luttik (1997) found a similar value for the Netherlands. As property values are lower for areas that are at risk of flooding, the contribution of green infrastructure to flood prevention also contributes to a higher value of properties.

(9) ’Insurance’ value

Table 6.13: Insurance value – underlying services/functions and resulting benefits

Benefits Group	Green Infrastructure services/function	Quantitative Benefits	Monetary Benefits
Insurance value	**Resilience Ecosystem Services** defined by a wider portfolio of services provided, with particularly emphasis on regulating and supporting services	• Scoring according to portfolio of services and functions provided	• Option value defined by stated preference methods

As outlined in previous sections, ecosystem resilience is playing a key role in ecosystem functionality, by crucially influencing the amount of benefits provided to human well-being. Rather than concentrating on individual elements of green infrastructure/ecosystem services, a balanced and informed approach which leads to a formation of connected, coherent and healthy ecosystem network is likely to secure undisturbed stream of benefits to people.

To obtain a fuller picture of potential impacts of various green infrastructure elements promoted by policy initiatives, it is desirable to value the range of benefits stemming from a change in ecosystems' resilience these elements can lead to. However, valuation of ecosystem's resilience is a difficult exercise which is faced by numerous challenges. First of all, an ecosystem might often happen to be close to a threshold, where most of the standard valuation techniques cannot provide reliable value estimates. This is due to the fact that most of the valuation techniques allocate economic value at the margin – ie assuming that marginal change in human action will cause marginal change in the provision of ecosystem goods/services. Secondly, the current scientific knowledge of when and under which circumstances ecosystems thresholds occur is deficient and if at all possible, it is very complicated and/or costly. Lastly, due to a high level of complexity and our limited understanding of ecosystems' functioning, it is possible that often some of ecosystems benefits might not be acknowledged until they are lost.

Nonetheless, given these challenges, economists are still trying to come up with possible ways how to value ecosystem resilience. Currently, relevant techniques to estimate the value of ecosystem resilience are thought to be stated preference methods (ie Contingent valuation method, choice experiments). It is also thought that valuation of resilience should be analogous to valuation of a portfolio of financial assets, ie the more diversified the portfolio, the lower the overall risk if there is a fall-out on certain financial assets. In addition, as some of the before-mentioned studies have shown, the linkage between biodiversity and ecosystem services is highest where a range of services is provided, and the diversity of species, habitats and genes represents an 'insurance' that if some components get lost, important ecosystem functions are still sustained as other components have worked as substitute. In this sense, rather than ecosystem's property, resilience is often currently regarded as natural capital stock providing a 'natural insurance' service, which might be therefore included in cost-benefit analysis (TEEB, 2010).

However, currently the amount of resilience valuation studies is very limited and, due to a relative novelty of this valuation approach, academic literature on this topic is often of rather theoretical than practical nature. Nevertheless, there are some promising approaches to resilience valuation which are being explored (see Box 6.16 below).

From the issues discussed above, it is clear that valuation of resilience represents challenging, but potentially very useful tool to assess the value of ecosystems. Due to its overreaching conceptual characteristic, resilience offer a framework which captures range of goods and services, some of which are otherwise difficult to focus on individually. Fundamentally, resilience encompass various supporting and regulating services underpinning ecosystem's functioning, such as nutrient cycling or maintenance of genetic diversity, which are otherwise difficult to consider in conventional ecosystem service valuation (due to double-counting problem). From this perspective, resilience valuation might offer a very useful complementary tool for the assessment of ecosystems benefits.

Box 6.16: Examples of resilience valuation

In what is thought to be the first application of choice experiment to value ecosystem's resilience, Scheufele and Bennett (2011) attempted to estimate the implicit prices for attributes used to describe the ecosystem resilience of Border Range rainforests in Australia. By offering various choice options with different resilience attributes, the paper found that the implicit prices for these attributes describing improved ecosystem resilience are positive and statistically different from zero. Due to their results, respondents would be, on average, willing to pay $854.91 to improve ecosystem resilience to the maximum level.

Vergano and Nunes (2006) illustrated their approach to value resilience in a case study on the Venice Lagoon. In the Lagoon an increased intensity and frequency of floods, which has serious consequences to local business activities, can be considered as a signal of low resilience of the lagoon ecosystem. With such a premise, authors considered off and on site damages, estimated at EUR 22 million per annum, as a proxy of the option value component of the total economic value of the Lagoon system's resilience.

(10) Conservation benefits (non-use values)

Table 6.14: Conservation benefits – underlying services/functions and resulting benefits

Benefits Group	Green Infrastructure services/function	Quantitative Benefits	Monetary Benefits
Conservation benefits	**Existence value of habitat, species and genetic diversity**		• Stated preference methods • Qualitative methods (eg, focus groups)
	Bequest and altruist value of habitat, species and genetic diversity for future generations		• Stated preference methods • Qualitative methods (eg, focus groups)

Some of the policy initiatives targeting green infrastructure might also offer significant non-use benefits. Such benefits are not associated with the actual use of ecosystem, nor to its potential use in the future (ie option value). Instead, non-use benefits stem from people's knowledge that nature and its elements exists (existence value) or because they wish it to exist for future generation (bequest value) or for others in present generation (altruist value) (TEEB, 2010).

Generally, the estimation of non-use values is thought to be one of the more challenging ones due to the fact that such values are often connected to morality, religion or aesthetics. Different to the valuation of ecosystem services (with maybe cultural services as an exception) the formation of the value stemming from non-use benefits mostly relates to experiences which happen in valuer's mind and therefore embodies a significant influence of subjectivity and context-dependency. In contrast, the majority of provisioning services, for example, are valued explicitly via price formation in markets and hence provide more 'real' estimates than valuation of non-use benefits might seem.

Despite these problems, there is a need for estimation of non-use benefits since they are thought to represent a significant part of the values embodied in ecosystems. For instance, several valuation studies suggest that non-use benefits might often represent the largest part of the total economic value of some biodiversity resources (OECD, 2004). Moreover, non-use valuation is to a certain extent thought to reflect a public perception of the value of biodiversity, which is by itself useful information for policy-making. The scope and the magnitude of the values provided in the literature indeed suggest that the non-use benefits are often non-negligible (see Box 6.17 below).

Given these complications, stated preference methods (eg, Contingent Valuation Method, Choice Experiment) are predominantly used for estimation of non-use benefits related to ecosystem services. These techniques aim to estimate the willingness to pay for certain environmental amenities of population in question and determining the main casual factors in the value formation. However, although a significant improvement in the execution and precision of the stated preference methods has been under way in recent years, it has to be noted that there are still many controversies connected to the use of these methods (for example, see Venkatachalam, 2004 for a discussion of the CVM).

Box 6.17: Conservation/non-use benefits

Jacobs et al (2004) used WTP surveys to estimate the non-use values associated with Natura 2000 sites in Scotland. Using Contingent Valuation method, the study made surveys for three groups of stakeholders – general public, visitors to case study areas and non-Scottish visitors –and eventually estimated the non-use values of Scottish Natura 2000 sites at £210 million per year.

Dubgaard et al (2002) estimated the non-use (existence) value of the Skjern River restoration project at DKK 50.6 million by using benefit transfer from a similar project area in the UK.

A contingent valuation method was carried out to value the improvement in non-use benefit resulting from Misi Rural Development Project in northwest Turkey. It was estimated that rural residents in the area are willing to pay 67.94 USD per annum, totalling 2,306,474 USD per year if generalised to households in the area (Gürlük, 2006).

In order to determine the optimum level of conservation for the scarce Large Blue butterflies, Wätzold et al. (2008) used contingent valuation method to construct the demand curve for specimen's conservation. Estimated benefits, mainly related to non-use values, ranged between € 260,000 and € 426,000, depending on the conservation scenario.

In a study aiming to determine the economic value of UK marine biodiversity, Beaumont et al. (2008) estimated the non-use benefits (related to bequest and existence value) at £0.5–1.1 billion per annum. However, it has to be noted that this figure is based on estimates from previous studies and it is thought to be an underestimate.

McVittie and Moran (2010) used stated preference choice experiment to estimate the benefits stemming from implementation of Marine Conservation Zones under the UK Marine and Coastal Access Bill. The total aggregate value for a policy that would achieve a halt in the loss of biodiversity through the introduction of the UK wide MCZ network was estimated at £1,714 million per annum. Moreover, the study estimates suggests that policy actions aimed at increasing the level of provision of environmental benefits would have a greater potential to pass the cost-benefit test, rather than policies aimed at improvement in biodiversity.

6.3.2 Cost-effectiveness of Integrated Approaches to green infrastructure Implementation

The green infrastructure elements, while analysed separately in section 6.2 above, cannot be managed effectively in isolation. This realisation has led to the development of a number of initiatives which seek to identify, support and integrate the wider green infrastructure through the development of strategic policy initiatives which streamline measures for the wider green infrastructure's enhancement and protection through measures across a wider range of policy sectors, thus better exploiting potential synergies across policy areas and increasing policy coherence with regard to green infrastructure.

In recent years, realisation has grown that the effective and sustainable delivery of the wide range of services provided by the green infrastructure, as presented in chapter 5 and the previous sections in this chapter calls for the development of a range of integrated approaches to green infrastructure implementation. These reflect for instance the recognition that core areas are vulnerable to the pressures resulting from activities taking place in the wider countryside around them. For example, diffuse pollution derived from agriculture or the burning of fossil fuels poses a serious threat to plant communities found on low-nutrient soils and to water bodies. In England, 89 per cent of the area of sensitive habitats experience concentrations of nitrogen that exceeds the critical load (ie the level which semi-natural habitats are damaged) (Lawton et al, 2010). Indeed, the cost of tackling eutrophication, in particular nitrogen deposition, constituted a significant component of the most expensive of the green infrastructure initiatives identified by the study. In Sweden, €49 million are foreseen to be spent per year on mitigating the impacts of eutrophication. Similarly, the effectiveness of restoration zones, which often require significant investments, can be jeopardised in the absence of efforts to improve the overall quality of the landscape within which they are located. Furthermore, integrated green infrastructure approaches, would not only allow the delivery of multiple benefits from the same piece of land, they are also thought to decrease the cost of achieving species and habitat conservation objectives in core areas by reducing the outside pressures and averting the need for costly mitigation measures. In this sense, sustainable use areas, particularly those that border or influence important nature conservation areas, will be particularly important in the delivery of an effective green infrastructure and the benefits they deliver go far beyond those they deliver locally as they contribute importantly to the overall resilience of the wider green infrastructure, across a wider range of elements, thus also indirectly underpinning the services provided by these other elements.

The approach exemplified by ecological networks recognises the importance of the interaction between the elements, and is often cited as a means to manage the biodiversity and ecosystem considerations at a lanscape scale. Indeed, the model has significant potential as a framework for optimising the management of the different elements and incorporating plans into regional spatial policy. Despite this, the approach has yet to prove its cost-effectiveness. A review of nine European ecological networks found that most have encountered difficulties in the implementation of the networks on the ground despite considerable resources deployed in planning and mapping the network from the point of view of the most important areas for biodiversity (IEEP and Alterra, 2010). To a large degree, the successful implementation of measures on the ground is dependent on buy-in from landowners and relevant stakeholders, who have the power to 'make or break' such initiatives. This highlights a difficult tension: ecological networks need to be carefully planned and researched in order to correctly identify those features and areas likely to be of most ecological value; however doing so risks being perceived as overly top-down and imposing restrictions on land without consideration of the land users. This necessitates careful public participation in such decision making.

Integrated spatial planning has also been seen as a response to better channelling the multiple demands on land in view of achieving efficient and sustainable outcomes. This is for example reflected in the recent development of initiatives such Integrated Coastal Zone management (ICZM) and Maritime Spatial Planning across Europe. In particular the initiatives in the area of spatial planning, which may also be seen as including improved public participation in EIA and SEA processes, can be seen to result in more sustainable outcomes through a better up-front integration of potentially conflicting views and interests. Thus these measures can result in decreasing the cost of conflicts which would have arisen in the absence of an integrated approach and help identify adverse impacts which can cost-effectively be avoided or mitigated.

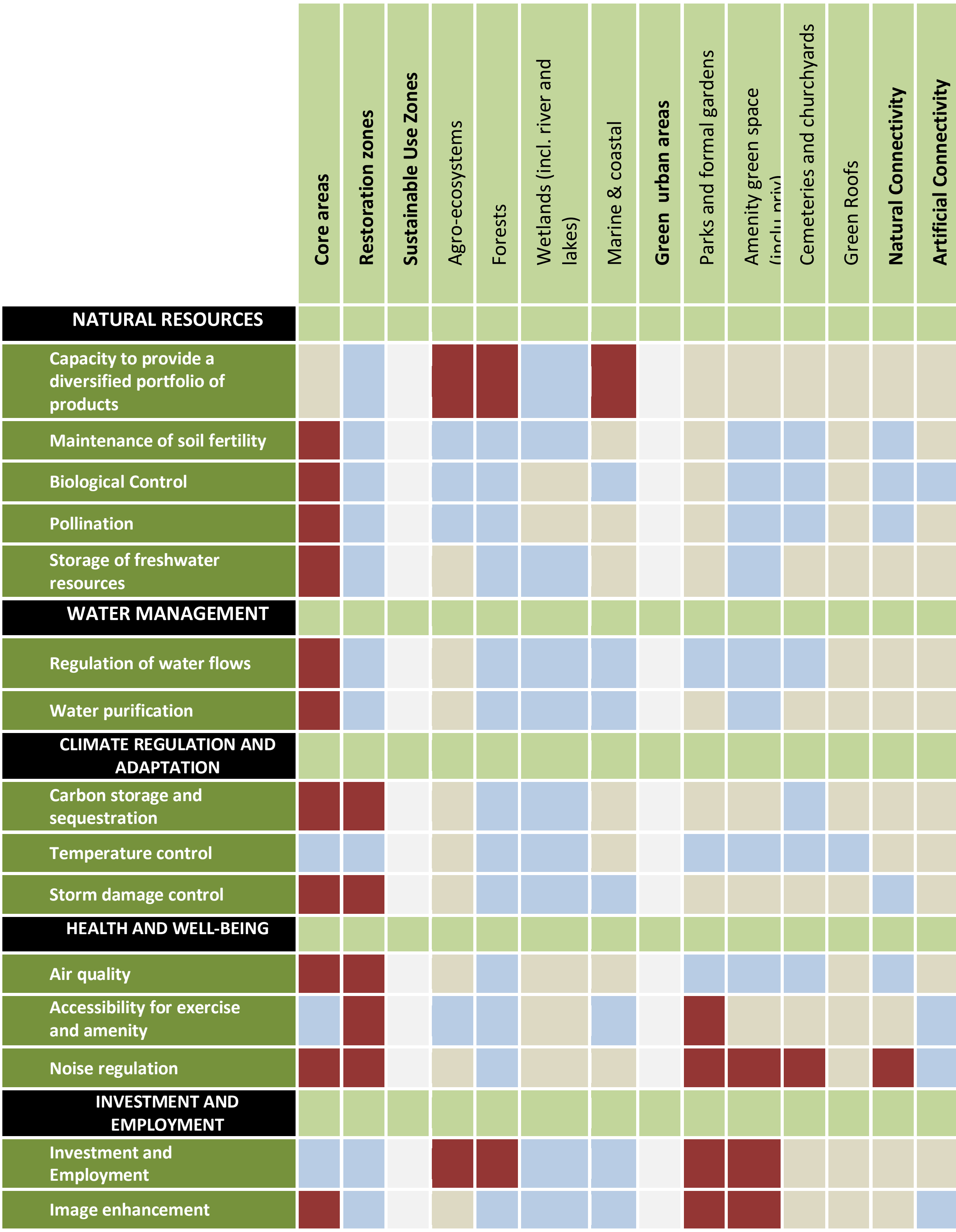
While biodiversity underlie the provision of ecosystem services, the optimisation of the habitat and species protection may result in lower service provision than alternative land management options. For example, research by Posthumus (Posthumus et al, 2010) found that in the lowland floodplains of England, policies targeted at promoting biodiversity would fail to produce the highest cumulative benefits to the full range of ecosystem services, despite producing reasonable biodiversity and excellent water quality results. Bradbury et al (2010) find that the co-delivery of farmland bird conservation and ecosystem service provision will create a significant challenge to land management and demands careful planning at multiple scales to account for the range of synergies and trade-offs. The English Entry Level Stewardship practice that scored the highest for delivering multiple non-biodiversity benefits (permanent grassland with very low inputs) still showed that certain services will be promoted over others, highlighting the need for trade-offs. The ecosystem approach, applied by the EU green infrastructure concept, therefore has the potential to resolve these tensions by optimising different land uses at a higher scale.

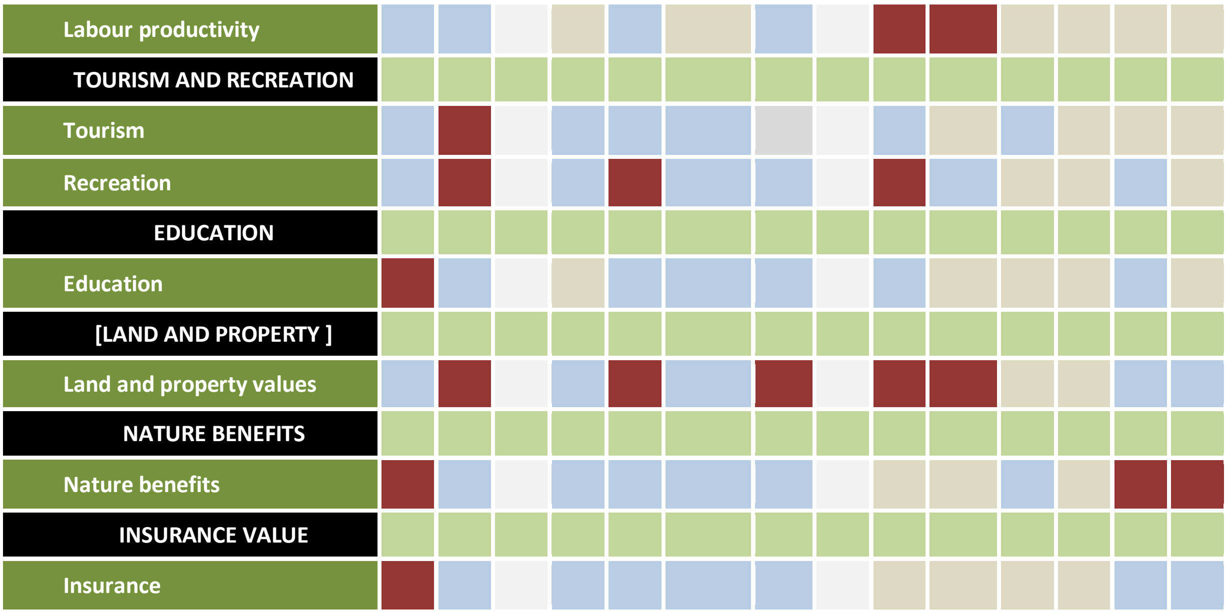
6.4 Conclusions

The previous sections either described ecosystem functions services supported by different green infrastructure elements or focused on benefit groups provided across the wider range of green infrastructure elements or resulting from integrated approaches to green infrastructure implementation. This summarises the results of both these sections into a short qualitative assessment. While it highlights the impacts on benefit provision of individual elements, it also emphasises the importance of considering green infrastructure as a system that delivers more than the sum of its parts (ie the different elements it is composed of) and taking into consideration the wider portfolio of services and benefits that it provides.

The qualitative assessment provided below only represents an estimate of the potential impact of different elements on the provision of benefits. Based purely on expert judgment, it aims at succinctly setting in relation the evidence on ecosystem services and benefits presented in sections 6.2 and 6.3 of this chapter. It is intended to signpost the likely relative importance of green infrastructure elements as regard the provision of the different types of ecosystem services rather than an accurate assessment. Much of the impact will be context-dependent and strongly dependent on the characteristics (eg ecological, economic and social) of an area. To a certain extent this has been made evident by further dividing elements into components. For example, in relation to green urban areas the benefits provided by parks and formal gardens are assumed to be quite different from those provided by green roofs.

Figure 6.4: Green Infrastructure elements and benefits – qualitative assessment of impact





Potential impacts

Colour code		Small impact or not relevant		Moderate benefits		High impact
		Benefits slightly increase, but less then double, or can be considered not relevant		Benefits are at least doubled		Benefits increased more than five fold

Note: Cells for green urban areas or sustainable use zones are blank as no average has been calculated for those elements

The assessments makes evident the key role that can is played by core areas, highlighting their high impact on the provision of a range of benefits. Though their impact can be expected rather small regarding their contribution to a diversified portfolio of products (keeping in mind that this has not to equal zero depending on designation schemes), their support of functions such as pollination or biological control can still be essential for the provision of natural resources. Complementing core areas with sustainable use zones can increase the impact on product provision and enhance investment and employment given those zones are rated higher in this regard, but figure less prominently on many other benefit groups particularly related to regulating services. Green urban areas on the other hand are less important in the support of natural resources but can have a very high impact on attracting investment and employment into an urban area, on adaptation to climate change (eg, temperature control) or their impact on human health and well-being due to the increase accessibility to areas of exercise and amenity. Also the role of natural and artificial connectivity features should not be under-estimated as they can be crucial for functions such as biological control.

Thus, though some elements might seem less important in the provision of certain services and benefits they can play essential roles in combination with other elements either by enlarging the portfolio or due to their importance in increasing the resilience of the system. However, it also emphasise that core areas, its extent and 'quality' have a key role to play to guarantee the provision of a range of services also for the future, and form the backbone of any green infrastructure. As already emphasised, much of the role of other elements will be context-specific. For example it is assumed that artificial connectivity features will have a higher beneficial impact in already highly fragmented areas, by strengthening the 'quality' of existing core areas. Strong consideration needs to be given how the different elements interact. Unfortunately, little evidence is yet available in this regard as many of the in-depth analyses have not provided an assessment of the socio-economic benefits expected from integrated approaches.

From a review of benefits and the cost-effectiveness, a number of headline conclusions can be made.

- Although data are sparse, there is good evidence to suggest that larger core areas provide optimum return on investment for both biodiversity and ecosystem services compared to other elements, where this is an option. Nevertheless, cost-effectiveness is affected by cost drivers such as size, effectiveness of management interventions and costs of alternative land uses.
- It is more cost-effective to maintain natural areas than to restore them, emphasising the importance of protecting core areas. Restored natural areas never achieve their former undegraded ecological state and although some services may be adequately restored they rarely provide the full range of ecosystem services and benefits. Nevertheless, restoration provides demonstrable biodiversity benefits in areas of significant degradation.
- The cost-effectiveness of restoration areas, particularly more expensive active restoration, is not always proven and is to a large degree dependent on long-term estimates of pay-back, the veracity of which is often difficult to prove. The development of indicators and monitoring programmes is therefore particularly necessary for restoration projects.
- Less information is available on sustainable use/ecosystem service zones, particularly on the benefits provided by certain schemes; nonetheless there is good potential to provide a wide range of environmental goals at a large scale. These areas essential to complement and buffer the benefits provided by core areas.
- Large benefits are expected in green urban areas, partly due to the high concentration of people to benefit from access to them. Aside from direct use and property value, it is expected that health benefits are the most valuable service provided. These features nonetheless have a high cost-benefit ratio even without considering direct use and property values.
- The on-going management of natural connectivity features (such as unfarmed features within agricultural landscapes) from an important part of the EU's green infrastructure (through providing habitat refuges and functional connectivity) and can be maintained at relatively low costs.
- However, the higher costs associated with the creation of these features, and uncertain ecosystem service returns, makes these a less cost-effective investment option, with a low or negative cost-benefit expected. Large-scale corridor initiatives are more likely to have a balanced cost-benefit if investments are also made in recreational use to ensure high direct use values.
- Given the low ecosystem service output, disputed biodiversity benefits and relatively high costs of artificial connectivity features, the cost-effectiveness of these schemes is likely to be low compared to other green infrastructure elements. Greatest potential for cost saving is through road collision prevention due to the high costs involved, but their collision reduction rate remains uncertain.

- It is evident that while biodiversity is often a necessary condition for supporting the provision of ecosystem services, the optimisation of the biodiversity will often produce lower services than alternative land management options.
- The value of all elements increases with greater accessibility of green infrastructure resources to the public. Direct use and cultural values are very significant and should be augmented in order to increase cost-effectiveness.
- Ultimately the cost-effectiveness of these elements will depend on the relative cost of alternative scenarios to achieve certain services. Integrated approaches will likely lead to more cost-effective investments.
- As many of the benefits are public goods and will only be realised over the long-term, public investment is likely to be needed in many circumstances.

7 THE FOUR DIFFERENT OPTIONS FOR A FUTURE GREEN INFRASTRUCTURE STRATEGY

This chapter's aim is to describe the EU level instruments and measures that would be expected to contribute to the implementation of each of the four policy options for a future Green Infrastructure Strategy and present information which would supports estimating their likely costs and impacts where the evidence is was not already included in previous chapters in this report. While Section 7.1 is a brief introduction to the four options, Section 7.2 provides a higher level of detail, especially with regard to the different changes included under each one of the options and some insights into their possible impacts which are of relevance for the assessment of the different options presented in Chapter 8.

One important point to highlight is that the changes foreseen under each one of the policy options are not mutually exclusive. This implies that as a general rule, measures taken under option 2 (eg increase in funding or providing technical assistance and guidance) are automatically and implicitly included among the measures taken under option 3, and those under options 2 and 3 also integrated within 4. Thus, the options are incremental and additive (ie option 2 = 1+2; option 3 = 1+2+3; option 4 = 1+2+3+4).

7.1 A brief introduction to the different options for a future Green Infratucture Strategy

7.1.1 Option 1: Business as usual

Rationale

No additional measures to promote green infrastructure are taken at EU level. In the absence of an agreement on a comprehensive approach to implementing target 2 of the EU 2020 Biodiversity Strategy, its implementation primarily relies on MS's own initiative. The differences in interpretation of green infrastructure across EU MS are thought to reflect different national circumstances and priorities resulting in green infrastructure being used in different ways at national and local levels. Consideration of green infrastructure at EU level continues to be comprehensive only in a limited number of areas, such as Natura 2000, but does result in some funding of green infrastructure through structural funds, the Cohesion Fund, LIFE+ and EAFRD, both for projects which clearly refer to green infrastructure and some which do not. In most MS, NGOs continue to be involved in implementing green infrastructure.

Governance and implementation

'Business as usual' is a scenario of no additional action – there is no policy change at EU level. Thus, in this baseline scenario the assumption will be that the existing Community framework (including the new Biodiversity Strategy) is the primary trigger for green infrastructure policy initiatives at a Member State level, as is currently the case. This option acknowledges that even without a green infrastructure Strategy, there is already action to identify, raise awareness of the benefits of, protect and/or enhance some types of green infrastructure elements both at EU level and, independently from specific EU action, at MS, regional and local level. The primary difference with other scenarios is that EU and MS activity, while supporting green infrastructure, do not necessarily do so in a coordinated way or by labelling it green infrastructure. In this scenario, therefore, the primary assumption is good implementation of the current EU framework and a pretty stable level/rate of green infrastructure development and implementation at MS level.

7.1.2 Option 2: Maximising the use of existing approaches: MS voluntary measures with EU support

Rationale

Option 2 should help realise the full potential of green infrastructure under current legal instruments and programmes – at least in a core set of Member States and/or regions. A group of countries particularly progressive as regard green infrastructure implementation would drive the process on a voluntary basis supported by EU coordination, inter alia, via guidance and facilitation. There will therefore be increased engagement in green infrastructure across most EU Member States, though still with leaders and laggards and different levels of investment and benefits. Hence, this option combines different non-legally binding measures, which should make its implementation within a rather short time-frame rather easy, to the extent that there is political and decision makers' will for new action.

This approach will supported by the initiation of a coordination process under the Open Method of Coordination (OMC), a voluntary political process offering a framework within which specific EU MS policies may be coordinated with EU support. The overall objective pursued would be an increased collaboration, coordination and assistance for the achievement of better green infrastructure outcomes in various policy areas. The benefits and information-sharing activities within the framework of the OMC would go beyond the MS participating in it and would particularly benefit other initiatives foreseen under this option such as the development of an EU spatial planning toolkit for a better integration of green infrastructure in spatial and regional planning, sector specific guidance (including best practice) on green infrastructure integration/implementation and the setting up of an Information Gateway for European green infrastructure information (on the model or linked with WISE/BISE).

This option relies on strategic objectives which would be reflected in the EU Green Infrastructure Strategy, which would call for an up-scaling of funding for green infrastructure within existing funding instruments. The strategy would highlight the green infrastructure measures (eg type of investments, associated required technical assistance, governance instruments, etc) that have a potential to achieve and/or facilitate meeting some of the objectives pursued across a wider range of EU policy areas (Water policy, Cohesion Policy, Climate policy, biodiversity policy, etc) or multiple objectives simultaneously (eg climate change adaptation and mitigation, biodiversity and water protection), clearly identifying related financing opportunities under existing EU funding instruments. One would expect an increased call from Member States to make use of existing funds for green infrastructure, pending awareness of the benefits, opportunities and within limits of existing programme priorities and rules.

Governance and implementation

Overview of changes - Option 2
2a) OMC is used at EU level
2b) Wider EU support for investments in green infrastructure
2 c) Awareness raising/ tailored guidance & technical assistance/ capacity building
2 d) Research supporting green infrastructure implementation
2 e) EU green infrastructure integration toolkit for spatial and regional planners
2 f) Creation of a Gateway for European green infrastructure information (modelled on WISE/BISE)

2 g) Non-legislative strategic EU level instruments

- *Review of the Thematic Strategy on the Urban Environment*
- *Review of the Environment and Health Action Plan*
- *Strategy on Forest Protection and information (new)*

Member States set their own levels of ambition on targets and to select the measures which they consider most appropriate and most cost-effective. One central pillar of this option would be a more efficient use of existing EU funding for encouraging the integration and implementation of the green infrastructure approach. Potential sources for increased and more effective funding for green infrastructure projects include:

- Cohesion Policy (through the ERDF, ESF and the Cohesion Fund) but also including technical assistance instruments, such as JASPERS, and financial engineering, such as JESSICA, for green infrastructure
- LIFE+ - in particular demonstration and integrated projects
- EAFRD
- Horizon 2020 - Framework Programme for Research and Innovation.

Another crucial component of option 2 is increased EU support for voluntary MS-led green infrastructure action by providing EU toolkits, guidance, advice and capacity building/technical assistance. The EU would also develop more research activities on green infrastructure and its benefits, and a consistent communication Strategy to ensure all potentially relevant stakeholders understand the multiple dimensions of the green infrastructure concept. Cross-cutting actions aim to address multiple sectors rather than making targeted changes to specific policy areas, bringing benefits both to individual policy areas and green infrastructure more generally.

Such support mechanisms for voluntary green infrastructure measures should ensure both and appropriate distribution and use of EU green infrastructure funds as well as an optimization of green infrastructure's functioning. Assistance from the EU within this option would appear in several forms, but would generally enhance the exchange of information and best practices at an EU level by offering guidance to support green infrastructure and ecosystem-based solutions across different policy areas. The guidance should mainly encourage MS to adopt more elaborate strategies for using and supporting their green infrastructure in smart ways whenever there are opportunities.

EU funded research projects gather extensive evidence on green infrastructure policy initiatives and projects, demonstrating the effectiveness of green infrastructure in contributing to meeting important policy objectives. This provides the basis for an awareness-raising campaign which would be initiated to accompany the distribution of relevant materials and aims to make policy makers, as well as the public at large, more aware of the demonstrated benefits of an integrated green infrastructure as well as specific green infrastructure elements. Additional guidance to relevant stakeholders would be provided for the delivery of green infrastructure (encompassing creation, restoration and protection). Expertise and advice would also be provided on optimal ways to utilise spatial and regional planning to protect and enhance green infrastructure at local, regional and national levels - a toolkit for spatial planning would be developed and made available.

Supporting activities from the EU would further include improved guidance on Environmental Impact Assessments (EIA) and Strategic Environmental Assessments (SEA) for better integration of biodiversity and green infrastructure concerns into plans and programmes, including expenditure programmes for regional and rural development. In other policy fields, communications could be revised by referring clearly to the specific role green infrastructure can have in fulfilling objectives, particularly promoting ecosystem based solutions.

Finally, with support from the EEA, the JRC and other relevant institutions, preliminary EU-wide green infrastructure maps and databases showing selected green infrastructure elements that have been identified as contributing to important EU objectives (eg water, climate change mitigation, provision of additional ecosystem services) would be provided and the use and consideration of those maps in strategic planning by MS would be strongly encouraged.

7.1.3 Option 3: Full integration of green infrastructure into EU policies: amending existing legislation

Rationale

In addition to the measure foreseen in option 2, option 3, with integration of green infrastructure into community policies at its core, would involve wider integration, by means of amendments to financial and legal instruments. The new Green Infrastructure Strategy would call for all MS to adopt national Green Infrastructure Strategies broadly based on the EU Strategy but adapted to national circumstances and priorities (ie vulnerability to CC, water scarcity, etc). The national strategies could for example identify in which Action Plans they might need to be integrated for an effective implementation. The EU Strategy explicitly addresses all objectives in other policy areas which can be supported through green infrastructure, eg the future EU Adaptation Strategy, and announces a range of changes to integrate green infrastructure across a wider range of EU policies as well as identifying funding instruments (eg technical assistance) to support MS in implementation the new commitments. Indeed, the conditions attached to receiving funds include adequate consideration/mitigation of impacts on green infrastructure and better reporting of project outcomes with regard to their impacts, in particular with regard to enhanced provision of ecosystem services and improved biodiversity status, to ensure these can be adequately weighted and rewarded.

Furthermore, the Strategy would outline the policies which need to be revised/ amended in view of achieving a more consistent and coherent approach to preserving and enhancing Europe's green infrastructure. Option 3 involves developments in EU policies both to enhance green infrastructure provision as a result of a better recognition of green infrastructure as a tool for meeting a wider range of policy objectives, and to reduce adverse impacts of some EU policies and instruments on green infrastructure. Policies affected would include: the Common Agricultural Policy (eg through adapting existing agri-environment instruments for this purpose), Cohesion Policy (eg clarified scope for Green Infrastructure financing under the next Cohesion Policy Programming period (2014-2020), Common Fisheries Policy, and the Transport and Energy infrastructure policies (in particular the trans-European transport and energy network - TEN-T and TEN-E - and the proposed by the Commission new Connecting Europe Facility) of the European Union. The use of some innovative financial instruments to support green infrastructure projects will be promoted, especially in support of climate change policy, where the potential of green infrastructure in mitigation and adaptation is more fully recognised. In addition, the need to implement green infrastructure would be reflected in the on-going revision of the EIA Directive and the 2016 revision of the SEA Directive (as it appears unlikely that there will be a revision before for the latter). Standards for the definition of green infrastructure elements are developed and MS are required regularly report on them under the Regulation on environmental economic accounts. EEA and/or JRC, together with other relevant organisation uses this information to produce harmonised green infrastructure maps whose use is strongly encouraged both by EU institutions and MS. At EU level, for example, EU policies and/or funding instruments take this mapping into account and, combined with biodiversity and climate proofing, this allows a more optimal/efficient allocation of funds.

Governance and implementation

Overview of changes - Option 3

3 a) Revised Regulation on Environmental Economic Accounts

3 b) Development of EU-wide 100x100 meter maps of Green Infrastructure (eg by EEA and/or JRC)

3 c) Green infrastructure is made a priority in the Common Strategic Framework and Regulations governing key EU funding instruments (Cohesion Policy, CAP, LIFE)

3 d) Biodiversity and climate proofing is streamlined into key EU funding instruments (eg Cohesion Policy, TEN guidelines and Connecting Europe Facility, CAP, etc.)

3 e) Revised EIA/SEA Directives

3 f) Range of sector specific changes to the current legal framework:

- *Biodiversity*
- *Water*
- *Marine*

While some common objectives, principles and non-binding targets relating to green infrastructure are set in the Strategy and a whole range of measures, as far as they relate to areas in which the EU has a competence, are harmonised through strategic amendments to key EU legislation. EU MS are invited to take additional measures in view of meeting more specific targets, but are left with the definition of the targets, the choices as regards the the policy-mix and the emphasis.

Revised regulation on environmental economic accounts introduces a mandatory requirement to report on green infrastructure stocks and their overall quality (ie habitat fragmentation). The information provided by MS is consistent with the clear/scientific definition of the components of green infrastructure (which the EEA/JRC, together with other relevant actors could produce) and serve as a basis for the EEA to update green infrastructure maps. Ultimately the objective is to establish a full requirement for MS and regions to map green infrastructure and develop natural capital accounts noting assets, quality/quantity, functions and flows of services in view of integrating ecosystemns and their services in policy development and assessment frameworks at the multiple levels of governance.

The EEA, supported by the JRC and other relevant actors would be requested to come up with a clear/scientific definition of the different components of green infrastructure (ie the “green infrastructure elements”) and to develop EU-wide, below NUTS-2 level maps of Europe’s green infrastructure and to make these available to all regions and MS authorities so they can be used when submitting their applications for funding, as would be required by the 2014-2020 Regulations on EU Cohesion Policy. Indeed, as part of the biodiversity and climate proofing, the EU would require applicants to use these maps for infrastructure development projects to demonstrate that the option chosen is the one which results in least harm to green infrastructure and minimises losses of ecosystem services.

The Common Strategic Framework and the new legislative packages governing 2014-2020 EU funding instruments (CAP, Cohesion Policy, etc) make 'green infrastructure' a priority; green infrastructure stocks/assets and their quality are information to be included in the SWOT analysis, ex-ante evaluations and description of environmental baseline in regional and rural development programmes. The new Regulations on EU Cohesion Policy also:

- Give ecosystem based solutions (green infrastructure projects) priority over alternatives
- Commit to supporting green infrastructure for flood risk management and climate change mitigation and adaptation.

In parallel to this, biodiversity and climate proofing is streamlined into key funding instruments with potential impacts on green infrastructure so that funding fully takes into account the conservation of ecosystems, natural resources and biological diversity, and explicitly addresses climate and freshwater security in plans, programmes, policies and sectoral and regional priorities. An additional new element would require regions and MS submitting applications for projects and programmes to be funded through the Connecting Europe Facility and Cohesion Policy to map their green infrastructure elements and to outline the impacts of their proposed programme on the green infrastructure network and ecological coherence.

Specific requirements to consider the wider green infrastructure in the revised EIA/SEA Directives widen their scope to include consideration of the potential impacts of projects and programmes on green infrastructure and to foresee opportunities for better avoidance and mitigation of impacts on green infrastructure, in particular where resilience, connectivity and ecological coherence are at risk of being undermined.

7.1.4 Option 4: Comprehensive, dedicated EU legal instrument

Rationale

This option would involve the Green Infrastructure Strategy calling for a comprehensive, dedicated EU legal instrument to develop the EU's Green Infrastructure, and setting out the key features of such an instrument. The difference between Option 4 and Option 3 is that Option 4 involves a new *Framework Directive for the Conservation and Restoration of Europe's Green Infrastructure* which establishes new objectives, binding targets and dedicated funding instruments, rather than simply promoting it by amending existing policies and relying on existing funding instruments. To support investments in green infrastructure and help Member States comply with new legislative and regulatory requirements, a new Green Infrastructure Investment fund ('TEN-G') would be set up alongside other funding instruments, to specifically provide funding to co-ordinated projects of European value which contribute to meeting objectives from across several policy areas.

This option would also involve the same measures to integrate green infrastructure into existing EU policy instruments as defined in Option 3.

The introduction of cross-cutting legislation would specify an overarching framework within which this process of integration would be co-ordinated. In particular, Option 4 would go beyond Options 2 and 3 in introducing new EU tools and instruments which require, and support, green infrastructure provision and require Member States to identify, map, protect, restore, enhance and/or monitor green infrastructure. Also, rather than using the OMC, a permanent expert group containing representative of all MS is set up and meets on a regular basis. Option 4 is a particularly comprehensive approach to the protection, enhancement, development/creation and better use of green infrastructure at the EU level. It gives green infrastructure substantial weight and profile and signals EU's intention to take decisive and wide-ranging action, through the setting of ambitious targets and reference to clear principles such as no net loss.

Governance and implementation

Overview of changes - Option 4

4 a) Binding "Green Infrastructure Implementation and Restoration Directive" implementing no net loss/net positive gains principles, and setting a framework for action by Member States
4 b) EU TEN-G fund is set up
4 c) Establishment of an EU-wide green infrastructure offset scheme designed to implement the principle of no net loss[29]
4 d) European Payment for ecosystem services system (EPES) established
4 e) Permanent expert group of which all MS are part

Specific legislation offers the opportunity for a comprehensive approach to green infrastructure, which goes beyond the integration of green infrastructure considerations into existing policies and initiatives. It may result in Member States having to adopt new legislation to support the principles, objectives and targets outlined in the Framework Directive and ensure that all relevant scales of governance integrate the principles in their decision-making and take the measures necessary for meeting targets and objectives. It therefore offers the potential to make the greatest change to green infrastructure provision at the EU level, and to achieve the greatest consistency of approach between Member States. At the same time, by requiring action at the MS level, it could impose the greatest costs and burdens upon Member States in the short term, even where there are net societal benefits in the long-term.

New legislation on green infrastructure at EU level could include some or all of the following elements:

- Establishing an EU wide definition of green infrastructure;
- Outlining key principles, objectives, targets and indicators (eg no net loss principle, binding 15 per cent restoration target, targets for slowing down fragmentation of key green infrastructure, good ecological status etc);

---

[29] as a means to off-setting for green infrastructure elements deteriorated/destroyed when creating grey infrastructure (Habitat banking should only be considered in those cases where primary remediation is not feasible or all on-site compensation options have already been explored within impact regulation procedures). See for example eftec, IEEP et. al (2010) *The use of market-based instruments for biodiversity protection – The case of habitat banking* – Summary Report. URL: http://ec.europa.eu/environment/enveco/index.htm

- Requiring Member States to develop their own Green Infrastructure Strategies and establish their own targets for green infrastructure development and/or maintenance as part of MS strategies, as well as mechanisms to map, measure and monitor green infrastructure and the ecosystem services it delivers, and to protect it through spatial planning policies;
- Establishing a requirement for MS and the Commission to monitor and report on trends in green infrastructure on a regular basis, including through the establishment of green infrastructure accounts;
- Establishing a commitment for the EU to integrate the protection and development of green infrastructure into all relevant policy areas, including agriculture, climate, cohesion, energy, transport, EIA/SEA and water policies, as well as recognising its contribution to key EU strategies (eg 2020 strategy);
- Establishing a commitment for the EU to co-fund green infrastructure development, through integration in existing instruments (eg LIFE+, cohesion and rural development policies) and/or through establishment of a dedicated financial instrument to promote green infrastructure (TEN-G);
- Establishing a European Payment for Ecosystem Services (EPES), either as part of the rural development programme or as a separate initiative;
- Requiring the EU and/or MS to introduce awareness raising, advisory and capacity building measures to support the above.

7.2 Detailed presentation of Options 1, 2, 3 and 4

In this section, the four policy options for an EU level Green Infrastructure Strategy are presented in more in detail. This includes a clear identification of the changes that have been included under each one of the options. Under each one of the scenarios both cross-cutting initiatives at EU level as well as more policy area specific changes were included. A description of each one of the changes is provided, followed by insights into the economic, social and environmental impacts associated with the change, based on the evidence presented in previous chapters and a range of other DG ENV studies relating to green infrastructure and the wider literature.

7.2.1 Option 1: Business as usual

The outcome of the assessment of existing EU policies and instrument relevant to green infrastructure, together with the overview of cross-cutting issues (drawing on country files and in-depth case studies) provided both the policy reference point (what we have now) and some indications as to the policy baseline.

Community legislation and policies

This section provides an overview of key EU level policies and instruments within policy areas relevant for green infrastructure which could play a role in ensuring the effective implementation of a future Green Infrastructure Strategy. These policies have been assessed through a SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis to clarify how each one of the policies relates to green infrastructure, whether this relationship is acknowledged and responded to in the current legislation/ instrument and how its contribution to green infrastructure protection/management/restoration or creation could be improved.

Final list of relevant policy areas, and policies and instruments to undergo SWOT analysis

Based on suggestions from the Commission and the policy area expertise of the project team, a list has been compiled of all of the EU specific tools and instruments whose potential role with regard to green infrastructure is to be scrutinised. Table 7.1 below summarises existing EU tools and instruments considered potentially relevant for measures to support Europe's green infrastructure. A SWOT analysis to identify current implications of those policies for green infrastructure was carried out for all of these policies and instruments in view of collecting the necessary elements for option 1 (reference scenario) and identifying tools and instruments in those different policy areas which could support in one way or another the objectives relating to green infrastructure.

Table 7.1: Policy areas and associated EU policies & instruments to be considered for EU action on green infrastructure

Policy area	EU policies & Instruments to be considered
Agricultural Policy	• CAP Pillar 1 – Cross-compliance (Reg 73/2009) • CAP Pillar 1 - CAP 2020 Communication • CAP Pillar 2 - EAFRD Funding (Reg 1698/2005) • CAP Pillar 2 - Training, advice, extension services, planning provisions – Farm Advisory System
Forestry Policy	• EU Forestry Action Plan • Green Paper on Forest Protection and Information

Biodiversity & Nature	• EU 2020 Biodiversity Strategy • Birds Directives • Habitats Directive • LIFE+ Regulation
Water Policy	• Water Framework Directive/ River Basin Management Plans • Floods Directive • EU Drought Policy (Communication on Water Scarcity and Droughts) • Future EU Water Blueprint
Soil Policy	• Thematic Strategy for Soil Protection, (COM(2006)231 final) • Proposal for a Directive establishing a framework for the protection of soil, COM(2006) 232 final
Climate Change Policy	• White Paper on adaptation • 2050 Low Carbon Roadmap
Territorial Cohesion and innovative financing	• Regional Policy (Cohesion Policy) • Technical assistance and innovative financing (Jaspers, Jessica etc.). • EU Strategies for the Danube Region/ EU Strategy for the Baltic Sea Region
EU 2020 & Resource Efficiency Flagship	• EU 2020 Strategy • Resource Efficiency Flagship under EU 2020
Transport & Energy	• TEN-T • EU White paper on transport IA • TEN-E • Energy Policy • Connecting Europe Facility
Impact Assessment, Damage prevention and remediation	• EIA Directives • SEA Directive • Environmental Liability Directive
Spatial Planning	• European Spatial Development Perspective • ESPON 2013 Programme • Territorial Agenda of the EU 2020 • Urban Strategy
Marine and Coastal zones Policy	• Marine Strategy Framework Directive • EU Maritime Spatial Planning Communication • 2002 Recommendation on Integrated Coastal Zone Management (ICZM) • Fisheries Policy/ EFF
Environment & Health	• Environment and Health Action Plan 2004-2010
Other	• Research Policy/ Horizon 2020, Framework programme for research and innovation • EC external development cooperation

The above EU policies and instruments relevant for green infrastructure were systematically assessed through a SWOT analysis (Strengths, Weaknesses, Opportunities, Threats), which has contributed to: (1) clarifying how each of the policies and instruments relates to green infrastructure (channel of support to green infrastructure and/or source of threats), (2) establishing the extent to which this relationship is currently acknowledged and responded to, (3) providing a basis for estimating the benefits from green infrastructure which accrue under the current policy framework to establish the reference point against which the other options will be compared, (4) identifying how the contribution of those policies and instruments to conserving or enhancing green infrastructure could be further maximised. In addition, the tools and instruments which exist in each one of the policy areas were identified to ensure that changes proposed under the policy options 2-4 build on existing tools and instruments where those exist. The full audit of all policy instruments and the existing tools and instruments tables can be found in Annex V. Below, short insights of the current relationship between the EU policies and instruments and green infrastructure are provided for each one of the policy areas listed above.

Agricultural Policy

Regulation 73/2009 (relating to the CAP Pillar 1 direct payments, including cross-compliance) identifies certain articles from the Habitats Directives, potentially relevant for maintaining ecological coherence at farm level and green infrastructure, as part of the Statutory management requirements (SMRs) within cross-compliance. Under the other part of cross-compliance, Good Agricultural and Environmental Condition (GAEC), there are several standards that make an indirect contribution to maintaining green infrastructure. Of particular relevance are three standards for ensuring a minimum level of maintenance and avoiding the deterioration of habitat, a standard for the protection of permanent pasture, and a standard for the maintenance of terraces (the primary goal of which is to counter soil erosion). In addition, the quantitative requirement for maintaining the share of permanent pasture at Member State level is relevant to green infrastructure as well. Green infrastructure is not explicitly addressed in the new CAP 2020 Communication (Pillar 1). However, the Communication proposes enhancement of environmental performance of the CAP through a mandatory "greening" component introduced to direct payments in Pillar 1. This would involve simple, generalised, non-contractual and annual environmental actions that go beyond cross-compliance and are linked to agriculture (eg permanent pasture, green cover, crop rotation and ecological set-aside). In addition, the possibilities of including the requirements of current NATURA 2000 areas, and of enhancing certain elements of GAEC standards, have been proposed.

Through the **EAFRD funding**, an indirect but very important contribution to green infrastructure is being made through the agri-environmental measure, the only compulsory RD measure. The agro-forestry measure (particularly the actions involving traditional pastoral woodland management), well-designed and implemented afforestation actions, actions for the restoration of forestry potential and the forest-environment measure also have a potential to contribute to green infrastructure. The measure focusing on rural heritage under the objective of improving the quality of life in rural areas additionally allows for green infrastructure-friendly actions to restore habitats, such as wetlands, and to finance Natura 2000 management plans. The **CAP Pillar 2** training and advisory measures, and the Farm Advisory System under the CAP Pillar 1, do not address green infrastructure directly in the measures relating to training, advice, and extension services. However, indirectly, it can be addressed through information relating to sustainable land management and to cross-compliance. Certain measures under Pillar 2 enable support for development of Natura 2000 management plans with indirect benefits for green infrastructure.

Forestry

While green infrastructure is not explicitly addressed in the **EU Forest Action Plan (FAP)**, benefits provided by green infrastructure and features associated with green infrastructure (eg restoration, afforestation, connectivity, urban forests etc) are discussed. The FAP outlines the potential for more widely implemented sustainable forest management (SFM), including actions that may optimize forest biodiversity, carbon sequestration, integrity, health and resilience. It also allows for habitat restoration and afforestation as well as the reduction of forest fragmentation. The potential role of urban and peri-urban forests is also highlighted. In the Green Paper on Forest protection and information in the EU, green infrastructure is indirectly addressed in terms of the socio-economic and ecological benefits provided by maintaining healthy forests (protecting settlements and infrastructure, providing ecosystem services and regulating climate) and the need for increased EU forest protection. The Green Paper also highlights the potential of enhancing the protection of EU forests and safeguarding their multi-functionality via SFM. The potential of the Rural Development Regulation (2007-2013) to co-finance afforestation, payments for Natura 2000 areas, restoration and other forest environmental measures is also mentioned.

Biodiversity & Nature Conservation

The **EU Biodiversity Strategy** aims to support the EU 2020 biodiversity target of ensuring that 'by 2020, ecosystems and their services are maintained and enhanced by establishing green infrastructure and restoring at least 15% of degraded ecosystems', and its 2050 vision that 'By 2050, European Union biodiversity and the ecosystem services it provides — its natural capital — are protected, valued and appropriately restored for biodiversity's intrinsic value and for their essential contribution to human wellbeing and economic prosperity, and so that catastrophic changes caused by the loss of biodiversity are avoided.

It includes six mutually supportive and inter-dependent targets, and packages of supporting actions, that aim to halt biodiversity loss and the degradation of ecosystem services. Of these Action 6b to support Target 2 (the maintenance and restoration of ecosystem services) explicitly calls for the development by the Commission of 'a Green Infrastructure Strategy by 2012 to promote the deployment of green infrastructure in the EU in urban and rural areas, including through incentives to encourage up-front investments in green infrastructure projects and the maintenance of ecosystem services, for example through better targeted use of EU funding streams and Public Private Partnerships.' The potential benefits of this Strategy are the focus of this study.

However, it's important to note that, if implemented, most actions in the Biodiversity Strategy would provide green infrastructure benefits, in particular those relating to the improved implementation of the Birds and Habitats Directives (see below), increasing ecosystem restoration, developing systems for ensuring no net loss of biodiversity and ecosystem services, and enhancing the positive contribution of agriculture and forestry to biodiversity conservation.

The **Habitats Directive** does not refer to green infrastructure directly, but has the intention under Article 3(1) of forming 'a coherent ecological network' referred to as the Natura 2000 network, which forms the cornerstone of the nature legislation in the EU. The term 'coherence' 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 network with numerous functional links amongst sites, which relates to the green infrastructure concept. Furthermore, Article 3(3) states that 'where they consider it necessary, Member States shall 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, as referred to in Article 10'. Article 10 states that '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'.

The **Birds Directive** does not refer to green infrastructure directly, but Article 2 requires MS to take the requisite measures to maintain the population of wild birds at a level which corresponds to ecological, scientific and cultural requirements, whilst taking account of economic and recreational requirements, or, to adapt the population of these species to that level. Thus, it is necessary to take measures to ensure the coherence and connectivity of sites, such as through green infrastructure initiatives, where this is necessary to achieve the aims of the Directive. In addition, Article 3 indicates that measures need to be taken both within and outside protected areas, and the enhancement of the movement and existence of species outside the sites designated for their protection is also supported by Articles 4.3 and 4.4. Furthermore, it should be remembered that Special Protection Areas designated under the Birds Directive form part of the Natura 2000 network (under Article 7 of the Habitats directive). Therefore, the coherence of the SPA network is also promoted through the measures in the Habitats Directive.

The current financing instrument for the environment, **Life+ 2007-2013**, has not specifically addressed the development of EU green infrastructure, but besides contributing to co-financing the implementation of Natura 2000, several projects under the LIFE+ strands of nature and biodiversity and environmental policy & governance provide examples on actions which support certain green infrastructure features/elements. This in particular includes projects to enhance the connectivity of species and habitats (eg corridors, stopover areas for migrating birds), strengthening the resilience of ecosystems (eg management measures to safeguard provision of ecosystem services, restoration of wetlands, climate change adaptation), and integrated spatial planning (eg stakeholder cooperation, more sustainable use of urban land).

Water Policy

The **Water Framework Directive** does not address green infrastructure directly. It does however aim to prevent further deterioration of water quality, to protect and enhance of the status of aquatic ecosystems and related wetlands and terrestrial ecosystems to ensure sustainable water use by protecting available water resources, to progressively reduce the pollution of groundwater, to prevent further pollution, to mitigate the effects of floods and droughts. It recommends the restoration of wetlands as possible supplementary measures to achieve the objectives. The opportunities for the involvement of stakeholders affected by the creation and management of river basin management plans (eg broader public, experts, landownders, may offer opportunities for green infrastructure identification and implementation in the area of water. The **Floods Directive** does not directly address green infrastructure. However, the Directive aims to reduce and manage the risks that floods pose to the environment as well as human health, cultural heritage and economic activity, and the flood risk management plans "shall take into account areas which have a potential to retain flood water". Green infrastructure is not directly addressed in the **2007 Communication on Water Scarcity and Droughts** in the EU which outlines the strategy for improving water scarcity drought risk management. However, the 2011 follow-up report mentions an upcoming Commission Communication that will address the multiple benefits of green infrastructure including its role in water retention and mitigation of the effects of extreme events, which will help develop current water retention measures. The **Blueprint to Safeguard Europe's Water** is a Commission Communication expected in November 2012, which will focus on improving implementation of current EU water policy, promoting integration of EU water policy and other policies, and suggesting policy options for completion of current policy. The Blueprint (in addition to other horizontal issues) will focus on measures for managing water demand, improving clean water availability and protecting water ecosystems. In this concept land use management and natural water retention measures will be assessed following an Ecosystem approach. The focus on land management represents a huge potential for green infrastructure as the main tool will involve measures such as reforestation, floodplains restoration, soil management, and sustainable urban drainage systems. Policy instruments /options that can enable these measures such as the development of methodological framework for the wider application of payments for ecosystem services, and the integration into territorial management instruments (ie CAP) will be identified and assessed.

Soil policy

The **2006 Thematic Strategy for Soil Protection** does not explicitly address green infrastructure approaches or ecosystem based approaches to address the challenges and threats to soil that it identifies. The contribution of different green infrastructure elements (or green infrastructure approaches/ ecosystem based approaches) to addressing some of the threats (eg soil degradation, erosion, fertility loss, loss of soil organic matter, salination, compaction etc) goes unrecognised. Arguably one exception is the reference made to what could be considered sustainable use zones (ie "integrated farming or extensive agricultural practices") and their beneficial effects on soils and their functions. Overall, the Thematic Strategy fails to identify the potential for green infrastructure to have a whole range of positive effects on soil and to recognise that green infrastructure might be a key approach to solving a wider range of the problems identified. This is also reflected in the research Agenda only to a very limited extent. The **proposal for a Soil Framework Directive** also does not make reference to green infrastructure, whether directly or indirectly (although the explanatory memorandum identifies inappropriate agricultural and forestry practices as leading to environmental pressures on soil). While the proposed Directive clearly identifies the functions provided by soils in its article 1, it does not acknowledge the interactions between soil (functions) and the green infrastructure and therefore the role of green infrastructure (or ecosystem based approaches) in helping address some of the threats to soils. This is arguably also the case because the Directive focuses on the identification of soil/areas at risk and avoids being prescriptive with regard to the measures that MS may have to take.

Climate Change Policy

The **White Paper on adaptation** addresses green infrastructure by providing a definition and stressing its crucial role in adaptation. The document, however, does not forecast concrete actions to support or protect green infrastructure. As a White Paper, it contains only proposals for European Union action in adaptation area, setting out an EU's Adaptation Framework intended to reduce the EU's vulnerability to the impact of climate change and improve the EU's resilience to deal with the impact of climate change. The framework is designed to evolve as further evidence becomes available. It intends, in the first phase 2009-2012, to lay the ground work for preparing a comprehensive EU Adaptation Strategy which is projected to be implemented during the second phase, starting in 2013. On this basis, it is difficult to assess how green infrastructure will be addressed in the future EU Adaptation Strategy.

Territorial Cohesion and innovative financing

Under **Cohesion policy** there are a growing number of ERDF projects which are financing green infrastructure, although they are only now beginning to be explicitly recognised as such. These projects aim to allow species to move and adjust, but they also restore ecosystem services. Many Operational Programmes provide co-financing for the management of Natura 2000 sites and implementation of measures that support ecological coherence and connectivity in the context of regional development. These measures are often funded under the budget for promotion of biodiversity and nature protection. The potential to integrate green infrastructure into Cohesion Policy lies in the growing recognition that investment in nature can lead to regional economic growth, employment and social benefits. The **EU Strategy for the Danube Regions** points to the role of regional cooperation in facilitating green infrastructure/ecosystem based solutions to risk management. The role of the Danube Region as a major ecological corridor is acknowledged and the need for a regional approach to nature conservation, spatial planning and water management is stressed, thus opening up opportunities for the use of green infrastructure. The **EU Strategy for the Baltic Sea Region** identifies the 'relatively unspoilt land environment rich in natural resources' as one the region's potential. Although the Strategy calls for a macro-regional approach to combat the Baltic Sea's deterioration, Green Infrastructure is not mentioned explicitly and the possibility for ecosystem-based solutions to be part of the solution is only acknowledged to a very limited extent.

Europe 2020 Strategy and Resource Efficiency Flagship initiative

Although the **Europe 2020 Strategy** provides the blueprint for EU's move towards 'smart, sustainable and inclusive' economic growth, the EU2020 Strategy does not directly address green infrastructure. However, it does at one point recognise that a resource efficient and climate resilient economy is necessary to protect the EU's natural capital and for biodiversity targets to be achieved. The clearest potential for green infrastructure lies in the resource efficiency flagship initiative (discussed in more detail below) and through green infrastructure's potential role in addressing climate change. The **Resource Efficiency Flagship Initiative** addresses green infrastructure to the extent that it aims to reduce the use and consumption of resources, where resources include not just raw materials, but also 'soil, water, air, biomass and ecosystems'. However, the Strategy focuses mostly on the extent to which resource efficiency could deliver climate change targets, and how reduced emissions would contribute to protecting valuable ecological assets. The Strategy therefore considers green infrastructure mostly in a reactive, rather than proactive, way. However, the associated 'Roadmap for moving to competitive low carbon economy in 2050', which sits under the Resource Efficiency Flagship Initiative, is slightly more explicit. It does, at one point, specifically mention that targeted measures within agriculture and forestry, such as the maintenance of grasslands and the restoration of wetlands and peat lands, can be used to preserve and sequester carbon.

Transport & Energy Policy

The **Impact Assessment of the 2011 EU Transport White Paper** defines green infrastructure as 'infrastructure designed in a way to minimise environmental impact'. This definition is incorrect and indicates that European transport policy does not adequately consider green infrastructure. However, the Impact Assessment does recognise the potential for transport infrastructure to increase ecosystem and habitat fragmentation: 'transport infrastructure, along with energy infrastructure, and land use changes such as uptake by urban sprawl and agricultural intensification contributes to the fragmentation of ecosystems'. It also identifies potential impacts of the White Paper relevant to green infrastructure: 'The greatest impact on other environmental resources would be caused by an increase in land use for infrastructure, generating increased pressure on biodiversity and ecosystem services due to direct damage linked to construction, habitat fragmentation and degradation and disturbance'. In addition to potential impacts, the Impact Assessment proposes that habitat fragmentation should be monitored to show the state of fragmentation of land and ecosystems due to transport infrastructure. The Impact Assessment suggests that the indicator should be calculated on the basis of the mesh size of un-fragmented areas, related to the construction of new or improved transport infrastructure.

Green infrastructure is not directly addressed by **TEN-E**. TEN-T's main purpose is the improvement of the functioning and the interconnectedness of European energy networks to increase the competitiveness and openness of the EU internal energy market. However, the potential effect of developing Europe's energy infrastructure is contained in the Impact Assessment (IA) of the Blueprint for an Integrated European Energy Network[30]. The IA recognises that, in certain circumstances, it may be necessary to change the choice of technologies (eg switch from overhead to underground power transmission lines), and the route of transmission networks, to avoid adverse impacts to protected areas such as Natura 2000 sites. Where adverse impacts cannot be avoided, the IA suggests that compensating measures may be necessary. The IA also acknowledges the potentially negative impacts on habitats of developing European energy infrastructure, but says that these negative impacts should be considered in the context of what would happen in the absence of an improved European energy network. Not upgrading the network could, according to the IA, increase the severity of the consequences of climate change, which would have negative impacts on European habitats. Green Infrastructure is not directly addressed in the **Renewable Energy Directive**, although there are some indirect links; besides the overall 20 per cent EU renewable energy target (national targets are differentiated by MS), the Directive includes a target to increase the proportion of renewable energy in the transport sector (ie a target to include 10 per cent renewable energy in transport energy to be met by each MS by the year 2020). The MSs' National Renewable Energy Action Plans (NREAPs) have shown that over 90 per cent of renewable transport energy will come from biofuels and that overall, bioenergy is expected to make up over 50 per cent of total renewable energy use[31]. The renewable energy targets are therefore likely to require a significant increase in the proportion of bioenergy crops grown in Europe. The resource use associated with the increased demand for bioenergy crops and biomass from agriculture and forest should be assessed with much caution in individual MS to prevent negative impacts on ecosystems, such as the conversion of grassland habitats to arable crops. The **EC's 2011 Energy Efficiency Plan** mentions green infrastructure in relation to the new Smart Cities and Smart Communities initiative which focuses on speeding up the translation of research results into real, practical innovation in

30 European Commission (2010) Energy infrastructure priorities for 2020 and beyond – A blueprint for an integrated European energy network. Impact Assessment. SEC(2010)1396

31 For an analysis of the NREAPs, cf http://www.ecn.nl/docs/library/report/2010/e10069_summary.pdf, Bowyer (2011) and Atanasiu (2010).

selected cities and communities. According to the plan this should also include supporting large scale demonstration projects on green infrastructure (ie "green infrastructure includes use of trees and plants to cool urban temperatures, reducing energy needs for cooling … it can mitigate flood risk and water, air and ecosystem quality").

Impact Assessment, damage prevention and remediation

The **EIA and SEA Directives** do not refer directly to 'green infrastructure'. Nevertheless, some green infrastructure elements are at least indirectly addressed through the outlined minimum requirements for impact assessment procedures. Reference may for example be made to green infrastructure elements in the EIA when outlining the likely environmental impacts of a proposed development. The SEA Directive does not refer to green infrastructure directly and does not explicitly request that the coherence of ecological and/ or protected area networks be maintained and fragmentation avoided. Article 2b of the SEA Directive, which requires a Strategic Environmental Assessment of plans and programmes (P&P) in accordance with the regulations governing Natura 2000 network (Habitats Directive), arguably makes reference to the need to avoid adverse impacts on core green infrastructure. Similarly, Article 11 of the SEA Directive stipulates that MS may provide for coordinated and joint procedures in situations where an obligation to carry out assessments of the effects on the environment arises from both the SEA Directive and other Community legislation, which creates a link to the Appropriate Assessments of plans and projects which have to be carried out under the Habitats Directive. The EIA Directive also requires that the impacts of certain types of projects (identified in its Annex II) on Natura 2000 need to be considered to determine whether a full EIA is required or not. Some green infrastructure elements may also already have to be considered at the scoping stage of the SEA process: according to Article 5(1) the significant effects on the environment has to be covered in the environmental report for the issues listed in its Annex I which includes biodiversity, flora and fauna. Overall, it seems that the EIA and SEA Directives do impacts on green infrastructure primarily as far as they concern core areas. Impacts on other types of green infrastructure elements are generally considered worth mitigating only to a very limited extent (ie if specific protected specifies of fauna and flora are at threat – so no real link to ecosystem services is created). While there may be some variation when it comes to national transposition, as regards green infrastructure elements, EIA and SEA seem primarily concerned with Natura 2000 and protected species and the potential of these instruments to be effectively used for the preservation (or even enhancement/optimization) of ecosystem services, overall coherence, connectivity and resilience remains largely underexploited.

The **Environmental Liability Directive** implements the 'polluter pays principle' and is meant to ensure prevention and remediation of damage to: 'animals, plants, natural habitats and water resources, and damage affecting the land'. Arguably, some of these damages could affect green infrastructure elements which would currently have to be restored in following ways:

- For damage affecting water or protected species and natural habitats: the Directive requests the environment is restored to how it was before it was damaged.
- For damage affecting the land: the Directive requires the land concerned to be decontaminated until there is no longer any serious risk of negative impact on human health.

The potential *vis-à-vis* green infrastructure is rather limited given current implementation of the Directive and the limited number of cases which have so far triggered its application. The most important green infrastructure elements (core areas) are already covered by the Directive and it is not expected that changes to the directive would result in huge benefits for green infrastructure.

Spatial Planning

Although the **European Spatial Development Perspective** (ESDP) does not explicitly refer to green infrastructure it can be seen as supporting the implementation of at least some aspects of a green infrastructure approach. This is for example the case of the objective of 'careful management of natural and cultural heritage' which calls for restoration of biodiversity, respect for protected areas (ie Natura 2000) and the important role of ecological corridors, and the need to reconcile the preservation of ecological functions with economic exploitation of ecosystems. The ESDP also proposes the preservation and restoration of large wetlands endangered by excessive water extraction or by the diversion of inlets, and an integrated management of the seas and more specifically refers to the need to preserve and restore threatened maritime ecosystems. In addition, under the objective 'territorial polycentric development and new rural-urban relationship', the ESDP points to the importance of green spaces in cities. The EU's **Territorial Agenda for 2020** mentions green infrastructure explicitly under priority 6 of the Territorial Priorities for the Development of the European Union. It calls for managing and connecting ecological, landscape and cultural values of regions and explicitly states its support 'to the integration of ecological systems and areas protected for their natural values into green infrastructure networks at all levels'. Similarly, it encourages integrated development in cities, rural and specific regions and supports the safeguarding and sustainable use of "territorial capital" as well as the ecological functions and services it provides, which clearly resonates with the concept of green infrastructure. The **ESPON 2013 Programme**, which *inter alia* offers the possibility of generating information on trends on territorial potentials and the larger territorial context of regions, does not refer directly the concept of GI. There however seems to be some scope for the ESPON 2013 to support activities which would benefit green infrastructure, as one of its priority lines supports research applied to the environment, natural resources, risks, biodiversity, Natura 2000 sites and other themes, with the objective of developing territorial planning tools that incorporate territorial cohesion and sustainability.

In the **Thematic Strategy for the urban environment,** green infrastructure is not mentioned explicitly and, although the text recognises that "integrated management of the urban environment should foster sustainable land-use policies which avoid urban sprawl and reduce soil-sealing, include promotion of uban biodiversity and raise awareness for urban citizens", green infrastructure's role for sustainable urban development is arguably largely underestimated. Thus, while under the heading 'nature and biodiversity', the issue of 'sustainable urban design'/ 'appropriate land use planning' are briefly mentioned (on page 9) the Strategy stays very vague with regard to what it means and no role for green infrastructure in delivering this objective is foreseen. The design of 'sustainable land use policies which avoid urban sprawl and reduce soil-sealing' would merit further elaboration. Sustainable urban development is not given its full meaning and the range of options mentioned to meet the Strategy's objectives is too limited. While the opportunities for assistance from Cohesion Policy to address environmental priorities in urban areas are hinted at, no mention of the potential advantages of ecosystem-based solutions is made.

Marine and Coastal zones Policy

The **Marine Strategy Framework Directive** does not refer to GI directly. It does however support the establishment of areas under the Habitats and Birds Directives and other international and regional agreements, and lends strong support to the Community's commitment to the CBD target for the network of Marine Protected Areas by 2012 (Para 6, 7 and 18 in the Preamble). Furthermore, it emphasizes that: 'It is crucial for the achievement of the objectives, to ensure the integration of conservation objectives, management measures and monitoring and assessment activities set up for spatial protection measures such as special areas of conservation, special protection areas or marine protected areas" green infrastructure's potential contribution to the achievement of good environmental status (GES)' (para 21 in the preamble) is nowhere recognised.

The **EU Maritime Spatial Planning (MSP) Communication** does not refer to green infrastructure directly. However the roadmap for maritime spatial planning provides a framework for arbitrating between competing human activities and managing the marine environment, including promoting the efficient use of maritime space and renewable energy, and cost-efficient adaptation to the impact of climate change. The ecosystem approach is highlighted as an overarching principle for MSP. Green infrastructure is not addressed directly in the **European Fisheries Fund**. However, Article 16 (under Priority Axis 3: Measures of Common Interest) provides opportunities for pilot projects in support of conservation measures for Natura 2000 sites. The potential for green infrastructure lies in the opportunity to fund pilot project under two articles in the EFF implementing regulation: Article 11: Aqua-environmental measures and Article 16: Measures intended to protect and develop aquatic fauna and flora. Axis 4, which is focused on sustainability of coastal communities, also offers some potential for green infrastructure as there is the expectation that coastal communities are likely to establish fisheries projects which will lead to sustainable fisheries and ecosystems, and, by default, local employment and supplies.

The **2002 ICZM Recommendation** does not refer directly to green infrastructure. However, the recommendation sets out the common principles, including coherence between spatial planning across the land-sea boundary, and calls for MS to develop ICZM strategies. It also encourages MS to cooperate with neighbouring third countries. The recommendation promotes a holistic approach to the management of the coast which includes recognising the natural capital of the coasts and the need to preserve and use this sustainably within the context of sustainable development and the demands on the coast from other sectors (both economic and social). Implementation of the recommendation depends on buy-in from all stakeholders and interests groups.

Environment and Health Action Plan

Green Infrastructure is not directly or indirectly addressed in the **Environment and Health Action Plan 2004-2010**. The main weakness with regard to green infrastructure is that, because it is underestimated, its potential positive impact on environmental factors such as air quality and temperature is not being fully acknowledged and exploited. One of the objectives of the AP is to step up cooperation between stakeholders in the environment, health and research fields which seem to be of particular relevance with regard to green infrastructure. Work could therefore be initiated in particular to investigate issues including the contribution of green infrastructure in achieving health related targets, but also of the benefits of access to high quality green spaces in urban area.

EC external development cooperation

Green infrastructure is not mentioned in key strategic documents of EC development cooperation. For example, the 2009 EU Strategy for supporting disaster risk prevention in developing countries does not mention green infrastructure despite it being an obvious candidate eg the use of green infrastructure or ecosystem based solutions in flood prevention etc. EC development cooperation and aid offers support for projects related to biodiversity, water and energy as well as in the area of climate change and disaster risk reduction. The Environment and Natural Resources Thematic Programme (ENRTP) 2011-2013 Strategy Paper & Multiannual Indicative Programme outlines current activities in those areas. Given some of the issues which are meant to be addressed through the funding (eg flooding, above) there seems to be important room for delivering these objectives through ecosystem based solutions, but this is currently not acknowledged.

Cross-cutting issues under option 1

The text below provides insights into the state of development of the main types of cross-cutting measures under a business as usual scenario. In short, the most striking features in relation to the green infrastructure elements are that:

- Cross cutting initiatives, such as those briefly discussed in section 3.2.8, are only developed to a very limited extent under this scenario
- There is an almost total absence of a co-ordinated and holistic approach to actions in support of green infrastructure
- While there is no co-ordinated EU initiative on green infrastructure there are some elements where green infrastructure is supported within some of the policy areas eg LIFE, EAFRD, Cohesion, Water Framework Directive, Environmental Impact Assessment.

Strategies and Action Plans

There is no Green Infrastructure Strategy at EU level. Arguably, the Habitats Directive with the Natura 2000 network offers a Strategic Framework for parts of the green infrastructure but it is targeted at primarily one green infrastructure element: core areas. EU regional strategies, such as the Baltic and Danube Strategies, hardly take into account the potential role of natural capital for delivering their objectives. There are some examples of partial green infrastructure Strategies at national (eg Ireland, France) and sub-national level (eg Pumlomon Initiative). Strategies and Action Plans for national protected areas (non-Natura 2000) and cross-border initiatives (eg Lower Danube Green Corridor) may also be considered partial building blocks of green infrastructure Strategies. Combined with the UNESCO Man and Biosphere label or the Council of Europe Initiative for Ecological Networks, the multi-purpose character present in the green infrastructure concept is reinforced but these initiatives only offer partial and rather weak frameworks and do not allow for overall coherent governance of the green infrastructure and consistent implementation of the concept.

Information gathering and mapping

Across Europe, there are a limited number of examples and none of the existing mapping exercises covers all the green infrastructure elements as understood in this project. Generally maps are limited to protected areas or particular ecosystems eg forests or wetlands. Maps of, for example, fragmentation of the territory or specific ecosystems are only experimental and localised. JRC produced mapping of Ecosystem Services but only at a level of NUTS 2 statistical areas; the level of detail might need to be increased if this is to be used at regional or local level, where much of the competency for spatial planning lies.

Natural capital accounts covering a variety of green infrastructure elements: No accounts covering all, or even most, of the green infrastructure elements exist at EU, MS or local level. In MS and at European level, the surface occupied by protected areas (eg Natura 2000 or CDDA), focused on specific land uses (EEA land take maps, CORINE land use maps, HNVF maps etc) or habitat maps, is being monitored but other areas are ignored and the focus is not on the different surface/stock of green infrastructure elements or flows of ecosystem service from green infrastructure elements.

Regulation and planning

Spatial planning taking into account green infrastructure elements: At EU level, the 1999 European Spatial Development Perspective (ESDP) does not refer directly to Green Infrastructure but promotes some of its ideas. Not very prescriptive however and on its own, a rather weak instrument to promote Green Infrastructure in spatial planning. At MS level (including local, regional) spatial planning is generally taking green infrastructure into consideration to a very limited extent. Core areas would be considered/ protected but most green infrastructure elements do not benefit from specific protection or strategic management. Higher level spatial planning strategies (eg ICZM) are starting to develop but seldom recognise the full range of green infrastructure elements and their benefits. Some countries have laws and institutions for preserving geographic areas (eg France coastal area law) but success is unclear. No consistent approach across MS.

Public Investments

Public investment in green infrastructure where cross policy area and meets multiple objectives: No specific strategy for such investments. Both EU investments and national investments generally focus on pursuing primarily one objective. In some cases multiple benefits (often a combination of biodiversity and tourism/ recreation) are emphasized but this is the exception rather than the rule. No dedicated EU TEN-G fund for co-ordinated projects of European value exists.

Governance

With regard to communication and advisory measures, there are only a limited number of events/sessions at conferences focused on green infrastructure at EC level, but happening on a regular basis. These are often concerned with economic spending on green infrastructure in specific policy areas eg regional policy. Communication exists in some MS which have taken green infrastructure initiatives eg the Netherlands, France etc to increase acceptability and explain the objectives. EC initiated advisory measures or provision of guidance for the development of ecosystem-based/ green infrastructure based solutions are rather limited.

With regard to governance measures in support of above mentioned initiatives, an informal EC working group was set up for limited amount of time. At MS level (eg France) formal institutions are in some cases set up to oversee the implementation of green infrastructure initiatives. Most institutions are however set up to manage core areas: the enforcement of bans on activities which could harm other green infrastructure elements is limited.

Research

Under previous framework programmes as well as under the current framework programme (FP-7) some projects relevant in the context of green infrastructure have been funded. Some of the most prominent projects include:

- SCALES (securing the conservation of biodiversity across administrative levels and spatial, temporal, and ecological scales), which could make an important contribution to green infrastructure in identifying what can be achieved at which scale for green infrastructure (ie identifying where competencies for issues affecting green infrastructure currently are and whether this is appropriate in view of the needs).
- SITXELL - development of 'A Territorial Information System for the Multidisciplinary Analysis of Open Areas of the Province of Barcelona'. A tool to support spatial planning at the municipal and regional level, through offering accurate and rigorous ecological and socioeconomically information.
- GRABS (Green and blue space adaptation for urban areas and eco towns) – a project looking into ecosystem based solutions for adaptation in urban areas. It acts as a network of leading pan-European organisations involved in integrating climate change adaptation into regional planning and development).
- Other research relevant to green infrastructure is being carried out by the EEA and the JRC.

The weakness of the on-going projects with regard to green infrastructure is that they have not been framed in view of producing research results specifically relevant in the context of the green infrastructure Agenda. Some of the findings can be expected to be of relevance to green infrastructure but if no effort is made to bring those findings together under a coherent umbrella and make it available to those actors responsible for the implementation of green infrastructure strategies they will not directly serve the purpose of green infrastructure.

7.2.2 Option 2: Maximising the use of existing approaches: MS voluntary measures with EU support

Overview of changes - Option 2

2 a) OMC is used at EU level
2 b) Wider EU support for investments in green infrastructure
2 c) Awareness raising/tailored guidance & technical assistance/ capacity building
2 d) Research supporting green infrastructure implementation
2 e) EU Green Infrastructure Integration Toolkit for spatial and regional planners
2 f) Creation of a Gateway for European Green Infrastructure Information (on the model of WISE/BISE)
2 g) Non-legislative strategic EU level instruments

- *Review of the Thematic Strategy on the Urban Environment*
- *Review of the Environment and Health Action Plan*
- *Strategy on Forest protection and information (new)*

2a) OMC is used at EU level

Description of measure 2a

The Open Method of Coordination (OMC) is a largely voluntary political process (generally) initiated by the European Commission[32] and offering a framework for coordinating specific national policies between a group of EU MS. The method is intergovernmental and relies on measures of soft law such as guidelines, benchmarking and best practices, to enhance cooperation and coordination between the MS.

In view of further supporting its green infrastructure, a group of concerned MS agreeing to collaborate within the framework of the OMC, would agree on common targets and guidelines for green infrastructure, which would be backed up with national action plans. The EC could possibly include best practice examples of innovative informal institutional approaches in MS in its own guidance documents. Another focus would be on measures in the area of spatial planning which are, strictly speaking, outside the scope of EU competence and in the responsibility of MS. In fact, the OMC could serve to facilitate exchange on best practices, also included in EU wide guidelines and advising documents. As a result of this process, the guidelines could be transposed into national and regional policies but measures might differ and could be adapted to specific conditions and national/regional priorities. To ensure an effective outcome of this process, benchmarks and indicators to measure best practice would be agreed upon. Respective results would be monitored and evaluated. Technical assistance from the EU would be provided, enabling selected MS to participate in this voluntary, intergovernmental political process.

Within this framework, interested MS could draw up green infrastructure and Natura 2000 Coherence Action Plans (APs) to be integrated in their existing spatial and regional planning tools which would aim to improve habitat conditions within Natura 2000 and to enhance

[32] They can also be initiative a Member State or group of Member States. Furthermore, the chair of OMC committees can also be Member States. A key point of OMC is that is does not have to be Commission led.

connectivity with the wider environment. Potentially, they could also include the identification of needs for new sites, site enlargements, buffer zones, and enhancement of corridors between different landscape elements as well as restoration priorities which are thought to be cost-effective (for example via integration with other spatial planning projects). Finally, these APs could also consider further utilisation of PES schemes and other innovative financing measures.

In conclusion, the main idea of an OMC for green infrastructure would be to develop a more coordinated policy approach and in turn ensure a maximisation of green infrastructure potential while taking the various regional ecologic, economic and social dimensions into account.

Insights into economic, social and environmental impacts associated with 2a

The potential effects that could be expected from the introduction of an OMC are to: achieve a high level of political participation; create joint commitment and a competition for best practices and standards; link policy areas on EU and MS level in order to achieve a common purpose; enhance the cross-border cooperation between MS; achieve multi-level stakeholder involvement (public and private); and promote cooperative practices, networking and mutual learning possibly resulting in non-binding guidelines (which can still be transposed into the national law of all MS).

As the OMC is a mere procedural instrument, a precise ex ante assessment of its economic, social and environmental impacts is not possible. In view of providing a response with regard to the potential impacts of using the OMC for green infrastructure implementation, the analysis focuses on past experiences with applying the OMC in environmental policies. The insights this can provide are thought to be, to a certain extent, relevant with regard to green infrastructure. Evaluating the advantages and disadvantages of the OMC is difficult because indicators of a successful OMC are seldom concrete and the OMC is often used in combination with the legislative procedures of the EU. The OMC has, however, yielded some benefits for environmental policy in specific areas it has sought to improve, namely learning, benchmarking and coordination. Learning to understand different MS perspectives and to generate corresponding solutions has, in some cases, created momentum toward future adoption of mandatory measures (ie the OMC can perform a bridging function to subsequent legislation). Sharing best practices has enabled countries to learn from each other ('mutual learning') and resulted in major policy shifts. Benchmarking to encourage compliance has proven successful under certain conditions, for example when the country has shown no particular resistance to the policy, or when the 'name and shame' (Ecologic, 2003) tactic is applied. Coordinating with other MS has facilitated collaborative approaches between neighbouring MS or MS with shared interests, and has tempered opposition to untried approaches (IEEP and Ecologic, 2005). The voluntary nature of compliance within the framework of the OMC has also proven beneficial for environmental policy. Often considered by MS to be less essential than fiscal and economic policy (Ecologic, 2003), environmental policy is more likely to be taken into consideration if the stakes for involvement are low (Trubek et al, 2005). Many MS have agreed to address environmental issues via an OMC approach because of these low stakes, a step they would likely have not taken in the form of binding legislation (IEEP and Ecologic, 2005).

However, even if MS take this step, it has been shown that they do not exhibit as much commitment to OMCs as they do to mandatory measures, even when they communicate interest in complying with them. The effects of the OMC on practices that MS show low interest in, or resistance to, are uncertain. On the one hand, applying the OMC to MS that resist binding legislation can theoretically yield better results than insisting on mandatory measures. On the other hand, practice shows that MS generally do not respond to those voluntary measures they are uninterested in acting on. In fact, settling for voluntary measures as precursors to mandatory measures can diminish the likelihood that binding legislation will be achieved in the future, especially in cases where OMC application requires significant efforts and costs (mostly administrative and transaction costs). Therefore future revisions become less appealing and these voluntary measures tend to become static and take on a *de facto* role as permanent substitutes for mandatory measures (Hatzopoulos, 2007).

In a green infrastructure context, the flexibility of the OMC is primarily thought to result in cost savings through improved coordination between MS, but it must be stressed that this would only prove to be the case if the commitment of MS towards a joint promotion of green infrastructure associated with concrete actions was high. While a strong resistance from MS towards an EU wide promotion of green infrastructure appears unlikely (as long as it stays quite general in its scope and does not require that further MS competencies be transferred to the EU level), only a more stringent framework is likely to yield the optimal level of green infrastructure provision across Europe.

Though the OMC has yielded some benefits for environmental policy, overall it has not proven a more successful strategy for achieving MS compliance in environmental policy than mandatory measures. This is particularly the case with regard to those MS who show no interest in complying. But under certain conditions, including the MS's willingness to comply, the OMC can be a successful bridge for future legislation (see other options 3 and 4).

2b) Wider EU support for investments in green infrastructure

Description of measure 2b

Wider EU support for investments includes efforts by the EU to create a more favourable context for investments in green infrastructure, both from public and private entities. To overcome the barriers which may hinder the socially optimal level of investment in green infrastructure projects, the EU may on the one hand use its funding instruments to raise awareness on the need for investments in natural capital to sustain societal benefits through ecosystem services and, on the other hand, increase the amount of money provided for projects and programmes including investments in green infrastructure. The additional funds would primarily be provided through relevant existing schemes in thematically related policy fields.

In practice, this would mean a more flexible interpretation of funding conditions when the applicant proposes delivering policy objectives through green infrastructure, and a better consideration of the often integrated and multi-targeted approaches of green infrastructure projects to enable project developers to apply more efficiently for funding under the different schemes. Moreover, this would imply a replenishment of funds to a degree needed for wider implementation of green infrastructure projects across the EU. For example, LIFE+

integrated projects could include a higher proportion of green infrastructure projects, if funding conditions would be more beneficial for applicants dealing with green infrastructure approaches. A priority for green infrastructure can also be manifested under LIFE+ demonstration projects, favouring projects which rely on ecosystem-based solutions to deliver environmental objectives. Another example could be Cohesion Policy Programmes focused on energy efficiency. These programmes should also fund initiatives for ecosystem-based urban micro-climate regulation, ie the cooling effect of green spaces and insulation of buildings through green roofs. JESSICA funds could be used to a greater degree to support the implementation of energy efficiency projects (as the projects should be revenue generating) thus freeing up grant money from the EU budget which can be redirected to ecosystem based climate change adaptation, nature conservation etc.

For more detail on how the EU could provide wider support to investment in green infrastructure in specific policy areas including forestry, biodiversity and nature conservation, water policy, regional policy and innovative financing, marine and coastal zones policy, and EC external development cooperation please refer to Annex VI.

Insights into economic, social and environmental impacts associated with 2b

In general, the evaluation of the cost-benefit ratio of 2b is strongly related to the assessments made for green infrastructure projects in general as 2b is primarily thought to result in an increase in the overall implementation of such projects. Adapting funding conditions to favour green infrastructure projects over traditional engineering projects does not have to result in higher costs in the long run, although adapting the application assessment procedures could in the short term result in some additional administrative costs. For this measure to be essentially cost-neutral and for it not to result in important opportunity costs, the social, economic and environmental benefits of different ways to deliver the project's objectives will need to be assessed and compared, and careful cost-benefit assessments will need to be carried out if green infrastructure projects are to be considered cost-effective in comparison with traditional infrastructures. Unfortunately, a direct comparison of costs and benefits is not possible for most green infrastructure projects[33]; while the costs of establishing and maintaining green infrastructure are known for many projects, the benefits are much more difficult to value. Benefits are often assessed in purely qualitative terms, or quantified only in terms of the extent of green infrastructure protected or maintained.

Case examples presented in section 6.2.2 have shown that the costs of ecosystem restoration and management, even if they seem high at the moment of investment, can result in both monetary and non-monetary returns (benefits) to society within sometimes quite short period of times. As the benefits are often site-specific, ex-ante surveys and studies to identify the most cost efficient types of green infrastructure projects and locations for them and need to be carried out if similar rates of return on investment are to be achieved for these kinds of projects.

In conclusion, this measure at least provides high potential for a significant increase in the implementation of cost-effective green infrastructure projects in the European Union,

[33] See Ecologic and GHK: Design, implementation and cost elements of Green Infrastructure projects. Draft Final Report 2011

especially for water management and climate change adaptation and mitigation. Costs to the EU budget and different instruments can be limited through the establishment of effective co-financing schemes with MS. A smart design of the funding conditions can ensure that projects which integrate various green infrastructure elements across ecosystems and have impacts at a broader scale are particularly encouraged.

2 c) Awareness raising/ tailored guidance & technical assistance/ capacity building

Description of measure 2c

This measure comprises a set of possible communication and advisory measures and activities within EU policies that are of particular relevance for the implementation of green infrastructure (such as agricultural policy including rural development, forestry, water, regional development and impact assessment and liability). In general, it would envision concrete advice on how the promotion of green infrastructure elements could be integrated in existing policy guidance documents at various levels. Such guidance documents usually include management and action plans, in which MS outline how they implement EU wide objectives on national (or regional) level.

The integration green infrastructure elements into these plans would be based on technical assistance from the EU and, given the acceptance and uptake of the MS, complement the general activities normally conducted under the respective policy. As the relevant policies are manifold and their implementation often has direct implications for different sectors, such integration cannot work without a broad awareness-raising concept on green infrastructure, targeting various stakeholders. Such concept would include a wide range of activities which aim to improve capacity to deliver green infrastructure measures, namely:

- dissemination of evidence on the need and the benefits of green infrastructure projects;
- targeted stakeholder workshops on the overall concept of green infrastructure and its integration into specific sectors and relevant activities; and
- the provision of web-based information and data and the creation of networks of current and up-coming green infrastructure initiatives.

Moreover, the uptake of a new element such as green infrastructure in existing guiding documents requires concrete advice from the EU level on the information to be provided and the training of responsible authorities in ministries and agencies how this information can be incorporated in current activities and in national guidance documents. This can also be realised by establishing working groups within existing boards of committees that coordinate MS activities within in particular policy field (eg the Standing Forestry Committee).

Technical assistance schemes such as JASPERS under EU Cohesion Policy can be used to help managing authorities for the development of green infrastructure projects and initiatives in new MS, given that green infrastructure would be recognised as an important topic of general infrastructure within the EU (JASPERS). JASPERS can also provide technical expertise to project promoters of grey infrastructure to better integrate and biodiversity/climate proof investment projects at the design stage and avoid irreversible adverse impacts on biodiversity and natural ecosystems. If it could more clearly provide support to green infrastructure implementation, the scope of JASPERS could be expanded to include MS-15, given that they might also be in need of technical assistance.

For more detail on how awareness raising, guidance and technical assistance to support green infrastructure could be implemented in specific policy areas, including agricultural policy, forestry, biodiversity and nature conservation, water policy, regional policy and innovative financing, transport and energy, impact assessment and liability, marine and coastal zones policy please refer to Annex VI.

Insights into economic, social and environmental impacts associated with 2c

The costs associated with these various measures focussed on awareness raising and provision of targeted assistance are very difficult to assess. However, since most of the costs are of an administrative nature and only occur in addition to already on-going initiatives, they can be assumed to be comparably low (see box 7.1). While the personnel effort to compile guidance documents, organise and carry out workshops with stakeholders and for the collection, processing and dissemination of information should not be underestimated, most of these activities will fall under the recurrent costs of EU staff and administration. One question that could be raised is the issue of opportunity costs: ie what other activities of the European Commission and other EU entities would be replaced by green infrastructure related engagements and what would be the effect? Providing an answer to this question is beyond the scope of this study. If the European Commission decided to assign green infrastructure a high priority in EU environmental policies, the costs arising from respective activities comprised under this measure would appear commensurate as the measures are considered essential for increasing the demand and acceptance of green infrastructure measures across Europe.

The effects of measures like guidance, assistance and voluntary involvement in promoting green infrastructure cannot easily be assessed ex-ante. Some doubts have been raised about the effectiveness of such measures in policy areas where the EU has no or only few stakes in regulation and governance (see eg for forest policies Winkel et al., 2009).

Considering that most activities could most probably build on existing processes to achieve environmental targets in sectoral policies, which have already been set, the outcomes could be seen as potentially promising. The added value of such measures would primarily lie in widening the perspective of sectoral policies to the more integrated approach envisaged by green infrastructure and to underpin this vision by knowledge and capacities as a pre-condition of successful implementation. In addition, these measures would enhance a better coordination between different sectoral policies leading to adjusting activities in order to achieve joint targets. One of the most important success factors for this measure would be a well-coordinated process and a good prioritisation in view of developing guidance and technical assistance that will be as effective as possible.

Box 7.1: Costs of guidance documents and technical assistance

The project found that variable amounts of money are spent on awareness raising activities and that rather than being targeted at decision-makers specifically many of those activities target the broader public. In the case of a green infrastructure initiative aiming at the protection and management of coastal habitats in Latvia, €440,000 was spent on awareness raising, which corresponds to approximately 25 % of the entire budget. This was spent on public information boards, publication of leaflets, seminars and conferences, as well as target public awareness campaigns on specific habitat types and their importance. In the case of the Pumlumon farmland restoration project in Wales, €301,000 was set aside for the promotion of new tourism facilities and promoting the area as a tourist destination. In the context of a communication campaign around the Madrid Ecological network, €145,000 was spent on awareness raising.

Source: In-depth case analysis on Multifunctional use of farmland and forest, Annex I.

2 d) Research supporting green infrastructure implementation

Description of measure 2d

In Horizon 2020, green infrastructure is identified as one of the priority areas for research required for the transformation towards a resource efficient, low carbon and resilient bio-economy.

A range of research projects, which would for most of them seek to increase the knowledge base with regard to the baseline situation, would be funded under the next EU research and work programmes. More specifically, they will address current stocks, the benefits of current green infrastructure as well as functional requirements and relevant indicators for supporting and implementing green infrastructure related policy initiatives. This would in particular include:

- Pilot projects to establish natural capital accounts in MS supported by Horizon 2020, including an assessment of green elements and associated benefits.
- Horizon 2020 would also support research activites relating to the interlinkages between soil functions and green infrastructure and the identification of the potential of green infrastructure to address the threats to soil quality as identified in the 2006 Strategy Thematic Strategy. Such research would contribute to best practice knowledge and facilitate the financing of cost-effective interventions through the EU budget.
- EU funded research project(s) on water-related green infrastructure indicators aimed at supporting a fast uptake of effective natural water retention measures in MS national policies.
- An EU funded research project for the development of a future vision of integrated spatial planning at MS or River Basin level, based on the example of the BaltSeaPlan project (spatial vision for 2030).

At a Polish Presidency Conference on the topic of ‘Planning for Biodiversity’, a presentation was given to further identify research needs in this area. Box 7.2 below provides an overview of the topics for future research which were identified as key to supporting the implementation of green infrastructure.

Box 7.2: EPBRS Assessment of the research needs on “Biodiversity and Planning”

The EU Biodiversity strategy 2020 research needs

- Improve baseline information and assessments of species and habitat distribution, status and trends, and human dependencies on the services they provide (>> target 2, action 5).
- Examine how the concept of green infrastructure and ecosystem restoration can provide sustainable nature conservation (>> target 2, action 6 a,b).
- Examine the concept of biodiversity offsets, and how, and under what conditions, they might contribute to "no net loss" of biodiversity (>> target 2, action 7).

Habitat and species conservation under climate change

- Develop methods to restore, maintain or improve the ecological functioning of protected areas, landscapes and seascapes for biodiversity conservation.

- Develop planning and management strategies that enhance the connectivity between protected areas to improve species exchange.
- Better understand the perceptions and knowledge of site managers and owners in order to develop strategies that optimise adaptive management.
- Develop a database about the relationship between spatial characteristics of landscapes and ecological networks and ecological processes in populations and ecosystems, to be applicable in developing planning targets and designing spatial solutions.

Planning for sustaining and restoring ecosystem services

- Better understand the disruption of ecosystem processes which result in depleted ecosystem services, at various scales in time and space, caused by natural and anthropogenic drivers.
- Develop and apply standardized indicators, methods and criteria for the measurements, mapping and assessment of ecosystem services for various temporal and spatial scales (>> target 2).
- Further develop cost-benefit assessments of ecosystem services (and other economic instruments) to identify optimal uses of resources.
- Develop stakeholder-oriented science-based tools for collaborative planning and design of ecosystem services in multifunctional and urban landscapes.

Mainstreaming biodiversity planning into sectoral policies

- Better quantify the impacts on biodiversity of existing and future policies (eg common agricultural and fisheries policies), such as those addressing land and sea use, by means of interdisciplinary and cross-sectoral research.
- Identify planning tools applicable across sectors in order to avoid or reduce these impacts.
- Develop better ways to involve regional stakeholders in awareness, use and maintenance of planning issues related to biodiversity.

Source: A rapid research needs assessment on "Biodiversity and Planning", a presentation by Dr. Stefan Schindler on the work of The European Platform for Biodiversity Research Strategy (EPBRS),
URL: http://prezydencja.gdos.gov.pl/files/PREZYDENCJA/DON-WAWA/Prezentacje/Stefan-Schindler.pdf

In addition, a research agenda on the links between green infrastructure and specific ecosystem services (eg health aspects in urban areas, such as respiratory diseases) should be further promoted. The potential role for green infrastructure in urban planning and its integration into the building stock is another area which would need to be looked into in more depth through future research projects. For example, green roofs and urban green spaces could mitigate urban heat island effect (and decrease magnitude and duration of heat waves); urban green spaces could contribute to further improving air quality and to decreasing obesity by offering space for outdoor recreation and exercising. The role of riparian vegetation in reducing the risks of high nitrates concentration in drinking or pollution in bathing water could also be a topic. Results from such research would usefully help in the development of effective policies which aim at the improvement of eg air and water quality.

ESPON 2013 provides another opportunity to link green infrastructure to cohesion and transport research. ESPON could further promote one of its priority lines to support research applied to the environment (eg natural resources, risks, biodiversity, Natura Network sites and other themes), with the purpose of elaborating territorial planning tools that incorporate territorial cohesion and sustainability.

Tools (such as the SITXELL but more concerned with mapping green infrastructure elements and associated ecosystem services) which can be used by public authorities throughout Europe need to be developed to support an effective implementation of a Green

Infrastructure Strategy by public authorities across relevant scales. The DG Research Framework programmes seem to offer the right context for supporting and developing research capacity on green infrastructure related issues and creating a pool of knowledge to support the development of future policies. Special attention would need to be given to monitoring of biodiversity and ecological/physical impacts (including ESS) of green infrastructure initiatives/measures as lack of such monitoring is one of the main barriers to the benefits of green infrastructure being adequately acknowledged in policy-making.

For more detail on how the above mentioned research activities to support green infrastructure could be implemented in specific policy areas, including biodiversity and nature conservation, climate change policy, spatial planning and environment and health please refer to Annex VI.

Insights into economic, social and environmental impacts associated with 2d

The costs of green infrastructure related projects very much depends on the priority given to this topic under the various EU research programmes (most importantly under FP7 and FP8). A description of biodiversity related expenditures under the recent EU Framework Programmes and ERA-Nets is given in Box 7.3. As indicated above, there is a particular need for data collection and basic research in the context of green infrastructure, which usually is more (financial and human) resource intensive than purely requiring analytical research.

Especially for an integrated research topic such as green infrastructure, there are important benefits arising from joint European research projects which can both usefully complement/bring together research results produced at national level while avoiding unnecessary duplication of research efforts. The collaborative effort required under FP projects usually results in policy relevant outcomes, which are of interest both for EU level policy-making and the development and implementation of policies at Member State level. In addition, the European level research projects contribute to enhancing mutual learning, creating knowledge networks and the exchange of information across research institutions and MS. This also usefully supports promotion and awareness raising efforts relating to green infrastructure. The effectiveness in the allocation of funds can be further enhanced by ensuring that the research projects enhance the knowledge-base in particular with regard to the benefits which arise from green infrastructure implementation by scaling up the monitoring of such benefits, including for projects and programmes supported by the different range of EU funding instruments.

Box 7.3: EU expenditures on Framework Programme research projects on biodiversity

EU expenditures on biodiversity research under the Framework Programmes have totalled as follows:

- FP5 (1998 to 2002) - € 136 078 000 for biodiversity projects.
- FP6 (2002 to 2006) - € 78 608 847 for biodiversity projects focusing on ecosystems from a total budget of €769 Million for Global Change and Ecosystems.
- FP7 (2007 to 2013) - € 29.6 million spent on biodiversity projects by 2009, out of a €1.9 billion budget for environmental research funding.

The figures indicate an average annual expenditure of €24 million by the EU over the period 1998 to 2006. These expenditures were co-funded by MS.

The FP6 funded BiodivERsA (ERA-Net in Biodiversity research) project received EU funding of € 2.8 million, with funding by MS of € 20 million. In 2008, BiodivERsA launched a major European call on biodiversity under FP7, through which 12 international research projects have been selected and supported for a total funding of € 14.2 million. In a second European call on biodiversity and ecosystem services in November 2010 a total budget of € 11.1 million was granted.

Source: Ecologic, IEEP and GHK (2011)

2 e) EU Green Infrastructure integration toolkit for spatial and regional planners

Description of measure 2e

Under this measure, the EU would develop a toolkit to support spatial and regional planners to better integrate green infrastructure. This would not require unanimous action of the Council in accordance with a special legislative procedure and after consulting with other institutions to adopt a measure in the area of town and country planning and land-use (cf Article 192(2) of the EU Treaty). Indeed, the Commission could simply take the initiative, building on respective mandates from the 1999 European Spatial Development Perspective (ESDP) and the 2011 Territorial Agenda the EC green infrastructure toolkit, to outline the ways in which a more integrated approach to spatial and urban planning would consider green infrastructure elements. The toolkit would address key issues of relevance to green infrastructure implementation, including the restoration of ecosystems, maintenance and enhancement of protected areas (Natura 2000), the integration of ecological corridors and the need to reconcile the ecological functions with economic exploitation. Specific advice related to the benefits of urban green infrastructure would also be provided in view of informing planners of the potential cost-savings that can be obtained by using green infrastructure. In order to visualise the benefits gained from better considering green infrastructure in the planning process, the toolkit would introduce valuation methods.

The toolkit, supported by the approach to green infrastructure adopted in the Strategy, would make clear that a pre-requisite of meaningful integration of green infrastructure into planning strategies is the setting of clear and reachable targets for future planning in the relevant documents. In multi-level planning structures (such as in Germany), it would recommend that targets and objectives are consistent across levels and competing demands on land use are considered upfront in the strategies. Sectoral laws in which green infrastructure considerations might still need to be integrated to reflect a more balanced prioritistaion between green infrastructure conservation and grey infrastructure planning (eg construction laws) would be identified. Recommendations with regard to effective participatory decision-making approaches in spatial planning at multiple levels, based on best-practice examples would be formulated.

As mapping can facilitate better integration of green infrastructure into spatial planning, consideration should be given to the establishment of a taskforce to develop guidance on technical and institutional aspects related to mapping green infrastructure elements. This task force could be coordinated by the EEA and would include a representative range of experts and key stakeholders. In line with the subsidiarity principle, EU MS could carry out the mapping of green infrastructure themselves. However, the task force could take up the role of compiling results from MS towards an EU wide assessment of green infrastructure's state and implementation. It would also encourage MS to apply GIS tools in spatial planning and to make use of the information from Spatial Observatory Networks to determine trends of territorial development and their relation to further green infrastructure integration.

Key EU level strategic documents relating to spatial planning and integrated territorial development could be further aligned with the green infrastructure approach. Even before this, however, some key strategic instruments may be referred to as they already provide relevant opportunities. The ESDP, for example, proposes the preservation and restoration of large wetlands endangered by excessive water extraction or by the diversion of inlets, and the concerted management of the seas, in particular preservation and restoration of threatened marine ecosystems. In addition, under the objective "territorial polycentric development and new rural-urban relationship," the ESDP points out the importance of green spaces in cities.

The integration of green infrastructure in spatial planning would require reform of spatial planning laws in many countries. To encourage the dissemination across MS, the toolkit would build on and refer to practical examples drawn from existing initiatives (eg Stockholm's blue-green infrastructure-RUFS 2010) while simultaneously providing information about possible sources for support (ie ESPON, LIFE+). Cities would for example be particularly encouraged to draft climate change adaptation plans referring to green infrastructure and EU would ensure that its funding instruments provide incentives to adopting green infrastructure-based approaches in spatial planning.

Insights into economic, social and environmental impacts associated with 2e

Spatial planning plays a key role in the promotion and implementation of green infrastructure. Spatial and urban planning have the instruments needed for a long term strategy of integrating green infrastructure elements in landscapes and urban areas such as mapping tools, data and information of land use practices and measures as well as their impacts on water bodies, soils, landscape elements and different ecosystems. Nonetheless, an EU based toolkit to support spatial and regional planners in better taking green infrastructure into account may lead to a higher uptake of green infrastructure in general and widen the perspective of regional and urban planners towards a more integrated approach.

Furthermore, the analyses required for the development of the toolkit could unveil possible obstacles to making green infrastructure a guiding principle for spatial planning and might develop strategic advice how these obstacles can be overcome. This could provide opportunities for a new vision of spatial planning across the whole EU, regardless of the administrative level spatial planning used in the different MS. Such a vision could build on more integrated concepts such as the ecosystem-based approach or the greater considerations of the provision of ecosystem services. It would also enhance a stronger relationship between regional and urban planning which currently act separately in many countries leading to inconsistent planning strategies with unbeneficial conditions for suburban ecosystems and ecological corridors.

It also needs to be noted, however, that a toolkit alone will probably not lead to the benefits described here. The highly voluntary nature of such toolkits does not guarantee for a high uptake of its recommendations by MS, unless the toolkit is developed as a result of a commitment for considering green infrastructure in spatial planning between MS and the EU. The costs of developing such toolkits can be comparably high, as it involves a wide range of different working steps, testing exercises and updating (see an example in Box 7.4 for the development of a toolkit which has some thematic linkages with green infrastructure).

Box 7.4: The case of SITXELL: Quantitative and qualitative insights into the benefits of integrated spatial planning

The SITXELL project started in 2001 as a project developed by the Barcelona Provincial Council. It was developed as a territorial information system about the open areas in the province of Barcelona. It uses the technology of geographical information systems (GIS). It pursued primarily the objective of providing knowledge and raising awareness about the ecological and socio-economic value of natural areas, which would lead to a better consideration of natural values and ecosystem goods and benefits in integrated land planning. Between 2001 and 2010, the cost of SITXELL has been around €3,285,000, averaging to approximately €330,000/a.

The establishment of the territorial information system by the province of Barcelona required 2 full-time experts and one part-time specialist, thus creating jobs over an extended period of time. Biodiversity benefits of SITXELL primarily stem from an improved functional connectivity of habitats and increases in ecosystem health via the designation of special protected areas: On a regional level, the Barcelona Metropolitan Territorial Plan approved the special protection of 2,280 sq. km (70.5% of the Region) proposed by the SITXELL analysis. In addition, during the Strategic Environmental Assessment, 38 areas of special interest for connectivity and associated regulations and proposals were developed. Additionally, since 2005, SITXELL information and approach has been used in the elaboration and approval of the numerous protection plans and has been the basis to elaborate the Protected Areas Network Conservation Strategy comprising four Natural Parks accounting for approximately 50,000 ha in total. With regard to socio-economic benefits, positive impacts have been produced in terms of,eg, the prevention and mitigation of natural risks, support to agrarian activities (agriculture and forestry) and the establishment of areas for education and recreation (Castell 2011). The annual costs of around €330,000 seem insignificant when compared to the area of the region protected as a result (over 70%; 2,280 km2) and the subsequent benefits for biodiversity via habitat conservation. Further, the number of local and regional plans that have profited from provided datasets are also difficult to quantify in purely economic terms. However, the direct savings for municipalities as a result of the project have only been estimated at €110,000 (Castell 2011).

The results of the SITXELL project also relate to a general change in the way spatial land planning and natural areas protection are approached on the part of experts, politicians and stakeholders. The direct effect of this conversion can be defined as a 'greening' of public administration and companies involved in land planning, referring to their placing a greater weight on natural values in their decision making processes. This has ultimately led to a more balanced territory in ecological, social and economic terms. As a result, positive impacts have been produced in terms of, eg, the prevention and mitigation of natural risks, support to agrarian activities (agriculture and forestry) and the establishment of areas for education and recreation.

Source: In-depth case analysis on Mapping for Planning; Castell (2011)

Box 7.5: Integrating regional planning with urban planning: RUFS 2010 - Guide to the Regional development plan for the Stockholm region

The RUFS 2010 is a regional strategy endorsed by the city administration and the city council setting out planning goals for 2030 and actions to be undertaken some of which are relevant for the establishment and protection of green infrastructure in and around the city.

Planning goals by 2030	**Action needed**
For natural, cultural and recreational values: Valuable natural, cultural and recreational environments are safeguarded and developed. Groundwater, lakes, rivers and coastal waters have good ecological status.	*Secure and develop the values of land and landscape. *Secure and develop the coastal area's natural, cultural and recreational values.*Protect Mälaren lake and the Baltic sea.
For the green wedges and beaches: People in the	*Maintain, develop and make green wedges accessible.

region have good access to urban nature of high quality.	*Develop shores' values and accessibility.
For multi-core and dense urban fabric: The Urban landscape includes more attractive, walkable and diverse urban environments.	Make the building structure denser and more variable. *Create an attractive city with its squares, parks and green spaces.

The RUFS states the importance of protecting the coherence of the green wedges as a connected whole. In this regard it is important to consider green structure planning together with other types of regional planning and development. Also, concerted action and cooperation between municipalities within the green wedges is necessary. Ecosystem services provided by green areas and wedges are also considered in the RUFS: recreation, purification of air and water, treatment and filtration of harmful substances, regulation of temperature and water flows and contribution to public health are emphasized and should be a component of a conscious planning effort. Connectivity of urban green areas and parks is considered important in the context of providing alternative routes in order to foster pedestrian and cyclist mobility and to increase general accessibility of green areas. Connected green areas are seen as complementary to a denser residential structure in order also to reduce residential development pressure on the green wedges around the city.

Source: Task 4.2. country file – Green infrastructure implementation and efficiency – ENV.B.2./SER/2010/0059

Box 7.6: Costs and methodology of the development of a toolkit in the REMEDE project

The REMEDE project (FP6) aimed to develop and explain resource equivalency methods to be applied in accordance with the requirements of the Environmental Liability Directive (ELD). It reviewed experiences in the application of resource equivalency methods and develops a toolkit for decision makers for the application of resource equivalency methods, thus contributing to the implementation of ELD under which compensation for such environmental damage may include restoration projects that provide environmental resources in lieu of the damaged resources, or some other type of compensation payment by the responsible polluters (Polluter Pays Principle). The project included the components methods development, testing the Toolkit, dissemination. The Community contribution to the project was € 885,758.

2f) Creation of a Gateway for European Green Infratructure information (on the model of WISE/BISE)

Description of measure 2f

A gateway for European green infrastructure information would be set up for green infrastructure following the model of WISE (Water Information System for Europe) and BISE (Biodiversity Information System for Europe). It could also be an expansion of BISE. This would become a key element of the institutional structure to promote the development of green infrastructure across the EU, and facilitate experience sharing and information exchange. A platform on the model of WISE would serve in particular as an 'Information Gateway' collecting, processing and disseminating information on green infrastructure. As for WISE, this information platform could be created by the European Commission in collaboration with the EEA.

It would consist of technical information and data on green infrastructure, but would also serve as the communication platform for green infrastructure related policies and how they foresee further integration of green infrastructure in the future (including sector specific guidance documents). Moreover, information and results from a wide array of research projects addressing the different (sub-) topics of green infrastructure will be made available in a comprehensive manner. Linking results and information to responsible (research) institutes and persons would allow for a better exchange among researchers, experts and practitioners, if they know where and from whom information and experiences can be obtained.

The platform, which could also be an expanded BISE plateform, would bring together information gained from most of the measures outlined under option 2, which involves a high coordination effort. As data, maps and technical information would represent a high share of the information to be processed and published, it could make sense to assign the responsibility for the platform to the EEA, which is best suited to oversee EU wide activities and well-experienced to gather this relevant information.

Finally, as for Natura 2000 portal, maps and data can be retrieved (eg green infrastructure maps produced at EU level).

Insights into economic, social and environmental impacts associated with 2f

For a new and still quite unknown topic as green infrastructure, the provision of comprehensive and accessible information is key for future promotion and development of green infrastructure initiatives. Besides sharing of information with all relevant actors and decision-makers, the process of collecting data and information for such a platform is of high value. When processing the information into an updated knowledge base and making it accessible through visualisation, many lessons can be drawn from the exercise and the evidence base of green infrastructure implementation can decisively be widened.

This would improve the conditions for a stronger application of green infrastructure in different policy fields. However, providing information alone does not automatically lead to political actions; hence, the Information Gateway on green infrastructure can only be regarded as a necessary add-on to a combination of policy measures required for the enhancement of green infrastructure initiatives in the EU.

Box 7.7: Costs of information Gateways

There are two similar approaches in EU environmental policy to facilitate a broad information platform on specific topics, namely

- WISE (The Water Information System for Europe) and
- BISE (Biodiversity Information System for Europe)

The on-off costs for such information systems can be generated from the respective tenders for the establishment of the systems: While the price range for WISE was fixed between € 230,000 and € 250,000 excluding VAT (including fees, travel and all other costs), the budget of BISE is a maximum of € 200,000 excluding VAT (including fees, travel and all other costs).

It has to be noted, that these costs only include the development of the information platforms. Recurrent costs for updating, revising and managing the portals would also have to be taken into account when estimating the overall costs of such information systems.

Sources: Invitation to Tender ENV.D.1/SER/2011/0025 (WISE) and ENV.B.2/SER/2011/0016 (BISE)

2 g) Review of a range of non-legislative strategic EU level instruments

Description of measure 2g

A range of existing non-legislative strategic EU level instruments would benefit from being revised, in a process duly engaging the wider public and relevant stakeholders at multiple levels, to better incorporate and reflect EU's endorsement of green infrastructure as a means to deliver a range of benefits. This is in particular the case of the Environment and Health Action Plan, which, where appropriate, should clearly refer to opportunities of delivering health benefits through the targeted creation of green infrastructure in urban areas. In some areas, new strategic documents could prove beneficial to raise awareness and achieve a common understanding of where opportunities to deliver on specific relevant objectives through green infrastructure lie in a given sector (eg forestry, regional development, urban areas). This is in particular the case in the area of Forestry and Regional Policy.

For more detail on how the review of a range of EU level strategic policy instruments could provide support to further green infrastructure implementation in specific policy areas, including forestry policy, regional policy and innovative financing, spatial planning and environmental and health please refer to Annex VI.

Insights into economic, social and environmental impacts associated with 2g

The costs of revising existing documents might be minimal, especially where revision takes place anyway on a regular basis. The development of new strategic documents targeted at specific sectors might come at higher costs, especially with regard to the human resources which might have to be collated. Apart from the fact, that green infrastructure is reflected to a higher degree both in revised and new strategic document, leading possibly both to a higher awareness of green infrastructure and its stronger reflection in policies and initiatives, benefits can also be derived from the engagement of relevant stakeholders in the development of the strategies. This might lead to an increasing ownership of the outcomes further resulting into the adoption of a systematic and strategic approach to implementing green infrastructure in a range of key sectors and policy domains. This can be expected to increase the local, regional and national demand for funding and, consequently, to a higher uptake of available funds.

7.2.3 Option 3: Full integration of Green Infrastructure into EU policies

Overview of changes - Option 3

3 a) Revised Regulation on Environmental Economic Accounts
3 b) Development of EU-wide 100x100 meter maps of green infrastructure
3 c) GI made a priority in the Common Strategic Framework and Regulations governing key EU funding instruments (Cohesion Policy, CAP, LIFE)
3 d) Biodiversity and climate proofing is streamlined into key EU funding instruments (eg Cohesion Policy, TEN guidelines and Connecting Europe Facility, CAP, etc.)
3 e) Revised EIA/SEA Directives
3 f) Range of sector specific changes to the current legal framework:

- *Biodiversity*
- *Water*
- *Marine*

3 a) Revised Regulation on Environmental Economic Accounts

Description of measure 3a

The *Regulation on Environmental Economic Accounts* ((EU) No 691/2011) undergoes a revision. In December 2013, in its report on the implementation of this Regulation, the European Commission proposes a range of new mandatory reporting requirements to support the implementation on the Green Infrastructure Strategy as part of its efforts to implement target 2 of the biodiversity Strategy (reitereated in the resource efficiency roadmap). Target 2 foresees that MS, with the assisstance of the Commission, will "map and assess the state of ecosystems and their services in their national territory by 2014, assess the economic value of such services, and promote the integration of these values into accounting and reporting sytems at EU and national level by 2020". The statistics might not have to be compiled and transmitted on a yearly basis. After a clearly set transitional period, MS would have to compile and transmit the statistics regularly, for example every three years.

Ultimately, based on a clear definition and typology developed at the EU level, all green infrastructure elements are quantified in all MS and regions. The objective is to establish a full requirement for MS and regions to map and take stock of their green infrastructure in view of developing natural capital accounts – noting assets, quality/quantity, functions, and flows of services. Harmonised green infrastructure monitoring indicators would be presented in the Annex to the regulation. This will also help in implementing a "no-net loss of green infrastructure" policy and monitor progress towards achieving the restoration target(s). While leaving a certain flexibility to MS, the provisions at EU level clarify what should be mapped, how it should be accounted and reported. In the maps, green infrastructure creation/restoration zones are also identified and are meant to be used in particular at EU level to channel funding to those areas in priority. These are to be identified based on a range of clearly outlined ecological criteria and in view of increasing the connectivity, resilience and coherence of the country's/region's overall green infrastructure. The general idea is that key ecological continuities and green infrastructure elements as well as gaps/bottlenecks in the network are addressed in view of strengthening the resilience of the network and maximising the provision of ecosystem services.

In the context of building the biodiversity knowledge base (points 2.3. in the new EU Biodiversity Strategy to 2020), the integrated framework for monitoring, to be developed jointly by 2012 by the Commission, together with MS and the EEA, also integrates the need to report on the green infrastructure. This could for example include a requirement for MS to report to the Commission, by the time of the first review of the Strategy in 2014 and for subsequent reporting exercises, on measures taken to ensure "Good environment status of overall green infrastructure". Indicators could include fragmentation, surface covered with certain green infrastructure elements, loss of connectivity features. MS could also report on trends in operational objectives set out in the Strategy. The Gateway for European green infrastructure information (or, alternatively, BISE) could be the main platform for data and information sharing.

Insights into economic, social and environmental impacts associated with 3a

The benefits associated with a sound information base with regard to Europe's green infrastructure and the state of ecosystems, while difficult to evaluate, are thought to be important and to outnumber the costs multiple times. A sound information base is essential to the identification of negative trends and a prioritisation of investments and ensuring that financing needs are met and proportional to the challenge. A mapping of ecosystem and their services helps illustrate the contribution of the green infrastructure to national, regional and local income, wealth and well-being and helps ne highlight the risks and trade-offs associated with its loss and degradation. It also allows a better identification of the most pressing needs for green infrastructure investments in specific countries or regions, thus ensuring the cost-effectiveness of spending on green infrastructure.

Box 7.8 Costs and benefits associated with developing such accounts

The National Ecosystem Assessment (UK NEA, 2011) was commissioned by the UK Government to assess stocks of natural ecosystem resources, their state and their trends. Overall, the cost of the initiative came to €1,300,000. These are the formal costs, personal communications suggested that, once in-kind contributions are taken into account as well, the real term costs of the assessment was probably amounted closer to about €10 million. These are one-off costs and regularly updating these accounts can be expected to come at a lower cost.

This is not much compared to the value of the contribution of biodiversity and its constituent ecosystem to our well-being and economic prosperity and is essential to the adequate assessment of the values of green infrastructure in economic analyses and decision-making. The full assessment of the UK's natural assets quantifies the benefits – and warns of the cost of failing to protect them. According to this first ever full assessment of the UK's natural environment its green spaces are worth at least £30bn a year in health and welfare benefits. Such assessments make clear what is at risk of being lost: Around one-third of the UK's natural assets – including green spaces, rivers, wetlands and important wildlife habitats – are in danger of being lost to development or degraded through neglect. On the contrary, if the UK's ecosystems are properly cared for, they could add an extra £30bn a year to the UK's economy; if they are neglected, the economic cost would be more than £20bn a year, the report found. Inland wetlands, for instance, are worth £1.5bn a year in improving water quality alone, and pollinators such as bees are worth at least £430m a year to agriculture.

Source: UK NEA (2011)

3 b) Development of EU-wide 100x100 meter maps of green infrastructure

Description of measure 3b

Based on the information provided by MS under the regulation on Economic Environmental Accounts and GIS data, EU-wide 100x100 meter maps of Green Infrastructure are developed (possibly by EEA or JRC) in view of making these available to all regions and MS authorities so they can be used when submitting applications for EU funding, as required by the revised regulations on structural and cohesion funds. The maps do not only identify existing green infrastructure but also green infrastructure creation/restoration zones – areas where green infrastructure creation and restoration is seen as key to ensuring connectivity and overall coherence of the country's green infrastructure. EU funding to support green infrastructure implementation is particularly channelled into these areas by increasing financial support where proposed agri-environment measures or green infrastructure creation/restoration projects are to take place in those specific areas.

Applicants for EU funds are also requested to use green infrastructure maps made available at EU level, to outline if and what sort of impacts their proposed project or programme is likely to have on the mapped green infrastructure elements and overall ecological coherence. They should demonstrate that the option chosen is the one which minimises impacts on green infrastructure and that adequate mitigation and remediation measures will be taken to ensure ecological coherence and connectivity.

Insights into economic, social and environmental impacts associated with 3b

The mapping of the different green infrastructure elements and the reporting on their state (green infrastructure stock and quality) is meant to ensure adequate implementation of the green infrastructure concept by ensuring green infrastructure can better be taken into account in policy-making and spatial planning (at various levels of governance). It allows making negative trends more apparent, trade-offs more explicit and would also ensure that funding for green infrastructure creation and restoration is channelled to priority areas, ie where investments in green infrastructure would be most cost-effective because they would provide the maximum return on investment in green infrastructure. A mapping therefore results in halting or reducing the deterioration/loss of valuable green infrastructure and maximising the benefits of all types of investment into green infrastructure restoration and creation (thus having a multiplier effect on the green infrastructure benefits achieved under option 2). Boxes 7.9 and 7.10 below highlight some of the costs and the benefits associated with this type of measures.

Box 7.9: Cost and benefits associated with green infrastructure mapping exercises

Costs of the Czech Territorial System of Ecological Stability

The Czech Republic ecological network (Territorial System of Ecological Stability - TSES) initiative which was initiated in June 1992 was thought to represent a network of ecologically significant segments of landscape, efficiently distributed on the basis of functional and spatial criteria, covering biotic, hydrological, soil and relief conditions. A map of existing and proposed bio-centres and ecological corridors was to be produced and to be used both for the development of TSES projects and for spatial planning in general. for example with regard to land consolidations and land use change, processing of territorial planning documentation, forest management plans, water management and other measures affecting the conservation and restoration of the landscape. A rough estimate of the funding spent for the initiative as of January 2010 indicates that €10 million were spent for the development of a range of TSES plans, and around €4 million for the actual implementation, pre-dominantly covered by the national budget.

Box 7.4 above also provides information on the costs and the benefits of the SITXELL territorial information system established by the province of Barcelona.

Source: GI-IE In-depth case study on mapping, (IEEP & Alterra, 2010b)

Box 7.10. French Trame verte et bleue - approach to nation-wide green infrastructure mapping

At the national level, a framework document entitled "National directions for the preservation and enhancement of ecological continuities (*"Orientations nationales pour la preservation et la remise en bon etat des continuities ecologiques"*) is prepared and updated by the competent authorities, together with a national « green and blue networks » committee whose members are, amongst others, representatives of local authorities, economic actors, national parks, environmental NGOs. At the regional level, a instrument is prepared which is entitled 'Regional Ecological Coherence Scheme' (*"Schema regional de coherence ecologique"*); this tool implements the national level framework at the regional level and is based on available scientific knowledge, the national inventory of natural assets and the local and regional inventories. The Regional Schemes are to be taken into account in local planning tools.

The government will spend EUR 58 million over the period 2009-2014. According to the impact assessment assessing the costs to the different administrations based on the evaluation of the costs in regions which had already piloted the establishment and management of such a green infrastructure/network (Alsace and Nord-Pas de Calais Regions and the Isère Departement), the size of the annual budgets allocated for authorities involved in projects leading on the development of a green infrastructure is of approximately EUR 600,000 for a regional authority and EUR 200,000 for a district administration (conseil general). These estimates have been produced base on the data from authorities which have already implemented such a project and extrapolation calculations (MEEDDM, 2009).

According to the impact assessment, this measure has no major costs to companies or households, with the exception of operators of large linear infrastructures who will have to integrate the constraints related to the ecological continuity in the context of their impact assessments.

The impact assessment however emphasizes that the costs compare favourably when compared with the benefits linked to the preservation of the ecological services and in particular those linked to the regulation of ecosystems (without however providing an overall quantitative or monetary assessment). Overall, the main benefits of this initiative are likely to be avoided impacts rather than measurable improvements. The mapping, however, also foresees to identify areas where investment in restoration and creation of GI is needed so in some cases it is expected to make a contribution to maintaining the overall coherence of the country's Green Infrastructure and to strengthen in some cases the populations of some plant and animal species
A pilot of the green network was established in 2003 on the plain of Alsace, following a feasibility study in 2001. After a positive assessment of the pilot study in 2006, the Regional Council decided to extend the network to the rest of Alsace.

Between 2003 and 2009, some of the results achieved in the Region Alsace were the creation of 1000 hectares of ecological corridors, the planting of 4000 high stem fruit trees, the restoration of 140 ha of the central nuclei of the network, the implementation of actions to enhance their ecological value by several business parks and housing estates, the creation of 15 km of wildlife passages have been created along the canal between the Marne and the Rhine rivers, financial support to 50 projects led by communities, associations or environmentally-aware farmers, the creation of 2 regional nature reserves (covering 200 ha) and the creation of an urban park was created (covering 12 ha).

Source: MEEDDM, 2009

3 c) Green infrastructure made a priority in the Common Strategic Framework and Regulations governing key EU funding instruments (Cohesion Policy, CAP, LIFE).

Description of measure 3c

The revision of EU funding instruments offers opportunities to both reduce the adverse impacts of a range of funding streams on the natural environment and in particular on Europe's Green Infrastructure and to encourage the delivery of policy objective through ecosystem based solutions when this appears feasible, effective and efficient. The policy changes here would affect Cohesion policy and innovative financing, the future Connecting Europe Facility as well as the CAP spending.

The **Common Strategic Frameworks** (for funds under shared management) may transform the green infrastructure related objective into an investment priority including key actions and focus areas for green infrastructure and outlining the mechanism for funds coordination for an integrated approach to investing in green infrastructure.

The **revised Regulation on laying down general provisions on the European Regional Development Fund, the European Social Fund and the Cohesion Fund** and repealing Regulation (EC) No1083/2006 would include, amongst other, "Enhancing Europe's green infrastructure and ecosystem resilience" in the list of thematic objectives, differentiated co-financing rates would be introduced (higher rate for green infrastructure projects in identified priority areas (cf. maps), create the condition for a more frequent use of LIFE+ integrated management projects, require members states to include stocks of green infrastructure elements in the environmental baseline. Ex-ante conditionalities applying to grey infrastructure projects would apply.

JASPERS could provide technical assistance on the development of green infrastructure projects and/or the inclusion of green infrastructure /biodiversity proofing elements in the feasibility studies of large scale infrastructure. **JESSICA** could be used to support projects delivering energy efficiency improvements through the use of trees and plants to cool urban temperatures, reducing energy needs for cooling (as foreseen by EC's 2011 Energy Efficiency Plan), thereby freeing up grant money under ERDF for non-revenue generating projects focused on ecosystems based climate adaptation projects (mitigation of flood risk and water, air and ecosystem quality).

In agricultural policy, the mandatory character of the agri-environmental measure and minimum spend requirements relating to them are maintained within the **CAP Pillar 2** (rural development). The focus on habitat restoration in agri-environment measures is strengthened. The provisions for Ecological Focus Areas and protection of permanent pasture under 'greening measures' under **Pillar 1** make these measures mandatory and thus contribute to green infrastructure-related management. New mandatory provisions for GAEC standards relating to green infrastructure (eg minimum connectivity elements; wetland protection, permanent pasture, HNV farmland, etc) would positively impact on land use across the EU.

For more detail on how green infrastructure could be made a priority in revised regulation governing key EU instruments in specific policy areas, including in regional policy and innovative financing, transport and energy policy and agricultural policy, please refer to Annex VI.

Insights into economic, social and environmental impacts associated with 3c

Making green infrastructure a priority across a wider range of funding instruments can be expected to result in an increase in investment in the green infrastructure which appears to be of particular relevance considering the objectives of the different funding instruments. Beyond an increase in the proactive investment in green infrastructure (Cohesion Policy) and retribution for the provision of ecosystem services (CAP), making green infrastructure a priority would also involve better taking into account the adverse impacts certain types of investments may have on the green infrastructure and its overall coherence and resilience and ensuring that all feasible options for minimising adverse impacts on green infrastructure are exploited by applicants when they develop their projects (TEN-T). While section 6.2.4 has provided a wider range of evidence of the contribution of green infrastructure to climate regulation and energy efficiency in urban areas, Box 7.11 below provides insights into the benefits associated with ecosystem based climate change adaptation projects. For information relating to natural water retention measures and water provision and purification linked to green infrastructure refer to chapter 6 and in paritcular section 6.3.1. (2).

Box 7.11: Costs & benefits from ecosystem based climate change mitigation and adaptation

Green infrastructure can contribute to climate regulation by protecting existing stores of carbon or reducing the rate of carbon loss, replenishing historically depleted stores by restoring soils and ecosystems, and creating new stores by promoting greater carbon storage/sequestration in areas where this service is currently low (EUCC, 2010).

The peatlands restoration strategy formulated by the state of Mecklenburg-Vorpommern, Germany in 2000 has been shown to yield significant greenhouse gas regulation benefits (Förster, 2010). By 2008, an area of 29,764 ha (about 10% of the area of drained peatlands in Mecklenburg-Vorpommern) had been restored, resulting in avoided emissions of about 300,000 tCO_2-equivalents every year. Assuming a marginal cost of damage caused by carbon emissions of 70 € per tCO_2, the value of peatlands restoration in the area amounts to €21.7 million every year, or €728 per ha.

The Pumlumon project launched in 2007 covers approximately 40,000 ha of upland habitats in the Cambrian Mountains, Wales. The value of the increase in climate regulation services (particularly carbon safeguarding) attributable to the project is estimated at £6.2 million over 10 years (Bailey, 2010).

The findings of a recent study (Naumann et al, 2011) suggest that the two most common EU funding sources used to finance the ecosystem-based approach projects have so far been the LIFE+ and ERDF (INTERREG) programmes. The study also finds that the most frequently EU funded projects fall within the areas of (in order of importance) nature protection, water, agriculture and forestry. Examples presented include the nature protection project “Management of Posidonia, vernal pools and halophytic wetlands in Natura 2000 sites” in Cyprus which was partially funded by LIFE+. The total budget for the four year project was €2,551,277, of which LIFE+ contributed €1,530,766 (60%). In the forestry sector, the project “Transnational Forestry Management Strategies in Response to Regional Climate Change Impacts” project (ForeStClim) has a total budget of €11.6 million budget, of which €5.7 million have been provided by the European Regional Development Fund (ERDF). Another project, ‘RESPONSE’, (“Responding to the risks from climate change - developing sustainable strategies for management of natural hazards in coastal areas taking account of the impacts of climate change”) aimed to develop sustainable strategies for the management of natural hazards in coastal zones in the UK. Its total budget was €1,682,954, of which €841,477 were contributed by LIFE.

Naumann et al (2011) conclude from an analysis of ecosystem based approaches at project level (the study included a total of 153 projects), that that ecosystem-based approaches in Europe have made a strong contribution to climate change mitigation and adaptation and also have the potential to further contribute to these climate goals. Of these 153 projects analysed in the context of this study, 109 were found to implement measures exclusively for adaptation, 15 focused solely on mitigation, and the remaining 29 projects addressed both objectives. According to Naumann et al, this is corroborated by findings from other studies which also found that nearly half of these projects had adaptation as a primary objective whereas less than fifteen percent of projects focused primarily on mitigation.

Source: chapter 6 of present report, In-depth case analysis on Multifunctional use of farmland and forests (Annex I), Naumann et al (2011).

3 d) Biodiversity and climate proofing is streamlined into key EU funding instruments (eg Cohesion Policy, TEN guidelines and Connecting Europe Facility, CAP, etc.)

Description of measure 3d

Biodiversity proofing is streamlined into key funding instruments with potential impacts on green infrastructure for them to fully take into account the conservation of ecosystems, natural resources and biological diversity, and explicitly addresses climate and freshwater security in plans, programmes, policies and sectoral and regional priorities;

Revised regulation on structural funds introduce a scoring system for EU funded projects which (inter alia) supports biodiversity proofing of the budget and require regions and countries submitting applications for projects and programmes to be funded through TEN-T (Connecting Europe Facility) and Regional (Cohesion) Policy to visualise the proposed developments in maps identifying green infrastructure elements according to official requirements (see changes 3b&c above) and are requested to outline the impacts of their proposed programme on the existing green infrastructure network and ecological coherence. Information on green infrastructure stocks and their quality is to be included in the description of the environmental baseline.

Applies to funding under:

- Regional Policy
- Connecting Europe Facility

All applications for Cohesion Policy projects and programmes which involve the development of grey infrastructure (a list is to be provided) undergo biodiversity proofing, along the line of transparent criteria, at EU level. This is to be achieved by expanding evaluation criteria for applications for funding to include green infrastructure relevant evaluation criteria to be integrated in a transparent scoring/ pointing system.

The provisions governing the functioning of the Connecting Europe Facility ensure that:

- biodiversity and climate proofing of investments is systematic,
- green infrastructure has been taken into account when planning a development,
- developers are provided financial incentives to off-set adverse impacts on the green infrastructure and
- members states invest strategically in mitigation of adverse impacts of existing infrastructure.

Insights into economic, social and environmental impacts associated with 3d

The biodiversity proofing of EU spending is thought to lead to increased efforts from project applicants to reduce adverse impacts of grey infrastructure development projects and programmes on the green infrastructure, ecosystems and habitats to an absolute minimum and to undermine the financial viability of the most harmful interventions (by not granting them any funding). With regard to costs, the introduction of this new practice is expected in additional costs to project applicants/developers who will have to put more effort into the quality of EIAs and SEAs, which will have to carried out assessments with an extended scope in view of complying with all the information requirements imposed by the practice of the biodiversity proofing by donors. It will also require more human capacity for EIA/SEA related activities within the relevant authorities. With regard to the benefits of this measure, the avoided loss of green infrastructure will ensure that ecosystem service benefits provided by the green infrastructure which would otherwise have been lost will be preserved. In addition, there may also be additional financial benefits from a better planning and design of projects and programmes upfront which would reduce the risks of challenges in court once the building works are initiated. This would both be due to a better acceptance of the project from better informed citizens and the reduced likelihood that the projects and programmes disregard the need to avoid impacts on the green infrastructure.

Overall the impacts associated with the biodiversity proofing of regional policy, TEN-T and TEN-E projects and programmes is expected to lead to similar outcomes as the revision of the EIA and SEA Directives outlined below. In the long run, this change is expected to result in a reduction of the number of applications for EU funding for as well implementation of projects and programmes with high adverse impacts on biodiversity and ecosystems and to result in funding going to projects which do not undermine ecological coherence and connectivity unless this cannot be avoided at all.

3 e) Revised EIA/SEA Directives

Description of measure 3e

A reform of the EIA and SEA Directives would ensure a fuller consideration of impacts on green infrastructure and its coherence (eg expanding to any projects and programmes which have impacts on any green infrastructure element while adapting the depth of EIA to the scale of development to ensure effort is proportionate to likely impact). This would de facto mean an expansion of the **scope** of the cases in which a EIA/SEA has to be carried out could be expanded/ further harmonised (eg requirement for a wider range of developments (ie smaller projects), requirement for using SEA when developing spatial policies and plans; systematic requirement for EIA/SEA for any EU funded project or programme which may affect any type of green infrastructure element to be subject to EIA/SEA) and the impacts to be considered (eg could be expanded to include impacts on all green infrastructure elements and/or to take into account impact on overall coherence and ESS, in particular in view of a better consideration of the requirements of Art. 6(3)-(4) of EU's Habitats Directive).

The revision of EIA/SEA Directives would make the guidance under option 2 a fuller part of EIA/SEA processes. For example, the adequate consideration of vulnerability to climate change when developing spatial plans. The revised EIA/SEA Directives would in particular require that green infrastructure maps be systematically used when presenting alternative options under consideration and that the ecosystem services associated with the green infrastructure elements potentially impacted be identified. Also, measures to avoid, reduce, mitigate and compensate non-evitable impacts on landscape larger range of landscape connectivity features and in particular the deterioration of key "ecological continuities"/connectivity elements should be systematically foreseen, also for smaller scale developments, as these do not have to be overly expensive to achieve positive results. Preferred options should tend towards no net loss of key green infrastructure elements and be those which undermine the overall coherence of the green infrastructure least and which minimise the fragmentation of the green infrastructure.

Insights into economic, social and environmental impacts associated with 3e

The adverse effects of grey infrastructure on ecosystem fragmentation are still important and better planned projects and more carefully designed programmes and plans which would effectively seek to avoid impacts on the green infrastructure upfront would both reduce the loss of the most valuable green infrastructure elements and safe costs associated with ex-post defragmentation measures. While the multi-annual defragmentation plan in the Netherlands (see Box 6.13, chapter 6) demonstrates that defragmentation measures can play an important role in addressing the adverse impacts of transport networks, it also provides an illustration for the significant capital costs which such measures involve. Box 7.12 provides further data on the practice of EIA and SEA and gives a grasp of the potential economic implications of such changes as well as their environmental benefits which would result from an expansion of the scope of both Directives.

Box 7.12: Main results of EC study on costs and benefits of EIA

The general findings of a recent study provides insights into the scale of the impacts such changes to the EIA/SEA Directives could have as well as insights into which groups primarily bear the costs (GHK, 2010):

- There are some 16,000 EIAs each year across the EU-27
- There has been a general increase in the number of EIAs undertaken each year from 2005 to 2008, with the exception of the UK and Estonia
- There is a strong variation in the number of EIAs undertaken annually across the MS but the number of EIAs is broadly correlated with the size of the MS population
- New MS appear to undertake a greater proportion of development projects relating to energy, water and waste infrastructure in comparison with the MS relating to the development stage they are currently at;
- There is very little information on the types of developers which are undertaking EIAs and data provided exhibits no particular (eg SMEs constituting a high proportion of developers)

An increase in number of EIAs and SEAs would undoubtedly impose some additional administrative costs to competent authorities. It must be pointed out that the number of EIAs would not necessarily increase proportionally to the enlargement of the scope however as the consequences in term of additional administrative costs/resources required depends very much on the implications of the provisions which would be added. While some might require that more EIAs and SEAs be carried out, others will only require that in a certain number of cases there cover additional aspects.
Also, since the EIA procedure is just one element of an often complex consenting process, the specific costs are hard to separate from the wider consenting cost. This cost may in some cases, depending on MS and Competent Authority, be wholly or partly recovered through charges on the developer for processing the development application (GHK, 2011).

The average cost of an EIA to (public and private sector) developers as a percentage of project development costs is about 1%. The average cost of an EIA based on data supplied by MS is roughly €62,000. Based on the estimated total number of EIAs per year in the EU- 27, multiplied by the average cost per EIA, the total EU expenditure per annum by developers is approximately €976m. In addition there are the administration costs of the Competent Authority and the costs to stakeholders of participating in public consultation (GHK, 2010).

The total project costs to developers in the case studies examined ranged from €4 million and €2.38 billion, indicating the very broad range of projects that the EIA regime covers. EIA cost as percentage of project cost ranged from 0.01% to 2.37%, suggesting that the EIA process absorbs a relatively modest cost in comparison with overall development costs.

Previous and more recent case study work indicates that environmental benefits include (GHK, 2011):

- The prevention of negative environmental impacts
- The identification of appropriate measures to mitigate impacts through the design of the scheme
- Raising the profile of the environment in the decision-making process when determining development consent
- Enabling of detailed modelling and evaluation of impacts

- Deciphering the cost and benefits through different measures by option development
- Simplifying the process of environmental assessment and reducing the administrative burden of having to deal with different authorities for different aspects of the development application.

A previous study commissioned by DG ENV found that all EIA processes had assisted decision-making, in one or more of the following ways (IVM, 2007):

- key environmental issues had been identified in 94% of cases
- the quality of the project design had been improved in 83% of the case studies
- higher standards of mitigation had been achieved than would otherwise have been expected in 83% of cases
- a better framework for preparing conditions and legal agreements to govern future operation of the project had been provided in 72% of cases
- environmental concerns had been incorporated from an earlier stage in the design process in 61 % of cases
- better decision- making had been achieved in 61% or more of the case studies due to :
    - a more systematic and structured framework for analysis,
    - more objective and credible information,
    - increased rigour in evaluating environmental information,
- the environmental credibility of the developer had been enhanced in 61% of cases,
- environmentally sensitive areas had been avoided through project re-siting or re-design in 56% of cases

Sources: GHK (2010), IVM (2007)

3 f) Range of sector specific changes to the current legal framework

Description of measure 3f (1): Revision of Habitats Directive

Should the Habitats Directive undergo a revision, this could be seized as an opportunity to introduce a selected number of changes to enhance its effectiveness in preserving the backbone of Europe's green infrastructure: projected areas. This would be achieved in particular by clarifying a selected range of articles and emphasizing the need for proactive steps towards coherence of the Network, to improve monitoring measures and adopt long-term funding strategies. More specifically, the Habitats Directive could undergo the following revisions: Article 3 of the Habitats Directive to require all MS to assess coherence and develop actions plans to tackle deficiencies. Require MS produce site management plans for all Naturta 2000 sites that identify coherence needs for vulnerable species and ecosystem processes; Habitat Directive revised to ensure the ecological impacts of Art 6.4 compensation measures are adequately monitored and to ensure MS adequately consider coherence issues in Appropriate Assessments; Requirement for MS to produce long-term funding strategies that are adequate to meet the objectives of the Directives.

Insights into economic, social and environmental impacts associated with 3f (1)

This set of changes would be expected to somewhat increase the management of the Natura 2000 network they are considered key for an effective implementation which is essential if the network is to become reality and yield an optimal level of ecosystem benefits and to be resilient to climate change. Section 6.2.1 of this report provided a brief summary of the costs and the benefits associated with the Natura 2000 network and protected areas more generally.

Description of measure 3f (2): Future EU Water Blueprint

The Future EU Water Blueprint could call for opportunity costs of natural water retention measures to be systematically considered and where relevant translated into land acquisition, compensation or service payments. The Water Blueprint would assess introducing fair and efficient water pricing policies to ensure that major water users adequately contribute to the financial and environmental resource costs of water services but also identifies EU funding instruments which can support investigation and implementation of ecosystem based solutions such as natural water retention measures (ie development of maps and models taking into account green infrastructure aspects are developed, such as river banks, wetlands, but also storm water in addition to the water quality and hydromorphology (ie maps in RBMP, mapping of water quality for the Bathing Water Directive). The EU Water Blueprint would make clear reference to the EU funding instruments which may support ecological flood risk management linkted to the Floods Directive as well as River Basin Management and Integrated Constructed Wetlands following best practice examples in the use of green infrastructure.

As a result the revised Water Framework Directive calls for the authorities responsible for the development and implementation of River Basin Management Plans to ensure that fair water pricing is introduced and that some of this money is invested into securing availability of water and improving its quality through appropriate creation and management of green infrastructure (ie through acquisition of land, compensation or establishment of PES-schemes at the river basin scale).

Insights into economic, social and environmental impacts associated with 3f (2)

In a range of cases ecosystem based water provision and purification as well as natural water retention measures (flood risk mitigation) can prove more cost-effective than alternative approaches, as illustrated in 6.3.1 of this report, which illustrated the benefits of using green infrastructure for water management purposes and to address both issues relating to quantify (flood risk management) and water quality (water purification). Ecosystem based solutions are not thought to result in higher costs initially and in many cases perform better with regard to recurring costs in the long run.

Description of measure 3f (3)

The Marine Strategy Framework Directive (MSFD) has a very detailed set of actions to be undertaken by MS to achieve Good Environmental Status (GES) by 2016 - these could be revised to include green infrastructure explicitly. Mapping of ecosystems and Marine Protected Areas could be added to the reporting requirements of the MSFD - MS required to report every 3 years under the MSFD - opportunity to harmonise impact objectives and include green infrastructure elements. Indicators of green infrastructure benefits could be included in MSFD, some overlap inevitable with indicators of GES. MS are required to notify the Commission of the environmental targets, determination of good environmental status and monitoring programmes. Article 12 requires the Commission to assess (within six months of notification) whether these elements constitute an appropriate framework to meet the requirements of Directive 2008/56/EC and may ask the Member State concerned to provide any additional information that is available and necessary;

Insights into economic, social and environmental impacts associated with 3f (3)

A wide range of jobs depend on the fisheries sector in Europe. If the deterioration of fish stocks continues at the current rate, the sector will face important challenges. The creation of Marine protected areas has in some cases proved to be effective in diversifying income opportunities of communities which are heavily dependent on fishing (ie by creating alternative sources of income such as tourism and alternative occupations in areas related to the management of the protected areas). On the other hand, marine protected areas have also proved to put the fishing activities on a more sustainable basis in the long run, by providing, in some cases, fish nurseries and allowing fish stocks to replenish. The careful and ecologically sound creation of (warm water and cold water) coral reefs has in some cases effectively enhanced wildlife and attracted divers and snorkelers.

Box 7.13: Positive effects of marine protected areas and marine Natura sites on overexploited fish stocks.

Marine Protected Areas (MPAs), as part of a wider network of connected marine areas, can have positive effects on overexploited fish stocks, as well as support a range of regulating and cultural services. A first cut illustrative estimate for the benefits of increasing MPA coverage to 10% of the EU marine area is that this could deliver improvements valued at €2.5-3.8 billion per year in 7 services and €1 billion per year of off-site fisheries benefits.

The value of benefits delivered by the marine area currently protected by the network (equivalent to 4.7% of the EU's marine area) can be estimated to be approximately €1.4-1.5 billion per year. This would increase to €3.0-3.2 billion per year if 10% of the sea area were protected, and €6.0-6.5 billion per year for protection of 20% of the sea area. The higher figures apply to stronger protection measures

This should be seen as a ball park value, illustrative of the importance of this issue. To obtain more robust results would need an improved understanding of how protection will influence habitats, services and off-site fisheries; the level to which benefits will depend on details of protection; and network effects.

Source: Tinch in ten Brink et al (Forthcoming)

7.2.4 Option 4: Comprehensive, dedicated EU legal instrument(s)

While in substance, this option involves very much the same measures to integrate Green Infrastructure into existing EU policy instruments as defined in Option 3, the cross-cutting legislation introduced provides for an overarching framework within which this process of integration into existing EU policy and instruments is co-ordinated.

Overview of changes - Option 4

4 a) Binding "Green Infrastructure Implementation and Restoration Directive" Directive implementing no net loss/net benefit gain principles
4 b) EU TEN-G fund is set up
4 c) Establishment of an EU-wide Habitat banking scheme[34]
4 d) European Payment for ecosystem services system (EPES) established
4 e) Permanent expert group of which all MS are part

4 a) Binding "Green Infrastructure Implementation and Restoration Directive" implementing no net loss principle

Description of measure 4a

All measures foreseen under option 2 and 3 are announced. In addition to measures foreseen under option 2 and 3 it also includes, in view of implementing the no net loss principle, a range of clear targets and objectives and additional measures to support them. The two main potential principles could be:

- **no net loss** of key green infrastructure elements, which could require MS to incorporate biodiversity "offsets" for all residual impacts from developments on green infrastructure (ie EU policies to be revised to require that green infrastructure adversely affected by developments is compensated for elsewhere); Legal requirement for compensation measures that ensure no-net-loss of biodiversity from the impacts of all projects and programmes.
- **net positive gain**: providing a framework for positive action and cost effective investment into green infrastructure development/creation and delivering public goods.

With regard to binding objectives and targets the Directive could require MS to:

- Safeguard ecosystems and the adequate provision of associated valuable ecosystem services in appropriate locations, and increase the resilience of those that are vulnerable to climate change and other pressures.
- Contribute to the restoration or enhancement of undersupplied ecosystem services in appropriate locations.
- Ensure the Natura 2000 network and other supporting core areas (eg national protected area / ecological networks) are sufficiently coherent (ie adequate in terms

[34] as a means to off-setting for green infrastructure elements deteriorated/destroyed when creating grey infrastructure (Habitat banking should only be considered in those cases where primary remediation is not feasible or all on-site compensation options have already been explored within impact regulation procedures). See eftec, IEEP et. al (2010) The use of market-based instruments for biodiversity protection – Thecase of habitat banking – Summary Report. URL: http://ec.europa.eu/environment/enveco/index.htm

of size and representation and functionally connected) and resilient (eg to climate change) that habitats and species of Community interest are maintained or restored to favourable conservation status.

- Contribute to no-net-loss of biodiversity in the wider environment by avoiding and reducing the impacts of habitat loss, fragmentation and degradation, through appropriate mitigation measures and compensation for unavoidable residual impacts (eg by habitat restoration of degraded habitats).
- Contribute to the restoration of biodiversity, particularly where this increases the resilience of habitats and species that are vulnerable to climate change and other pressures (such as habitat fragmentation).
- Set binding targets for forests, such as:
  - maintain and restore favourable status of all forests in the EU by 2020 and making them resilient against harmful impacts (climate change adaptation) so that they can continue providing multiple benefits to society. This target could be pursued in a regionally differentiated way and could support the coordination of regional approaches depending on forest types in order to optimise the provision of forest ES.
  - Designation of 20 per cent of multifunctional forests within public forests by 2020 in order to maximize most needed non-provisioning services in certain regions such as carbon sequestration, water quality and quantity regulation (eg near important drinking water reserves), erosion control (eg in mountains), climate regulation (eg near cities); Achieving this target might in some cases involve creating new forests.

<u>Range of specific objectives</u>:
The Directive could require MS to:

- Develop green infrastructure strategies, setting out targets for the protection, maintenance and restoration of green infrastructure within their territories
- Establish indicators, monitoring and reporting systems covering trends in the extent and condition of green infrastructure;
- Take steps to integrate green infrastructure into spatial planning.

Insights into economic, social and environmental impacts associated with 4a
Option 4 – with a new and binding EU Directive on green infrastructure at its heart – can be expected to deliver the highest level of benefits – but also the highest levels of costs – of the four options.

Option 4a is the only option capable of ensuring achievement of the target of no net loss of green infrastructure and ecosystem services it provides. While Option 2 encourages the protection, maintenance and enhancement of green infrastructure, it cannot guarantee that this will take place. Option 3 – though it introduces specific measures to enhance green infrastructure through integration into EU policies – does not provide a comprehensive approach and applies only to existing EU policy areas. By comparison, Option 4 requires MS to take action to achieve no net loss and sets binding targets requiring them to do so. This should ensure the maintenance of the overall stock of green infrastructure in the EU, and the range of provisioning, regulating and cultural services it delivers to society.

The costs of Option 4, and particularly Measure 4a, are also significant. They include:

- The costs to MS of developing strategies, implementing targets and regulating activities affecting green infrastructure, in order to achieve no net loss;
- The costs of protecting, maintaining, creating and restoring green infrastructure in order to achieve no net loss.

Achieving no net loss will require MS to introduce a requirement to offset damage to green infrastructure caused by development and other activities. In England, Defra is currently examining options for the introduction of a system of biodiversity offsets, and has examined the costs of achieving this (Box 7.14).

Box 7.14: Benefits and costs of biodiversity offsets in England

In England, Defra has proposed the introduction of a system of biodiversity offsets, in order to achieve a target of no-net loss of biodiversity from development. This is due to be piloted by local authorities in 2012. While the planning system already encourages compensation for losses of biodiversity through development, the actions undertaken are currently too fragmented and inadequate to offset current losses of biodiversity through development.

Defra considers that biodiversity offsetting has the potential to improve the delivery of the requirements of the planning system relating to biodiversity. A consistent framework for offsetting could:

- Enable resources to be used more effectively to deliver greater biodiversity benefits. Local planning authorities, working with their partners and specialist offset providers, would be able to identify how to use resources most effectively.
- Encourage specialist offset providers to come forward. This would help ensure the effective, long-term management of sites by organisations and people with the right expertise.
- Streamline the process for all involved. Consistent approach to offsetting could provide a efficient way to assess the impact of a development and agree the requirements for compensation.

Defra commissioned GHK and eftec to assess the potential costs of delivering offsets in England. The study modelled offset requirements based on projected changes in land use and development, and assessed the costs of habitat restoration and creation work required to offset these losses. The costs were estimated at between £50 million and £400 million annually, varying according to the requirements of the policy and the metrics applied to assess offset requirements.

GHK estimated that the benefits of the policy would be to create or restore between 5,400 and 16,900 hectares of priority habitats annually by 2015, at an overall average cost of between £8,100 and £25,500 per hectare in present value terms, depending on whether or not land is purchased. This would halt the loss of biodiversity due to development and make a substantial contribution to biodiversity conservation in England. The annual expenditures involved represent between 15% and 115% of the overall estimated annual costs of delivering Habitat Action Plans in England. The estimated costs of biodiversity offsets amount to between 0.1% and 0.8% of the overall value of new build development annually.

Source: GHK and eftec (2011)

Establishing specific targets for particular types of ecosystems, such as forests, can enhance the delivery of particular ecosystem services. For example, forests are protected in Austria in order to deliver regulating services such as protection against soil erosion and natural hazards (Box 7.15).

Box 7.15: Protection Forests in Austria (Bann- und Schutzwälder in Österreich)

Approximately 780,000 ha (20 per cent) of Austrian forests are classified as 'protection' forests (Bann- und Schutzwälder), by the Austrian Forest Act. The primary objective is not the conservation of biodiversity, but the protection of forests which play an important role regarding the benefits provided to human well-being, particularly regarding their protective function (eg natural hazards control), their value for recreation and tourism and general socio-economic functions. The status 'protection forests' limits the use of forests for timber production or sets requirements for the application of specific silvi-cultural measures.

According to the Austrian Forest Act, protection forests are divided into:

- Site-protection forests, are issued to protect the site itself, eg. to halt soil erosion
- Object-protection forests, are forests which protect humans, human settlements or agricultural areas
- Protective forests per se are forests whose use is restricted for the provision of a protective function against natural hazards (eg, avalanches, wind) or services (eg climate regulation, water provision).

Different requirements apply depending on how the forest has been classified. Timber production is still allowed for the first categories as long as they do not impact the stability of the forest ecosystem. Timber production might be strongly limited for Bannwälder, as the welfare value of limiting the use is considered higher than the value associated with its use. The owner of the site-protection forests is required to cover costs arising from the management of those areas through revenues arising from timber production in the same area. Owners of object-protection forests are required to carry out the management of those forests in so far the costs are covered by public entities, and has the obligation of reforestation. The owner of a protection forest per se is entitled to compensation measures if the classification leads to income forgone. In the framework of the initiative 'forests protect humans' the Federal Ministry of Agriculture, Forestry, Environment and Water Management (BMFLUW) is committed to investing €10 million in afforestation and restoration measures every year starting in 2010 (Tiroler Tageszeitung, 2011).

In 2010, €275 million were invested in 1,900 projects across Austria for the protection against natural hazards, €160 million of which were covered by the BMFLUW (Tiroler Tageszeitung 2011). According to the ministry, without protection forests additional € 600 million would need to be invested in technical solutions every year to achieve the same level of protection against natural hazards such as avalanches, rock slides. In the regional state of Tirol, the value of the protective function of those forests were estimated at €100,000 per ha.

Source: In-depth case analysis on Multifunctional use of Farmland and Forests, Annex I

4 b) EU TEN-G fund is set up

Description of measure 4b

Under the Connecting Europe facility, a EU TEN-G fund is set up and provides funding in particular for cross-border projects which contribute to meeting objectives pursued in a wider range of policy areas. The fund would also finance projects to facilitate the implementation of the Green Infrastructure Framework Directive, in particular mapping, accounting and capacity building for actors meant to implement new requirements in specific sectoral policy areas; include provisions for land purchase by public authorities under the TEN-G fund to enable creating connectivity components on land currently under ownership that does not allow for such conversion; Creation of a special programme for habitat restoration with specific objectives under TEN-G Fund; creation of a permanent management committee for the TEN-G Fund; Reporting on implementation of TEN-G fund. Given the widespread nature of green infrastructure and likelihood of limited resources, eligible projects would have to be of a strategic nature and designed to promote sharing of best practice in aspects of the implementation of the Directive.

MS could be asked to set up national funds to finance ecological restoration activities and creation of green infrastructure, with support to projects being implemented in areas where the mapping has identifies the need for new ecological continuities and green infrastructure elements (because of gaps/bottlenecks in the network). PES-schemes, governed by land management contracts between the fund governing body and land owners may also be financed. EU provides guidance on how income for the fund can be generated. The choice of the portfolio of income sources is at MS discretion but some MS funds are generated by the Connecting Europe Facility (see CEF below).

Insights into economic, social and environmental impacts associated with 4b

The benefits of a TEN-G fund would include that it would:

- Enhance the creation and restoration of green infrastructure in the EU, by contributing to the capital costs of green infrastructure provision;
- Fund the delivery of strategic green infrastructure projects, capable of delivering substantial benefits at EU scale;
- Signal the EU's commitment to green infrastructure alongside grey infrastructure, raising awareness of its ability to deliver benefits at the EU level, and emphasising the strategic benefits of green infrastructure investments to Europe's economy and society;
- Catalyse the development of an EU wide green infrastructure network, rather than a series of individual networks in the MS;
- Work alongside major grey infrastructure projects – eg trans-European transport networks – to counteract their negative impacts – for example by proving green bridges and corridors to address habitat fragmentation.
- Encourage collaboration between MS in strategic green infrastructure projects.

The main costs of the fund will depend on the level of finance provided; these costs will be matched by the investments in green infrastructure funded.

Box 7.16: The Alpine Carpathian Corridor – A Strategic Green Infrastructure Project

The Alps and the Carpathians provide habitats for a variety of large wild animals such as deer, lynx, wolf and bear – species that nowadays strongly depend on humans for the conservation of their natural habitat. The corridor between the Alps and the Carpathians as a traditional migration route. In the context of the Alps-Carpathians corridor, a transboundary project financed by EU funds, several actors collaborated with the aim of implementing activities to improve ecological connectivity. These actors, from nature protection and landscape planning, cooperated with partners from transport, agri- and silviculture, hunting or tourism and the concerned communes. The project supports the aims of the Alpine Convention and constitutes, besides the Danube and the Green Belt along the former "iron curtain", a major migration route of European importance.

The project has already achieved the mapping and designation of the Alpine-Carpathian corridor, covering 10,000 ha. Current and future management tasks will ensure the continued protection of this area, thereby safeguarding the habitat and enabling the migration of and genetic exchange between wild animal populations. Furthermore, after the three planned green bridges are constructed, the negative effects of landscape fragmentation from motorways will be diminished. Additional planned activities such as the restoration of forest zones within the corridor to serve as stepping stones will provide even greater connectivity benefits for affected wildlife species.The project is estimated to have incurred costs of €4.9 million between 2002 and 2012, of which €3 million relate to the provision of a green bridge, and just over €1 million to planning, surveys and preparatory studies. There are plans to provide further green bridges in future, at an estimated cost of €3-4 million each.

Source: http://www.alpenkarpatenkorridor.at/

4 c) Establishment of an EU-wide Habitat Banking Scheme

Description of measure 4c

In order to implement the requirement for no net loss of green infrastructure, the Directive could require MS to introduce a requirement for green infrastructure offsets. Such a scheme would require any developments that reduced the scale or quality of green infrastructure to be accompanied by additional measures designed to enhance green infrastructure on another site, through creation and/or restoration measures. Metrics would be specified, taking account of the condition and importance of the green infrastructure degraded or enhanced, as well as issues such as risk, uncertainty and time preference, in order to implement the principle of no net loss. Application of such metrics would mean that the offset requirement could be more (or potentially less) in extent than the green infrastructure damaged through the development. Habitat banking – which involved green infrastructure restoration or creation schemes designed to meet offset requirements – could be encouraged to assist the implementation of the policy[35]. Such an offsets scheme would play an important role in implementing the no net loss principle, subject to a requirement that it should not be seen as a justification for relaxing protection of existing green infrastructure.

Insights into economic, social and environmental impacts associated with 4c

The main benefit of a habitat banking scheme will be to facilitate the delivery of offsets required to achieve no net loss of green infrastructure.

Habitat banking will allow developers and others engaging in activities that result in the loss of green infrastructure to offset these losses by purchasing credits from green infrastructure providers. Credits may be issued for actions to restore or create habitats or other green infrastructure elements in other locations. Providing that credits are issued for additional conservation activities (rather than habitats that would have been created or restored even if there was no offset requirement), and relate to green infrastructure of equal or greater value to that lost, then habitat banking can help to achieve no net loss of green infrastructure.

Habitat banking is not the only means of delivering offsets and hence achieving no net loss of green infrastructure. There are alternative options, such as the developer undertaking his own actions to offset green infrastructure losses, or entering a negotiated agreement with a third party. However, habitat banking has the potential to deliver a number of benefits:

- By encouraging green infrastructure to be created or restored prior to losses occurring, it can increase certainty that compensatory activity will deliver green infrastructure of at least equal value to that lost;
- By allowing flexibility regarding the location and method of compensatory activities, it encourages cost effective solutions to green infrastructure provision;
- By encouraging the emergence of green infrastructure providers with suitable land and appropriate expertise, it encourages creation or restoration of green infrastructure by those best qualified to do so; and

[35] as a means to off-setting for green infrastructure elements deteriorated/destroyed when creating grey infrastructure (Habitat banking should only be considered in those cases where primary remediation is not feasible or all on-site compensation options have already been explored within impact regulation procedures). See for example eftec, IEEP et. al (2010) The use of market-based instruments for biodiversity protection – The case of habitat banking – Summary Report. URL: http://ec.europa.eu/environment/enveco/index.htm

- By developing common standards for the award and sale of credits, and standardised certification systems, it helps to encourage efficient systems of monitoring and regulation of offsetting activity.

Therefore habitat banking can be a cost effective means of securing the benefits delivered by the no net loss requirement outlined in option 4a.

Experience of habitat banking in France (Box 7.17), Germany and the UK offers potential insights and lessons which could inform the development of a scheme at EU level.

Box 7.17: Habitat Banking – a pilot scheme in France

To assess the potential of habitat banking in France, CDC Biodiversité, the French Ministry of the Environment and regional government agencies launched a pilot experiment in 2008. The habitat banking approach seeks to anticipate potential demand through financing positive actions for biodiversity before the damage from development occurs, which will be used for compensation at a later stage.

The pilot site is located in the Plaine de Crau, in the Provence-Alpes-Cotes d'Azur (PACA) region in the Western part of Marseille. It is the last semi-arid steppe in Western Europe and contains several rare and threatened species of bird (Pin-tailed Sandgrouse, Little Bustard, Lesser Kestrel etc.), insects (endemic species of grasshopper) and plants. These steppes used to cover 40,000ha (98,842 acres) in the 17th century and only 11,500ha (28,417 acres) were remaining in 1990, which are partially fragmented due to human activities. Multiple factors are driving the degradation of this habitat, including fragmentation by road infrastructure, development, agricultural intensification, and pollution.

CDC Biodiversité bought a 357 ha plot in September 2008, in accordance with local and national environmental agency, to serve as the first in situ experiment of habitat banking in France. Through this project, CDC Biodiversité has committed to providing biodiversity offsets by converting abandoned orchards into grazing pastures and managing them sympathetically in the long term, for the benefit of endangered birds and other wildlife. These activities are designed to compensate for future losses from development. By offsetting the impacts of several developers it is hoped to achieve a more coherent approach to compensation and better conservation outcomes.

If successful, this pilot project will demonstrate the benefits from the banking mechanism: effective offset measures before the impact on biodiversity occurs, secured finance and land tenure through long term contract with the project developers, aggregating several offsets to have more coherent actions and larger-scale conservation outcomes and building field knowledge and experience. Moreover, it will also be an opportunity to think or develop an offset scheme with biodiversity offset banks at national level and develop partnerships with project developers to invest in habitat banking.

Source: eftec (2010) The use of market-based instruments for biodiversity protection - Habitat Banking case studies

4 d) European Payment for ecosystem services system (EPES) established

Description of measure 4d

A legal framework for a European Payment for ecosystem services system (EPES) is provided to support cross-border ecosystem benefits (eg carbon storage). This would aim to ensure that land owners (eg private forest owners) have longer term financial incentives to raise management practices to well above the minimum standards, rewarding them for providing public goods; The EPES would be mainly supported by public money from EU and Member State sources as it is difficult to single out a group of beneficiaries. In the future, however, the EPES scheme could also integrate other players or consumers (eg water companies or carbon traders). To avoid this only becoming an additional burden for the State's budget, guidance is be provided to MS on how to best use resource pricing to recuperate part of the costs from users.

This measure would need to recognise existing PES type schemes operating within the EU, such as agri-environment and forest environment measures funded under EAFRD. EAFRD could therefore play a catalytic and gap filling role, covering situations where ecosystem services are identified but there are gaps in the ability to reward them under current financing mechanisms.

Insights into economic, social and environmental impacts associated with 4d

Green infrastructure delivers a wide range of ecosystem services that benefit the economy and society. However, unless land owners and land managers are rewarded for the delivery of these services, the incentive to deliver them is reduced. This market failure can lead to the under-provision of green infrastructure.

Market failure may result for different reasons. For example, many ecosystem services (such as climate regulation and the cultural services related to biodiversity) have strong public good elements and are therefore underprovided by markets. In other cases – such as the role of ecosystems in water purification – it may be possible to identify green infrastructure providers and beneficiaries, but there may be barriers such as imperfect information or the difficulty of co-ordinating service provision, that prevent the formation of markets.

Payments for ecosystem services (PES) are a mechanism for rewarding the delivery of ecosystem services, and hence incentivising the maintenance and enhancement of green infrastructure. PES schemes already operate widely in the EU. For example, agri-environment schemes reward farmers for managing agricultural land in ways that delivers benefits to society. However, a comprehensive PES scheme that rewards all forms of ecosystem services by all types of green infrastructure is currently lacking. A new, EU wide PES scheme could help to fill the gaps in the payments for ecosystem services currently available. This would help to enhance the delivery of a range of services, especially regulating and cultural services for which markets are less likely to develop.

The main costs of PES schemes relate to the costs of the payments themselves. There are also significant costs in administering, establishing and regulating PES schemes. An EU wide scheme would require significant resources to be devoted to mapping green infrastructure, assessing ecosystem service delivery, identifying gaps in existing schemes, designing payments, matching providers and beneficiaries, and administering and regulating the scheme.

The National Forest scheme in the UK has used a variety of incentive measures to encourage the establishment and restoration of forests and other habitats (Box 7.18).

Box 7.18: National Forest, UK

The National Forest in central England is a major woodland expansion project which has used a variety of incentive measures to encourage the large scale creation and restoration of woodlands and other habitats in order to provide a range of benefits for society.

The initiative has supplemented funding available through the national Woodland Grants Scheme and EU-funded agri-environment programme with targeted measures to enhance rates of woodland creation and to encourage the development of forest related businesses.

Eftec (2010) was commissioned by the UK Department for Environment, Food and Rural Affairs (Defra) to assess the costs and benefits of the UK National Forest project. The analysis focused on the public benefits gained as a result of the public funds invested this long term woodland creation project in central England over the period 1990 to 2100. This long time-scale was necessary to appraise fully the benefits of forest development, which involve decades for trees to mature and their full benefits to be realised. The present value (PV) of costs and benefits over this period was estimated using a discount rate of 3.5% (for costs and benefits up to 30 years into the future), 3.0% (years 31-75) and 2.5% (years 76-100).
The costs of the project include the annual grant in aid from Defra to the National Forest Company (NFC) and Forestry Commission grants. The costs over the 1990 to 2100 period were estimated to have a present value of £188 million (€210 million).

The following categories of benefits were assessed, using benefits transfer and market pricing methods:

- Regeneration – The benefits of the forest to the regeneration of the area were estimated at £0.05 per household per hectare of forest created, giving a PV of £39 million (€44m);
- Biodiversity, wildlife and non-use values – PV of £50 million (€56 million);
- Landscape – The contribution of woodland to landscape enhancement was valued using estimates transferred from other studies, of £400/ha in peri-urban and £40 per ha in rural areas, giving a PV of £51 million (€57 million);
- Recreation – The number of recreational visits to the area was modelled an valued at £12.50 per visit for “high access” visits (with facilities and interpretation) and £2.50 per visit for informal “low access” visits, giving a PV of £561 million (€628 million);
- Carbon sequestration – The study modelled rates of carbon sequestration and valued these at £50 per tonne of carbon, giving a PV of £187 million (€209 million); and
- Timber production – The value of timber production was estimated using forecast yields and market prices to have a PV of £10 million (€11 million).

Some other potential benefits (water supply, purification and regulation; air quality; cultural heritage benefits) could not be valued. The authors suggested that these could be significant but were likely to have lower value than those estimated. The benefits were estimated to have a total present value of £909 million (€1017 million), exceeding the costs by £721 million (€807 million), and giving an estimated benefit: cost ratio of 4.8 to 1. The benefits were also found to exceed the costs by a factor of 2.6 to 1 over the 1990 to 2010 time period; the benefit: cost ratio was therefore found to increase over time. These overall conclusions were not found to be sensitive to the individual assumptions employed.

Source: Nauman et al (2011)

4 e) Permanent expert group comprising all MS

Description of measure 4e

This measure would be introduced in view of dealing with potential challenges arising from the institutional innovations proposed under 4e. Rather than using the OMC, a permanent expert group of which all MS are part would be set up. It would meet on a regular basis to exchange information on best practice and assess progress towards implementing national Strategies (or framework law) through Action Plans identifying the key necessary measures for a better consideration of green infrastructure across all policy areas and other supporting cross-cutting measures to be put in place. Participants are generally MS representatives responsible for green infrastructure implementation at MS level but MS are encouraged to send representatives from Ministries other than the Ministry of Environment depending on the issues on the Agenda since the issue of integration into key policies is discussed and the different approaches to transposing the changes are compared.

Insights into economic, social and environmental impacts associated with 4e

The costs associated with this change are primarily thought to be transaction costs. The main costs relate to the administration of the expert group at EU level, and the costs of time, travel and subsistence incurred by participating experts in the MS. The benefits associated with having a permanent framework are particularly important for the MS which have not the capacity to take the lead in experimenting with green infrastructure implementation as it allows them to benefit from the experience of front-runners/vanguard countries.

The benefits of this measure include:

- More effective approaches to green infrastructure provision, as a result of sharing of experience and best practice;
- Enhanced cost effectiveness of green infrastructure, by encouraging more efficient approaches to be adopted;
- Enhanced learning at the EU level regarding the measures that can be taken to facilitate the delivery of the green infrastructure strategy;
- Improved co-ordination of Member States actions, helping to deliver a more integrated green infrastructure network in the EU.

Overall, therefore, the measure should help to strengthen green infrastructure provision and maintenance and hence facilitate the delivery of the benefits of achieving the no net loss target in Measure 4a.

8 OVERALL ASSESSMENT OF OPTIONS 1-4 AND SYNTHESIS

The previous Chapter focused on describing the policy options for developing an EU Green Infrastructure Strategy, how they might work, which changes they would include and provided, where possible, insights into the their potential impacts. For each one of these options, presented in the previous sections, a synthesis assessment of the likely economic, environmental (with a focus on biodiversity and ecosystem service benefits), social and governance impacts up to 2030 are identified. These synthesis assessments draw on the evidence reviewed in the previous chapters and the more in-depth assessment in Annex VII. This is followed by a synthesis overview table across all options (1-4) and a final comparison across all four options. The reference point, ie an insight into the existing stock for each one of the green infrastructure elements, their current quality and recent trends was presented in section 2.5 of this report.

A 2030 dateline is used for the assessment because this comprises the halfway point between the date the biodiversity target was set and the 2050 biodiversity vision target. The shorter 2020 target has not been chosen as the focus of the analysis because it is considered that it would be too short a times-scale to provide a useful assessment. This is because many green infrastructure initiatives will require at least 10 years to be planned and implemented and then to have a significant ecological impact. A discussion and identification of impacts foreseen which could be felt as early as 2020 is however included in each one of the assessments.

The overall impacts of each one of the options cannot be determined with precision, largely because the exact scale and intensity of some actions (eg spending) is uncertain under each option. It is also uncertain how ecosystems will react to some of the measures, especially in the face of future pressures (such as climate change) that are likely to increase to some extent. Nevertheless, where possible, we have based our assessments on quantified indicative estimates with respect to 2011 reference point. As still visible in Annex VII, initially, percentages have been used for some of the assessments because some of the options are only likely to provide small incremental benefits, which could be obscured by a simple and broad category-based assessment. It must however be highlighted that, unless specific references are given the impact and cost estimates in Annex VII were not based on objective calculations, but are expert judgements informed by the findings from the present study on the biodiversity and ecosystem service benefits of the different green infrastructure elements and the costs associated with green infrastructure measures. More specifically, the judgements build on the earlier material in this report and on the insights on biodiversity/resilience indicators in Chapters 4 and 5, costs, benefits and efficiency in chapter 6.

Thus, given the many uncertainties the synthesis assessment presented in this report only kept arrows, which broadly reflect the ordinal categories defined in the table below. The expected changes are therefore presented primarily by arrows to give direction and scale of the change (an approach the MA (2005) and NEA (2010) also adopt) with the exception of the costs, where orders of magnitude of the costs were indicated. Green boxes indicate beneficial changes and light red indicates detrimental changes.

↗↗↗↗↗	Very high increase (eg >100%)		Very Beneficial change
↗↗↗↗	High increase (eg 50-100%)		
↗↗↗	Moderate change (eg 20-50%)		
↗↗	Small change (eg 10-20%)		
↗	Minor change (eg <10%)		
→	Stable/ no change		
↘	Minor change (eg <10%)	**e.g. €100,000**	Very Detrimental change
↘↘	Small change (eg 10-20%)	**e.g. € millions**	
↘↘↘	Moderate change (eg 20-50%)	**e.g. € 10s millions**	
↘↘↘↘	Large decline (eg 50-100%)	**e.g. 100s € millions**	
↘↘↘↘↘	Very large decline (eg >100%)	**e.g. € billions+**	
V	Variable, changes being context-specific		

The assessments of the impacts included in the tables below are generally the result of a combination of the impacts for each green infrastructure element taken individually. Table 8.1 below provides an example of this intermediate step towards coming to a combined assessment for an ecosystem service category. The tables included in this report only include a single estimate, representing the combined impact on the issue being assessed. The thinking underpinning the estimate is briefly outlined in the tables under the heading "short rationale/explanation".

Table 8.1: Intermediate step of assessment leading to overall expected impact estimate

Carbon storage and sequestration	**Core areas**	**Restoration zones**	**Sustainable use/ Ecosystem service zones**	**Green urban and peri-urban areas**	**Natural connectivity features**	**Artificial connectivity features**	**Overall estimate to be included in table**
	↗	↗	↘ (ag land)	↘	↘	→	↘ *-5%*

It is important to clarify upfront that the impacts reported for options 2, 3 and 4 relate to the reference point rather than the baseline scenario (ie BAS/ options 1/ no policy change). In other words, the values provided in the assessments below consistently, across all four options, describe the impacts/trend compared to the reference point. An alternative approach would have been to compare the impacts of options 2, 3 and 4 to the impacts under the business as usual scenario (ie the baseline) and to highlight the difference between options 2, 3 and 4 and the BAS. While both are valid approaches, this approach adopted here was chosen in particular because of the non-exclusive character of the four options. Indeed, as explained more in detail earlier in this report, the changes foreseen under each one of the policy options are not mutually exclusive: they are structured in an "incremental way" (option 1; option 2 = 1+2; option 3 = 1+2+3; option 4 = 1+2+3+4)."

The narrative accompanying the individual assessment does however occasionally highlight how certain impacts for options 2, 3 and 4 compare to the impacts under the baseline scenario (BAS/option 1/no policy change) scenario.

8.1 Synthesis overview of impacts associated with option 1

Table 8.2 below provides a synthetic overview of the environmental, economic and social impacts associated with the implementation of option 1.

Table 8.2: Synthesis: Overview of impacts associated with implementation of option 1

	Reference Point *(see section 2.5 for more detail)*	**Option 1** – *Baseline*
General Issues		
Addressing the problem/challenge - biodiversity & ESS loss[36]	Not sufficient. Loss ongoing (with some exceptions e.g. Natura 2000)	No – significant opportunities missed; expected continued risk of loss of biodiversity and ESS ↘ ↘
Environmental Issues (synthesis)		
Biodiversity & habitats	Significant biodiversity benefits from existing green infrastructure	Overall declines despite progress in some areas ↘
Overall coherence and resilience	Limited connectivity undermining effective coherence and reduce resilience	Expected decline (from expected fragmentation et al) ↘ ↘
Provision of other environmental benefits	Significant range of very important benefits (provisioning, regulating, cultural and supporting services)	Overall decline ↘↘
Economic Issues		
Administrative costs (at EU and MS level)/yr		↘ Magnitude: small: Hundreds of thousands per MS
Financial costs (one-off)/yr	Core area (N2K): 5.8bn/year Other areas un-estimated	→ of action / ↘↘↘ of non-action Magnitude: incremental costs: tens of millions/year
Financial costs (recurrent)/yr		→ of action / ↘↘↘↘ of non-action Magnitude: hundreds of millions / billions /year
Opportunity costs/yr	-	No additional opportunity costs
Social Issues		
Number/quality of jobs; economic activity generated	GI and its services an important foundation for the economy and livelihoods	Limited/sub-optimal →
Health benefits & quality of life	Important benefits	Decline from loss of air pollution regulation services / access to nature ↘↘
Recreation & Tourism	Important benefits	Decline from loss of access to nature ↘
Other issues: Good governance / Practicability and Enforceability		
Practicability	n/a	Unchanged →

[36] ie halting the loss of biodiversity and ecosystem services in Europe. This question looks at whether the design of the option actually addressed the real problem – in the sense of focus rather than effectiveness. Hence it is the intention and targeting of the option that is assessed here and not its effect.

Enforceability	n/a	Unchanged→
Acceptability	Some lack of coherence; important public goods losses	Limited ↘
Clarity, consistency and understandability	Insufficient integration and 'joined up thinking'	Lacking ↘

The most striking features of the outcome of this option compared to the reference point and the baseline scenario (BAU - option 1) are:

Option's overall effectiveness

Under this option, the objectives are not met.

- **Environmental dimension**

Increase in overall stock of core areas, primarily due to increase marine protected areas. Improvement of the ecological quality of core areas, especially due to restoration activities linked to conservation objectives. Other green infrastructure elements outside protected areas are expected to decline to 2030, whether due to degradation or fragmentation or to loss of natural areas from urban sprawl. These improvements in the core areas will not compensate for losses from the wider green infrastructure.

- **Socio-economic dimension**

A certain number of jobs are lost but others compensate for this loss, especially in areas which can be considered defensive expenditure, i.e. replacement of ecosystem services lost, restoration activities, ex-ante or ex-post mitigation of impacts of grey infrastructure. Overall, this is a combination of one-off costs and recurrent expenditure but defensive expenditure investments have a rather limited potential to result in long-term growth/increase in economic activity; proactive investment in natural capital arguably offers greater potential support for growth/economic activity.

Option's costs and acceptability

- **Economic dimension**

Overall we would expect rather high costs of loss of ecosystem services and needs to invest in substitutes under the BaU compared with scenarios (under different policy packages) which would have seen the stock of other elements stabilise or increase and their quality improve. As the context here is one of deterioration and loss of a range of green infrastructure elements which are essential for coherence and resilience, in particular sustainable use zones, artificial connectivity features, the costs are higher than they would otherwise need to be.

With deterioration of its quality, the productivity of the green infrastructure declines as the green infrastructure declines and measures to improve the quality of the remaining stock of green infrastructure are insufficient, although locally there might be exceptions, for example where restoration measures are actually implemented.

While in the absence of any additional measures, there are no new costs associated with such measures, defensive measures, to address the adverse impacts related with further ecosystem deterioration, need to be taken. These are very costly indeed. In addition, the cost associated with the continuation of current measures to support Europe's green infrastructure increase, as overall coherence and quality is on the decline.

- **Governance dimension**

From a social and political point of view, there is a lack of coherence in this policy option which results in its efficiency being questionable. Not addressing the needs for wider environmental and social goods to be integrated into policies affecting green infrastructure will would most probably result in a loss in credibility and trust in the political system due to an increased perception that the type of growth it delivers comes at the cost of a deterioration of the quality of life and well-being.

Synergies / trade-offs between the different measures components of the option

When looking at the measures under the BAS, there are important trade-offs that are not acknowledged and accounted for, resulting overall in a lack of coherence and integration across existing policies which undermine the cost-effectiveness both of policies in place to support the green infrastructure and those policies which have adverse effects on the stock and the quality of green infrastructure.

Identification of impacts foreseen which could be felt as early as 2020

Most of the impacts described in option 1 are already being observed and in the absence of any additional measures they are expected to further amplify.

8.2 Synthesis overview of impacts associated with option 2

Table 8.3 below provides a synthetic overview of the environmental, economic, social and governance impacts associated with the implementation of option 2.

Table 8.3: Synthesis: overview of impacts associated with implementation of option 2

	Reference Point *(see section 2.5 for more detail)*	**Option 2**
General Issues		
Addressing the problem/challenge - biodiversity & ESS loss[37]	Not sufficient. Loss ongoing (with some exceptions e.g. Natura 2000)	The challenge is partially addressed, but insufficiently ↘
Environmental Issues (synthesis)		
Biodiversity & habitats	Significant biodiversity benefits from existing green infrastructure	Still significant losses in some areas ↘ ↘
Overall coherence and resilience	Limited connectivity undermining effective coherence and reduce resilience	Improvements do not contribute much to increasing resilience/coherence ↘ ↘
Provision of other environmental benefits (water & climate)	Significant range of very important benefits (provisioning, regulating, cultural and supporting services)	The provision of key regulating services is, at least in part, enhanced ↗
Economic Issues		

37 ie halting the loss of biodiversity and ecosystem services in Europe. This question looks at whether the design of the option actually addressed the real problem – in the sense of focus rather than effectiveness. Hence it is the intention and targeting of the option that is assessed here and not its effect.

Administrative costs (at EU and MS level)/yr		Magnitude: Hundreds of thousands ↘
Financial costs (one-off)/yr	Core area (N2K): 5.8bn/year Other areas un-estimated	**of action** Magnitude: A couple of additional millions ↘↘
Financial costs (recurrent)/yr		↘ **of action** Magnitude: A couple hundreds of thousands/year
Opportunity costs/yr		↘
Social Issues		
Number/quality of jobs; economic activity generated	GI and its services an important foundation for the economy and livelihoods	Overall small net increase in jobs ↗
Health benefits/quality of life	Important benefits	Health benefits still on the decline ↘↘
Recreation & Tourism	Important benefits	Still slight decrease ↘
Other issues: Good governance / Practicability and Enforceability		
Practicability	n/a	↗↗
Enforceability	n/a	↘
Acceptability	Some lack of coherence; important public goods losses	↗↗↗
Clarity, consistency and understandability	Insufficient integration and 'joined up thinking'	↘

The most striking features of the outcome of this option compared to the reference point and the baseline scenario (BAU - option 1) are:

Option's overall effectiveness

Under this option, the objectives are not met. The Strategy allows Member States to set their own levels of ambition on targets and to select the measures which they consider most appropriate and most cost-effective. Therefore, the costs and benefits will depend on this level of ambition and will also vary according to the extent to which Member States make use of the possibilities offered by existing legislation, such as cross-compliance within the CAP or ecosystem based climate change adaptation or natural water retention measures in Cohesion Policy funding.

- **Environmental dimension**

The overall effectiveness of option 2 in meeting the objectives associated with the development of a green infrastructure strategy in the EU are rather minimal or at least uncertain, because all measures are of voluntary nature and, therefore, their implementation very much depends on the willingness and openness of MS.

All measures can (potentially) contribute to the achievement of targets if the uptake and implementation is satisfactory. But due to the lack of binding mechanisms in core areas of ecosystem losses (such as land use, habitat fragmentation etc.) the effect can be expected to be rather low.

- **Socio-economic dimension**

Under this option, a range of particularly pro-active municipalities, cities and regions take advantage of the increase in funding available for green infrastructure implementation, with direct benefits to their inhabitants. The toolkit for integrated spatial planning addressing the need for the conservation and strategic creation of green infrastructure in urban areas, combined with the revised Strategy for the urban environment results in notable improvements in pro-active urban areas. In a majority of urban areas this approach is however not applied consistently, in part because of a lack of funding for a proper mapping of green infrastructure which could be used in spatial planning. Overall this therefore still results in a decrease in the health benefits compared with the baseline, although this loss is divided by two compared to the baseline scenario (BAS/ option 1).

Additional jobs are created by the increase in investment in restoration of green infrastructure elements. Investments in ecosystem based solution to flood management and climate mitigation and adaptation might crowed out some jobs in sectors which would have offered to pursue the same objective through alternative (grey) solutions but the net effect is neutral.

Option's costs and acceptability

- **Economic dimension**

The costs associated with the option are comparably low as, with the exception of wider EU support, the measures either do not require many financial resources (such as building an information platform or coordinating an OMC) or are already integrated in ongoing processes (such as reviewing existing policies of integrating green infrastructure in regional and spatial planning structures). However, due to the uncertainty of their effectiveness outlined above, the issue of opportunity costs should be bared in mind.

- **Governance dimension**

The acceptability of option 2 is, just because of its voluntary and non-binding character, likely to be high among MS. It might shrink with the adoption of the OMC and MS becoming resistant against "progress" made in coordinating activities that require a certain amount of (financial) resources. But in general it seems likely that many MS would support this option as they can show their commitment to EU environmental targets without particular obligations to fulfil them.

Synergies / trade-offs between the different measures components of the option

The positive effects of the soft measures of guidance, coordination and awareness raising in option 2 can mostly be enhanced if wider EU support in investments will be ensured. More green infrastructure projects through more flexible funding schemes and a replenishment of funding would also raise the awareness of the concept if projects are carried out successfully and their benefits are disseminated via the foreseen information platform. Also research activities could benefit from more green infrastructure projects as a higher "critical mass" to investigate their benefits could solidify research results, and, consequently, decision-making and the overall effectiveness of the projects and programmes implemented. Higher awareness through information campaigns and websites, which collate the most relevant and updated information, is beneficial for almost every intended step forward in terms of green infrastructure development in the EU. A good basis of information is a pre-condition for a high uptake and spread of green infrastructure activities across MS, sectors, stakeholders and administrations.

Identification of impacts foreseen which could be felt as early as 2020

The shift in expenditure towards ecosystem based projects relying on green infrastructure to deliver its objectives, and the associated small increase in occupation liked to this type of investments, would already be felt by 2020. A wider range of green infrastructure projects can be expected to have been implemented by 2020, and they can be expected to already deliver some of the benefits for which they have been implemented. The toolkit for spatial planning as well as the improved guidance on EIA/SEA will already have practices on the ground and helped preserve green infrastructure which would otherwise have disappeared. The improved practices will however only really become mainstream and achieve their full potential in the decade between 2020 and 2030.

8.3 Synthesis overview of impacts associated with option 3

Table 8.4 below provides a synthetic overview of the environmental, economic, social and governance impacts associated with the implementation of option 3.

Table 8.4: Synthesis: overview of impacts associated with implementation of option 3

	Reference Point *(see section 2.5 for more detail)*	**Option 3**
General Issues		
Addressing the problem/challenge - biodiversity & ESS loss[38]	Not sufficiently. Loss ongoing (with some exceptions e.g. Natura 2000)	GI increase with only limited new losses, most of it with stable quality ↗
Environmental Issues (synthesis)		
Biodiversity & habitats	Significant biodiversity benefits from existing green infrastructure	Some losses but reduced, important gains for some species/habitats ↗
Overall coherence and resilience	Limited connectivity undermining effective coherence and reduce resilience	Overall, small increase in resilience ↗
Provision of other environmental benefits (water and climate)	Significant range of very important benefits (provisioning, regulating, cultural and supporting services)	Stable increases, limited new losses ↗↗
Economic Issues		
Administrative costs (at EU and MS level)	Core area (N2K): 5.8bn/year Other areas un-estimated	↘↘↘ Magnitude: Tens of millions
Financial costs (one-off)		↘↘↘ Magnitude: Tens of millions
Financial costs (recurrent)		↘↘ Magnitude: Couple of millions/

38 ie halting the loss of biodiversity and ecosystem services in Europe. This question looks at whether the design of the option actually addressed the real problem – in the sense of focus rather than effectiveness. Hence it is the intention and targeting of the option that is assessed here and not its effect.

		Year
Opportunity costs		↘↘↘ Magnitude: Tens of millions
Social Issues		
Number/quality of jobs; economic activity generated	GI and its services an important foundation for the economy and livelihoods	Notable creation of new jobs with no major losses ↗↗
Health benefits/quality of life	Important benefits	Small increase ↗
Recreation & tourism	Important benefits	Potential maintained and in some areas increased ↗↗
Other issues: Good governance / Practicability and Enforceability		
Practicability	n/a	Feasible but requires political will ↗
Enforceability	n/a	More reporting and data available ↗↗
Acceptability	Some lack of coherence; important public goods losses	Straightforward and effective ↗
Clarity, consistency and understandability	Insufficient integration and 'joined up thinking'	Notable enhancement ↗↗

The most striking features of the outcome of this option compared to the reference point and the baseline scenario (BAU - option 1) are:

Option's overall effectiveness

Under this option, some of the most important objectives of the Strategy would be met.

- **Environmental dimension**

Together with the changes included under option 2, option 3 delivers an increased effective in the conservation of existing green infrastructure such as connectivity elements in the wider landscape. The decline in stock and quality of sustainable use/ ecosystem service zones and natural connectivity features is thought to stop and the ecological quality of the former is even expected to slightly increase. Only in an around urban areas, a small decrease in green infrastructure still appears unavoidable.

This has important implications for biodiversity and resilience. Under option 3, for the first time, resilience is actually improved compared to both the reference point and the baseline scenario. While conditions of habitats and population of species to community interest both significantly improve, option 3 will still not be able to avoid losses of area of community interest and populations of species which are not of community interest.

Option 3 is also more effective than option 2 in actually increasing the provision of environmental benefits (regulation of water flows, water purification, carbon storage and sequestration, temperature control) across the board.

Under this option, green infrastructure elements are not only created thanks for the increased in funding (option 2) but green infrastructure is also better preserved. This option therefore delivers significantly higher biodiversity benefit thanks to preservation of the stock and improvement of the quality of elements which are valuable for biodiversity conservation and the provision of key ecosystem services

- **Socio-economic dimension**

As in option 2, additional jobs are created by the increase in investment in restoration of green infrastructure elements. Investments in ecosystem based solution to flood management and climate mitigation and adaptation might crowed out some jobs in sectors which would have offered to pursue the same objective through alternative (grey) solutions but the net effect is neutral. In addition, a small increase in jobs is thought to result from the additional number and wider scope of impact assessments which have to be carried out and an increase in mitigation and off-setting measures.

Health benefits and education, both still on the decline compared to the reference point under option 2, show notable improvements under option 3 compared to both the baseline and the baseline scenario (BAS/ Option 1). This is in particular linked to the increase in number (wider scope) and quality of implementation of the revised EIA/ SEA Directives.

The amenity value of a whole range of multifunctional zones (outside urban areas) is preserved and in some places strategically enhanced, thus increasing their attractiveness for recreation and tourism (including from overseas) and educational purposes, in particular due to a better conservation of urban and peri-urban green infrastructure and the conservation and enhancement of green infrastructure which have a high biodiversity value.

Option's cost and acceptability

- **Economic dimension**

These options results in higher overall costs than the baseline scenario, but some categories of costs decline compared both to the reference point and the baseline scenario. This is particularly true for the costs resulting from ecosystem degradation and loss of their services under the other scenarios. Additional financial costs to the private sector (but also to a certain extent for public authorities) come from the increased requirement from the EIA/SEA. Additional resources will also need to be available by public authorities which are expected to witness and significant increases in administrative and financial costs from more data collection and reporting on green infrastructure (mapping), increased transparency and public participation (in spatial planning and EIA/SEA).

This is however to a certain extent compensated by the fall in some other costs recorded in the business as usual scenario. Indeed, the recurrent cost associated with the provision of services in replacement of ecosystem services lost is significantly reduced, as is the cost of maintaining the ecologic quality of protected areas (compared to the baseline).

The conversion of some land to sustainable use zones suggests a decline in provisioning services compared to the reference pint, although the sustainable management of the land resources is through to provide benefits in the range of billions in the long run, compared to the baseline scenario (BAS/option 1).

- **Governance dimension**

With option 3, clarity and consistency as well as understandability are clearly improved, both in comparison with the baseline scenario and option 2. The legal revisions, in particular those increasing reporting requirements, contribute to a slight improvement in the practicability and enforceability compared to the BAS and option 2. On the downside, option 3 looses a bit in terms of political acceptability as much of the benefits associated with a voluntary approach in option 2 get lost with option 3.

Synergies / trade-offs between the different measures /components of the option

The different measures included under option 3 mutually reinforce each other. The effectiveness of the measure under option 2 is significantly increased when combined with the measures under option 3. The benefits from green infrastructure implementation under this option results in measurable improvements in the area of biodiversity and ecosystem services, both in the area of regulating services and human health. This results in cost savings which are proportionate with the additional financial means that have to be made available for the implementation of this option and some additional opportunity costs which it results in. Overall, this option is clearer, more consistent and while it might result in some resistance, the notable benefits make it overall an acceptable option, especially since improved enforceability ensures that all MS participate in the effort.

Identification of impacts foreseen which could be felt as early as 2020

It is likely to take until around 2020 for all jobs associated with the revision of the EIA and SEA Directives to be created. As the EIA revision may take place earlier than the SEA Directive, the benefits associated with its wider application would already reflect by the end of 2020 in a better state of the stock of green infrastructure across most elements compared to the baseline and option 2. This is also in part due to the climate and biodiversity proofing of EU funding. Together, these changes have allowed reducing the loss of key green infrastructure elements as early as 2020 and could have achieved, in some places, notable biodiversity and ecosystem benefits compared to the BAS.

8.4 Synthesis overview of impacts associated with option 4

Table 8.5 below provides a synthetic overview of the environmental, economic, social and governance impacts associated with the implementation of option 4.

Table 8.5: Synthesis: overview of impacts associated with implementation of option 4

	Reference Point *(see section 2.5 for more detail)*	**Option 4**
General Issues		
Addressing the problem/challenge - biodiversity & ESS loss[39]	Not sufficiently. Loss ongoing (with some exceptions e.g. Natura 2000)	Offers the most comprehensive approach to GI protection and enhancement. Should halt biodiversity and ESS loss through implementation of no net loss principle. ↗↗
Environmental Issues (synthesis)		
Biodiversity & habitats	Significant biodiversity benefits from existing green infrastructure	Biodiversity benefits are greatly enhanced through protection, enhancement and restoration of GI, largely through no net loss policy and strategic offsetting,. ↗↗↗
Overall coherence and resilience	Limited connectivity undermining effective coherence and reduce resilience	Comprehensive GI strategies and offsetting helps enhance connectivity, coherence & resilience. ↗↗
Provision of other environmental benefits (water and climate)	Significant range of very important benefits (provisioning, regulating, cultural and supporting services)	Enhanced extent and quality of GI enhances delivery of ecosystem services, especially regulating and cultural services. ↗↗↗
Economic Issues		
Administrative costs (at EU and MS level)	Core area (N2K): 5.8bn/year Other areas un-estimated	Significantly increased administrative costs at EU, MS, regional and local levels. ↘↘
Financial costs (one-off)		High capital costs of mapping, planning, expansion and restoration. ↘↘↘
Financial costs (recurrent)		High recurrent costs of maintaining GI stock and implementing GI plans and policies. ↘↘↘
Opportunity costs		High opportunity costs as this option restricts development and land management options more than others. ↘↘↘
Social Issues		
Number/quality of jobs; economic activity generated	GI and its services an important foundation for the economy and livelihoods	Largest increase in employment opportunities in GI expansion, restoration, protection and maintenance. ↗↗
Health benefits &	Important benefits	Greatest health benefits through enhanced living

[39] ie halting the loss of biodiversity and ecosystem services in Europe. This question looks at whether the design of the option actually addressed the real problem – in the sense of focus rather than effectiveness. Hence it is the intention and targeting of the option that is assessed here and not its effect.

quality of life		environment and access to green recreational areas. ↗↗
Recreation & Tourism	Important benefits	This option delivers greater quality of life benefits than others. ↗↗
Other issues: Good governance / Practicability and Enforceability		
Practicability	n/a	Most demanding and wide ranging option, therefore presents practical challenges. ↘
Enforceability	n/a	Requires substantial action at MS, regional and local level, thus presenting challenges for enforcement. ↘
Acceptability	Some lack of coherence; important public goods losses	The demanding nature of this policy, high costs involved and likelihood of wide ranging trade-offs present challenges regarding political acceptability. ↗
Clarity, consistency and understandability	Insufficient integration and 'joined up thinking'	Offers a clear, consistent, wide ranging and integrated approach to GI. ↗↗↗↗

The most striking features of the outcome of this option compared to the reference point and the baseline scenario (BAU - option 1) are:

Option's overall effectiveness

- **Environmental dimension**

Option 4 is the most ambitious, demanding and wide ranging option and would have the greatest effect in enhancing the area, quality and connectivity of green infrastructure in the EU. The no net loss requirement should stem the loss of green infrastructure, while the requirement for strategies and targets at Member State level should lead to a planned and co-ordinated approach to the expansion, enhancement and maintenance of green infrastructure. New initiatives such as a TEN-G fund, biodiversity offsets and an EU wide PES scheme should facilitate this trend. As a result the enhanced stock and quality of green infrastructure, there should be an increase in ecosystem service delivery, particularly regulating and cultural services.

- **Socio-economic dimension**

Option 4 will require the highest level of effort to be devoted to the creation, enhancement and maintenance of green infrastructure and should therefore create higher numbers of green jobs than the other options. The net overall effects on EU employment are more complex and depend on the macro-economic consequences of funding the strategy, as well as direct negative effects on employment in other activities such as agriculture. This option will maximise opportunities for outdoor recreation and education – as a result health, recreational and educational benefits should be greater than under other options.

Option's costs and acceptability

- **Economic dimension**

Option 4 is expected to have the highest level of costs. These include the capital costs of expanding and restoring green infrastructure, the recurrent costs of maintaining that infrastructure, and the administrative costs of developing and overseeing strategies and co-ordinating initiatives at EU, national, regional and local levels. The greater protection and enhancement of green infrastructure can also be expected to result in opportunity costs, as opportunities for development may be more restricted than under other options. The economic value of ecosystem services will be highest under this option. While the value of agricultural and forestry output can be expected to be constrained in the short term, the enhancement of regulating services should help to maintain the long term viability and sustainability of provisioning services, thus maintaining the overall value of natural resources. Enhancements in green infrastructure will improve the living and working environment, and can be expected to enhance property and land values, at least in the vicinity of green infrastructure improvements.

- **Governance aspects**

Option 4 is the most demanding, wide ranging and costly option and therefore faces challenges than with regard to its political acceptability, practicability and enforceability. It offers a clear, comprehensive and consistent approach to green infrastructure policy at EU, national, regional and local levels. The development of new economic and financial instruments (TEN-G fund, offsets, PES schemes) should enhance the practicability of delivering green infrastructure strategies, though Member States will continue to rely on a range of funding instruments at different levels.

Synergies / trade-offs between the different measures /components of the option

The introduction of a habitat banking scheme as well as a Payment for Ecosystem service scheme, addresses some of the trade-offs (including some opportunity costs) that arise under option 2 and 3. It does however result in a high increase in other opportunity costs, which accrue to both specific groups in society and public authorities. This results in a limited practicability of this option, at least until there is more certainty with regards to its practicability and cost-effectiveness. This means that, while option 4 is probably the most coherent and would deliver the highest return in terms of benefits to biodiversity and habitats and meeting potential green infrastructure related targets and objectives under the Strategy, this success would also come at quite high cost. It would also be expected to result in challenges relating to practicability and enforceability, mainly linked to the uncertainty with regard to how habitat banking and PES-schemes would play out and how effectively they could be implemented. The limited guarantee that the positive effects would be achieved means that it would be difficult to justify the costs at this stage, before more experience has been gathered on how to design such schemes for them to work effectively. This is reflected in a rather modest level of acceptability, making the overall feasibility of this option limited in the short term, despite its high overall clarity and consistency.

Identification of impacts foreseen which could be felt as early as 2020

While the institutional developments included in this option should be finalised and become operational towards 2020, the additional impacts in terms of increased ecosystem and biodiversity benefits will primarily start accruing in the decade between 2020 and 2030, as will the additional job creation associated with the schemes. The measures implementing the no net loss scenario will take some time to be put in and implemented as well, hence some delay in achieving their full potential but already some concrete impacts in terms of reduced biodiversity loss and loss of green infrastructure elements in the MS which have been fastest in introducing the principle in their legislation.

8.5 Synthesis: Comparison of impacts associated with the different options

Table 8.6: Synthesis: overview of impacts associated with implementation of options 1-4

	Reference Point	Option 1	Option 2	Option 3	Option 4
General Issues					
Addressing the problem/challenge - biodiversity & ESS loss 40	Not sufficient. Loss ongoing (with some exceptions e.g. Natura 2000)	↘↘	↘	↗	↗↗
Environmental Issues (synthesis)					
Biodiversity & habitats	Significant biodiversity benefits from existing GI	↘↘	↘	↗	↗↗↗
Overall coherence and resilience	Limited connectivity undermining effective coherence and reduce resilience	↘↘	↘↘	↗	↗↗
Provision of other environmental benefits (water and climate)	Significant range of very important benefits (provisioning, regulating, cultural and supporting services)	↘↘	↗	↗↗	↗↗↗
Economic Issues					
Administrative costs (at EU and MS level)	Core area (N2K): 5.8bn/year Other areas un-estimated tbc	↘	↘	↘↘	↘↘↘
Financial costs (one-off)		→ of action ↘↘↘ of non-action	↘↘	↘↘↘	↘↘↘↘
Financial costs (recurrent)		→ of action ↘↘↘↘ of non-action	↘	↘↘	↘↘↘
Opportunity costs		↘	↘	↘↘↘	↘↘↘↘
Social Issues					
Number/quality of jobs; economic activity generated	GI and its services an important foundation for the economy and livelihoods	→	↗	↗↗	↗↗
Health benefits/ quality of life	Important benefits	↘↘	↘↘	↗	↗↗
Recreation & Tourism	Important benefits	↘	↘	↗↗	↗↗
Other issues: Good governance / Practicability and Enforceability					
Practicability	n/a	Unchanged. →	↗↗	↗	↘
Enforceability	n/a	Unchanged. →	↘	↗↗	↘
Acceptability	Some lack of coherence; important public goods losses	Limited ↘	↗↗↗	↗	↗
Clarity, consistency, understandability	Insufficient integration and 'joined up thinking'	Lacking ↘	↘	↗↗	↗↗↗↗

40 ie halting the loss of biodiversity and ecosystem services in Europe. This question looks at whether the design of the option actually addressed the real problem – in the sense of focus rather than effectiveness. Hence it is the intention and targeting of the option that is assessed here and not its effect.

8.6 The options which delivers the highest net benefits

Overall, option 3 seems to be the one which has the potential if properly implemented to deliver environmental, economic and social benefits most efficiently and with acceptable costs. As outlined in more detail in the assessment provided above, the different measures included under option 3 mutually reinforce each other. The effectiveness of the measure under option 2 is significantly increased when combined with the measures under option 3, not the least because the changes under this option allow for a better conservation of existing green infrastructure elements across the wider landscape. The benefits from green infrastructure implementation under this option results in measurable improvements in the area of biodiversity and ecosystem services, both in the area of regulating services and human health. This results in cost savings which are proportionate with the additional financial means that have to be made available for the implementation of this option and some additional opportunity costs which it results in. Overall, this option is clearer, more consistent and while it might result in some resistance, the notable benefits make it overall an acceptable option, especially since improved enforceability ensures that all MS participate in the effort.

Option 4 is arguably the most coherent option and could probably deliver the highest returns, especially in terms of biodiversity benefits. While it would therefore be the most effective in meeting potential green infrastructure related objectives and other EU targets, these achievements would probably come at quite a high cost. The development of a new Directive would also be expected to result in political and practical challenges, and its enforcement would be problematical, not least because of the current difficulties of defining and measuring green infrastructure. It is clear that the Option 4 measures of comprehensive offsetting of residual impacts on green infrastructure and the development of schemes that provide payments for ecosystems services would provide substantial benefits. However, there is uncertainty over how these measures may be established and how effectively they would be implemented, with or without a supporting EU Directive. This uncertainty over the practicality and political acceptability of a dedicated green infrastructure Directive, as well its expected high costs and probable long development time, means that Option 4 is difficult to justify at this stage. Instead it would seem prudent to reconsider it when more experience has been gained from better implementing other green infrastructure policy measures.

9 CONCLUSIONS AND POLICY RECOMMENDATIONS

9.1 The need for an EU Green Infrastructure Strategy and its priorities

This study has reaffirmed the potential benefits for biodiversity and ecosystem services that could be realised in the EU through the development and implementation of a Green Infrastructure Strategy. However, it is also apparent, that to be of value, the strategy will need to clarify and define the green infrastructure concept and provide a clear vision and specific objectives in terms of its desired impacts (in terms of biodiversity and ecosystem service benefits) and green infrastructure measures. Careful consideration should be given to defining its objectives and in particular its priorities to ensure that the Strategy is realistic and that green infrastructure measures are effective and efficient, and also contribute to other EU objectives.

9.1.1 Green Infrastructure's support to the delivery of EU policy objectives

This study has shown that green infrastructure delivers a wide range of benefits both to humans and biodiversity and is key to overall ecosystem resilience and may therefore support achieving policy objectives in a wide range of policy areas. A few examples of the benefits which it may deliver, thus potentially helping to meet policy objectives across EU policy areas includes:

- Meeting air quality standards in urban areas set by the Air Quality Directives – the cleansing capacity of urban green infrastructure can contribute to cost-effectively improving urban air quality and reduce associated health impacts
- Meeting water quality standards set by the Water Framework Directive (targets) - green infrastructure can assist in achieving the aims of the Water Framework Directive (WFD) that requires preventing further deterioration and protecting and enhancing the status of aquatic ecosystems.
- Reduce the risk of floods and droughts. Natural water retention measures (eg floodplain creation, wetland restoration, green roofs) may help in managing water quantity and therefore stabilise water provision, thus helping meet, eg, the objectives of the Floods Directive. The risk of avalanches can also be reduced through the designation and management of protection forests on mountain slopes.
- Reducing overall CO_2 concentration in the atmosphere and limit temperature rise to 2 degrees Celsius. Green infrastructure can act as a carbon sink and its conservation and enhancement can thus contribute to meeting emissions reduction targets, thus contributing to meeting some of the targets of the Climate and Energy package. In addition, soils can act as important carbon sinks and a range of practices may increase the soil capacity to store CO_2. Green infrastructure may also be used in line with the White paper for Climate Change adaptation, where it may contribute to increasing resilience to climate change and help responding and mitigating the impacts of more extreme weather events.
- Green roofs and green walls might contribute to stabilising the climate in cities (micro-climate regulation, reduced occurrence of heat waves) and contribute to the insulation of buildings, thus reducing overall energy use.
- Natural waste water management plants may contribute to the assimilation of waste water and in some cases might be suitable to comply with the requirements of the Urban wastewater treatment Directive

- Creation of green infrastructure in urban areas might improve quality of life and offer recreation opportunities, thus contributing to the objective of social cohesion and integrated territorial development set in Cohesion Policy
- Maintenance and/ or development of green infrastructure might contribute to meeting objectives relating to species and habitat conservation, increasing ecosystem resilience and the overall coherence of the Natura 2000 Network in line with the objectives of the Habitats Directive and the target of the Biodiversity Strategy
- Green infrastructure, and in particular natural connectivity features and vegetation on slopes might help slow down soil erosion and thus support soil protection, thus helping meet the objectives of the Soil Thematic Strategy (and Directive).
- Designation of marine green infrastructure (marine protected areas) might be an important element of an overall Strategy aiming at achieving the CFP's objective of more sustainable fisheries.

9.1.2 The priorities of the Green Infrastructure Strategy

The Strategy should carefully consider the priorities for the maintenance and expansion of green infrastructure elements. In this respect, it is suggested that:

- A particular focus should be given to ensuring **core areas** form a coherent network that is adequate to achieve the EU's environmental targets, because such areas clearly provide substantial long-term, and robust biodiversity and ecosystem benefits in a cost-effective way. Such core-area networks should extend beyond Natura 2000 sites to include other areas that together provide areas of habitat that are sufficiently large and, where necessary, functionally connected to maintain viable and resilient populations of targeted species, habitats and key ecosystem processes and services.
- **Restoration zones** and restoration projects often provide clear and cost-effective benefits in terms of biodiversity and ecosystem services, and should therefore be promoted more widely, especially where they provide alternatives to built infrastructure that have detrimental environmental impacts. Restoration measures may also contribute to the enhancement of core area networks, for example by increasing the size of sites such so that they are able to support resilient ecosystems and viable populations of important species. Such benefits can be increased through strategic planning, which can be facilitated through integrated green infrastructure initiatives. However, restoration measures have in many instances also proved difficult, expensive and unreliable, and restored ecosystems have rarely provided the range and magnitude of ecosystem services provided by intact ecosystems. Restoration efforts should not be at the expense of existing viable ecosystems and species populations.
- The wider environment should increasingly be managed as **sustainable use areas**, with the dual aim of maintaining biodiversity whilst also optimising the provision of ecosystem services in a sustainable way. Such actions may also further support the coherence of core area networks, by increasing the ability of species to exist in and move through the wider countryside, which in itself provides important cultural ecosystem services.
- A high priority should also be given to promoting **urban green infrastructure** as this has been shown to provide highly cost-effective benefits across an number of ecosystem services (such as in terms of climate regulation, health and recreation).

Again such benefits can be increased if they planned strategically and linked to other green infrastructure elements, such as natural connectivity features that extend into rural environments and nearby core areas.

- **Natural connectivity features** provide habitats for species and ecosystems benefits in themselves, as well as providing connectivity functions. A high priority should therefore be given to protecting and appropriately managing such features, especially where they have been shown to have important habitat and/or connectivity functions for species of EU and national conservation importance. However, careful consideration should be given to the restoration, and in particular, the creation of new specific connectivity features (especially narrow linear corridors), as requirements will be context-specific and they may not be cost-effective in terms of biodiversity benefits (eg compared with other options such as increasing core areas), and in some cases may be detrimental (eg by facilitating the movement alien invasive species etc).
- **Artificial connectivity features** are increasingly used as biodiversity mitigation measures eg for new road and rail schemes, and have been shown to facilitate movements of species between patches of habitat that would otherwise be isolated to some greater extent. Some measures such as fish passes and tunnels for mammals and amphibians have been shown to be effective in maintaining migrations and populations and/or are of low cost, and these should be constructed where appropriate. However, other features such as wide habitat bridges are very expensive and the overall impacts of many such features on the population status of species of conservation importance have yet to be proven. Their efficacy and cost-effectiveness is therefore uncertain in many situations, and it is consequently recommended that such mitigation measures should only be undertaken where fragmentation impacts cannot be avoided by other means (eg re-routing). Developers should also demonstrate for each specific situation, that the use of the intended feature provides the most effective, robust long-term benefits for species of conservation importance compared with other possible actions, such as undertaking habitat restoration or creation to reduce habitat fragmentation in the wider impacted area. Public funding of the installation of artificial connectivity features on existing roads and other possible barriers (eg as part of habitat defragmentation programmes), should only be undertaken after very careful scrutiny of their likely cost-effectiveness and risks of failure.

9.2 Opportunities for more EU coherence in and mainstreaming of green infrastructure implementation

There is a wide scope for further integration of green infrastructure across EU policies and within specific instruments implementing EU policies. In addition, the EU can support Member States in developing policies also in areas where it has only limited competencies, thus helping them to achieve the objectives which would be set in a Green Infrastructure Strategy.

9.2.1 Cross-cutting instruments

Wider EU support to investments in green infrastructure

For its Green Infrastructure Strategy to be fully implemented, it will be necessary to ensure that Member States make full use European sources of funding for investments in green infrastructure whenever this appears an appropriate way to pursue a wide range of policy objectives. To date, a wider range of EU instruments have been used to support investments in green infrastructure and this should continue to be so in the future while being prepared to respond to a higher uptake of funding which might result from the availability of technical assistance, EU level coordination, guidance and encouragement for investments in green infrastructure projects and programmes. The funding instruments which are relevant here would include the CAP (Pillar 1 greening of direct payments), Pillar 2 (EAFRD), Cohesion Fund (ERDF), European Social Fund, LIFE+ and the EMFF (see policy area specific recommendations below). It will be important for the Common Strategic Frameworks (for the five funds under shared management, including total development) to translate green infrastructure related objectives into an investment priority including in key actions and focus areas for green infrastructure. The mechanism for funds coordination for an integrated approach to investing in green infrastructure will need to be outlined.

Innovative financing, might in some cases support investments in technical assistance (eg JAPSERS) and specific types of green infrastructure investments (eg climate change adaptation in urban areas through JESSICA). The main way in which an increase in investments through JESSICA can be beneficial to green infrastructure is by freeing up grant money that could go into investments in green infrastructure, because direct short term returns on investments are less likely and therefore less attractive for innovative financing instruments.

Biodiversity and climate proofing of EU expenditure

Proper coordination and targeting of spending across the different EU funding instruments should be ensured to amplify synergies and avoid duplications. Better targeting of public expenditure is necessary particularly in times of sovereign debt crisis and austerity measures with a view to deliver highest EU added value. The mainstreaming of green infrastructure under the different funding instruments requires that appropriate actions are undertaken depending on the specific rationale and intervention logic of each instrument. For example, LIFE+ should provide ‘seed money’ for innovative, experimental and demonstration projects (including on the interlinkages between green infrastructure and climate change) which can then be replicated under other larger funding instruments. Cohesion Policy can focus on investments in macro-regional (eg Baltic and Danube), regional and urban level, and also through the newly introduced community-led initiatives. The ESF is suitable to support projects for the development of new jobs and skills including administrative capacity building, human resources and training for both managing authorities and beneficiaries for the development of meaningful green infrastructure projects and the horizontal integration of green infrastructure (proofing) across other types of expenditure. The EAFRD shall promote green infrastructure in rural areas and ecosystem friendly agricultural practices. The Connecting Europe Facility should ensure that large scale and cross border transport and energy infrastructures do no disrupt the integrity and health of ecosystem and where appropriate integrate green infrastructure elements into the design of these infrastructures. Technical assistance should be made available both for the design, planning and implementation of green infrastructure policies and projects and for the mitigation of adverse impacts of developments on green infrastructure.

Improving the knowledge base, information collection and dissemination/ awareness raising

The Horizon 2020 framework programme should prioritise research on green infrastructure as part of the knowledge base needed to underpin the transformation processes towards a resource efficient and sustainable green economy. Further research is required in a wider range of areas to investigate under which conditions green infrastructure can effectively contribute to meeting policy objectives across a wider range of policy areas. The research Agenda would reflect some of the recommendations from EPBRS's assessment of the research needs on "Biodiversity and Planning" (see box 7.2). In particular, a better understanding needs to be developed with regard to ecosystems and their functioning, physical (ecosystem service) flows and their link to ecosystem health, the effects of fragmentation on habitat coherence and resilience, the health, climate, water and wider ecosystem service benefits of green infrastructure. Horizons 2020 should also support research activites relating to the interlinkages between soil functions and green infrastructure and the identification of the potential of green infrastructure to be used to address some of the threats to soil identified in the 2006 Strategy Thematic Strategy in view of promoting best practice in this regard and identifying cost-effective interventions which could be financed through the EU budget. Equally important for the development of future green infrastructure initiatives and in particular the identification of the most cost-effective green infrastrucutr interventions would be a better monitoring of the impacts of green infrastructure projects and policy initiatives on biodiversity, ecosystem services and human wellbeing. The potential of ESPON 2013 to support research for the development of the tools necessary for the integration of green infrastructure in spatial planning should be more fully exploited.

All these research activities would underpin the implementation of the revised regulation on Environmental Economic Accounts, which would make the standardised mapping and stock taking of green infrastructure elements mandatory as well as request regular reporting on the state of ecosystems and their services. This is key for an EU level monitoring of the implementation of the Strategy, the integration of green infrastructure in EU policies and the climate and biodiversity proofing of EU expenditure.

To ensure the best use of the knowledge produced and effective dissemination of best practice examples and guidance to practitioners throughout Europe, a European information gateway could collect, screen and disseminate available information on green infrastructure implementation and make it available to the relevant stakeholders across the different sectors of importance to green infrastructure. The importance of increasing awareness of green infrastructure and promoting capacity building was also stressed by other recent studies which looked into green infrastructure implementation at the project level (Naumann et al., 2011).

Supporting the integration of green infrastructure into spatial and territorial planning

The EU's competence in the area of spatial planning is limited under current treaties. The EU can, however, build on a number of existing EU-level processes which can support best practice with regard to green infrastructure integration in spatial planning. In addition, building on the 1999 ESDP, the EU could promote spatial planning in a more pro-active way, by developing and disseminating a toolkit for spatial and regional planners. This toolkit could also underpin EU-financed capacity building activities (technical assistance) in some cases.

Building on respective mandates from the 1999 European Spatial Development Perspective (ESDP) and the 2011 Territorial Agenda the EC green infrastructure toolkit would outline the ways in which a more integrated approach to spatial and urban planning would consider green infrastructure elements. The toolkit would address key issues of relevance to green infrastructure implementation, including the restoration of ecosystems, maintenance and enhancement of protected areas (Natura 2000), the integration of ecological corridors and the need to reconcile the ecological functions with economic exploitation. Specific advice relating to the benefits of urban green infrastructure could also be provided to make planners aware of the potential cost-savings that can be obtained through green infrastructure initiatives. In order to visualise the benefits gained from better considering green infrastructure in the planning process, the toolkit could introduce valuation methods. Mapping is essential for a better consideration of green infrastructure in spatial planning, but the mapping of existing and required green infrastructure in a meaningful way is challenging. Consideration should therefore be given to the establishment of a taskforce to develop guidance on technical and institutional aspects related to mapping Green Infrastructure elements.

Key EU-level strategic documents (eg Territorial Agenda 2020) relating to spatial planning and integrated territorial development could be further aligned with the green infrastructure approach. Where hooks exist (such as in the ESDP) these would be more frequently referred to. EU funding would support investments which are thought to implement projects and programmes resulting from integrated spatial planning approaches, such as climate change adaptation plans adopting an ecosystem based approach to climate change mitigation and adaptation. The ESPON 2013 programme would more pro-actively supports research which provides the territorial data information required for integrated spatial planning and integrated territorial development.

Making impact assessment a more effective tool for green infrastructure protection and enhancement

Future reforms of the EIA and SEA Directives should ensure that impacts on green infrastructure and its coherence are better taken into account and mitigated. The depth with which EIA and SEA are carried out needs to be improved as well as the number of cases in which EIA and SEA are required further expanded. It is particularly important for SEA to systematically take place and consider green infrastructure when developing spatial policies and plans. EU funded programmes or projects which could potentially have impacts on any type of green infrastructure should systematically undergo an EIA/SEA.

Revised guidance on the application of EIA/SEA should help implementing the new requirements. EIA and SEA guidelines should in particular:

- provide unified criteria for better green infrastructure consideration;
- recommend indicators for assessing impacts on green infrastructure elements and ecosystem services;
- illustrate how green infrastructure coherence and ecosystem resilience to climate change can best be taken into account;

- promote best practice in consultation procedures/promote public participation in EIA/SEA to better integrate green infrastructure and its benefits;
- emphasize the need for the maintenance of existing green infrastructure, firstly through mitigation measures to prevent and reduce impacts, and secondly by necessary offsetting significant residual impacts on green infrastructure (eg by the appropriate restoration or creation of green infrastructure elements);
- stress the scope within EIA/SEA to identify positive opportunities for enhancing green infrastructure and seizing opportunities to enhance biodiversity (eg through measures to increase the ecological coherence of core area networks) and provide ecosystem services (eg green roofs, carbon storage, etc.);
- include clarification and guidance on application of SEA to Cohesion Policy funds; and
- improve the coordination between EIA, SEA and Appropriate Assessments of the Habitats Directive in terms of green infrastructure and in particular the coherence of the Natura 2000 network and the dependency of Natura sites on other core areas.

External development cooperation

The next 'Environment and Natural Resources Thematic Programme' (ENRTP) should foresee financing for ecosystem based approaches to delivering services such as carbon storage, flood prevention/water management, water cleansing and wastewater management and provides incentives for developing countries proposing such projects. In other programmes which are more concerned with the development of grey infrastructure (eg road, electricity distribution networks) requirements are added for EIAs and cost-benefit analysis of such infrastructure projects to clearly acknowledge impacts on Green infrastructure and the ecosystem services it delivers to ensure that ways to minimise impacts are devised. Funding is made conditional to adequate mitigation and the choice of the option which minimises adverse impacts.

9.2.2 Agricultural Policy

In a primarily land based policy such as the CAP, the aim of environmental integration over the past decade has been to produce an integrated policy that addresses multiple environmental objectives in a coherent way. While it is helpful to emphasise the need to deliver specific environmental outcomes like biodiversity, water, climate, soil (and possibly green infrastructure in the future) for their individual merits, there is a limit to the need for 'new' measures. It is therefore recommended that emphasis be put on the role of existing CAP measures in delivering green infrastructure and ensuring that MSs have the guidance and expertise to design and implement them appropriately. The message that tools are there and implementation is the key has been stressed by several recent projects on the related topics. With this in mind, the following conclusions as regards supporting green infrastructure in agricultural policy may be formulated:

Within the CAP Pillar II (rural development), the mandatory character of the agri-environmental measure and minimum spend requirements relating to them should be maintained, while the focus on habitat restoration in agri-environment measures could be strengthened. Bonus/top-up payments should be granted to recipients of rural development funding who commit to landscape-scale management involving multiple holdings. The measures supporting infrastructure built on agricultural land and holdings should require establishment of connectivity features which provide ecological added value as a compulsory part of the investment.

Within the CAP Pillar 1, a range of changes are currently being proposed, including greening measures based on multiannual contracts. Amongst the proposals, the measure that perhaps has the most potential to deliver green infrastructure benefits is the 'ecological focus area', which requires a proportion (seven per cent is proposed) of a farm's eligible hectares (excluding land under permanent grassland) to be allocated for ecological purposes, for example as landscape features, buffer strips or fallow land. This undoubtedly has the potential to provide important biodiversity benefits, such as for birds, mammals and invertebrates, as well as benefits for aquatic biodiversity as a result of reduced run off and pollution of water courses. However, the actual magnitude will depend on the precise details of this measure, which are not yet clear. The benefits for biodiversity could be increased significantly by integration with green infrastructure planning and targeting and appropriate tailoring of management practices, which in many cases might be achieved through the use of agri-environment agreements.

The mandatory Pillar 1 greening measures could be further supported by new mandatory provisions for GAEC standards relating to green infrastructure could be usefully introduced (eg minimum connectivity elements; wetland protection, permanent pasture, HNV farmland, etc). Also beneficial to green infrastructure would be a further strengthening of organic farming support under greening measures for Pillar 1, provision of a bonus under Pillar 1 for Natura 2000 and HNV farms. Further consideration should therefore be urgently given during the current debate on the Commission's proposals for Greening Pillar 1 on the ways in which these measures may best support the intended Green Infrastructure Strategy.

Agri-environment schemes and other measures under Pillar 2 of the CAP are by far the largest funder of conservation measures in the wider environment, and therefore have a special role to play in the maintenance and enhancement of green infrastructure. Evidence shows that many agri-environment schemes already make major contributions in this respect, and therefore further benefits would undoubtedly come from increased funding for such schemes. Their beneficial impacts could also be enhanced by explicitly including green infrastructure related priority objectives (eg reducing fragmentation of priority threatened habitats) in the development of Rural Development Programmes and agri-environment schemes and detailed measures. Where they should also seek to provide landscape-scale impacts (eg by judicious targeting) where these are necessary to realise lasting and significant benefits. Where Natura 2000 coherence action plans or other plans for implementation of Habitat Directive Article 10 exist in Member States, the agricultural authorities should be encouraged to integrate them into Rural Development programmes and agri-environment schemes, and other measures such as GAEC cross-compliance, Nautra 2000 payments and non-productive investments on agricultural land.

EU guidance and encouragement for the sharing of experience by Member States on mapping and monitoring of High Nature Value farmland should be reinforced. In particular, this guidance should seek to encourage the use of the Land Parcel Information System (LPIS) for monitoring of landscape features by Member States more comprehensively and rigorously, and to enhance the LPIS across the EU-27 to include land use elements relevant to green infrastructure. In addition, Member States should be encouraged to use the training, advisory and information measures under the rural development policy to promote green infrastructure related management. The farm advisory system would benefit from revisions aiming to provide more focused advice on green infrastructure-related management.

9.2.3 Forestry

In EU forest policy, the changes developed and specified under the different options encounter a political environment which, under the Forestry Action Plan, already consists of mainly coordinating and cooperating measures with the aim to streamline Member States activities. However, as recent studies have found (see eg Winkel et al. 2009), actions derived from this process have not always proved effective, especially regarding the protection and restoration of forest ecosystems. Besides the efforts of even more coordination between Member States, the authors call for a more Community oriented approach for forest protection.

The concept of green infrastructure and the debate about its implementation could serve as a new boost firstly towards a more integrated view of forest protection across Europe, which also encourages better liaison between foresters and other stakeholders, and secondly, for stronger commitments for – and possibly less opposition against – joint and adjusted action at a Community level. The "Green Paper on Forest protection and information in the EU: Preparing forests for climate change" poses the right questions for such a new approach. However, several elements need further specification in a common EU forest strategy (eg sharpening of the SFM standards and different targets for adaptive afforestation, reduction of damage at felling, genetic diversity of forests, increased adaptive capacity of forests, key elements of functional connectivity) in order to support the development of a green infrastructure network in Europe.

In this context, we recommended that:

- The Green Paper should result in an EU strategy on Forest Protection and Information, which will not only integrate the objectives of a green infrastructure in Europe, but will also be designed to complement the green infrastructure approach from a forestry perspective.
- The Commission should provide a concept for additional funding to fulfil the targets of the forest strategy in order to stimulate acceptance by Member States and to mobilise resources to implement the measures proposed therein.

9.2.4 Biodiversity and nature

The review of biodiversity policy carried out for this study has shown that the EU has a relatively comprehensive biodiversity conservation policy framework, with many measures integrated across the various sectors (as reflected in the relevant recommendations elsewhere in this chapter). These are recognised and brought together in the EU Biodiversity Strategy, which includes a reference to the intention to create an EU Green Infrastructure Strategy. It is therefore obvious that the implementation of the Biodiversity Strategy and development of a Green Infrastructure Strategy in accordance with the priorities is of fundamental importance in terms of maintaining and restoring biodiversity and increasing ecosystem resilience and related ecosystem services.

The Birds and Habitat Directives are the main EU instruments with a specific focus on biodiversity conservation. With their broad objectives and scope, which cover the whole of the EU territory and a wide range of species and habitats (and not just protected areas) their full implementation contributes substantially to the envisaged aims of an EU Green Infrastructure Strategy. Indeed, they already contain a number of specific measures that support the maintenance and enhancement of green infrastructure elements. As suggested in another recent study for DG Environment (IEEP/Alterra, 2010) it is therefore particularly recommended that:

- 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 wider green infrastructure objectives and the provision of other ecosystem services, whilst also taking into account future actions that may help increase resilience to climate change. This would help to justify increased targeting of Natura sites and biodiversity under existing funding instruments, in particular agri-environment schemes and be a step towards widening the range of funding options for management plan measures that provide ecosystem service benefits (such as carbon sequestration and protection, or water resources).
- Member States should 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:
    - Identify species and habitats of Community interest that are already impacted by, or vulnerable, to fragmentation and/or changes in suitable climate space.
    - Assess the functional connectivity requirements of vulnerable species and habitats, taking into account likely habitat fragmentation and climate change impacts where necessary.
    - Integrate functional connectivity requirements into ecological networks and generic habitat measures across the wider environment.
    - Implement connectivity measures through existing mechanisms, such as protected area management plans, planning regulations and policies, land-use policies, and EU funding mechanisms (see relevant recommendations elsewhere in this chapter).
- Further promote and support the implementation of existing green infrastructure initiatives, such as ecological networks, that have the potential to strengthen ecological coherence and deliver significant biodiversity benefits. Actions should focus on those that have been found to be associated with successful implementation, 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, 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 (eg 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, the EU Structural Funds, Member States measures to deliver River Basin Management plan requirements, habitat banking initiatives 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.

This study has revealed that a major constraint on the planning and monitoring of green infrastructure initiatives is our inadequate knowledge of some key aspects of landscape ecology and species ability to move through the wider landscape. In the development of fragmentation guidelines for the Commission Kettunen et al (2007) provided a number of research recommendations and those below still seem to be highly pertinent today, and therefore should be a focus of further EU funded research:

- Increase our understanding of the interrelationships between connectivity and landscape structure and role in maintaining favourable conservation status amongst habitats and species.
- Identify and quantify the cost-effectiveness of practical measures that can be take to increase matrix permeability.
- Establish which habitats and species of Community importance are particularly at risk at a national and biogeographic scale from habitat fragmentation and the likely impacts of climate change.
- Develop and implement monitoring schemes (including the collection of baseline data) that aim to measure the actual impacts of ecological networks and other connectivity measures in relation to specific quantifiable biodiversity related objectives (including the coherence of the Natura 2000 network and the wider maintenance and restoration of favourable conservation status in habitats and species of Community interest.

9.2.5 Water Policy

There are two main challenges for future water policy with regard to green infrastructure. First, water policy needs to more clearly refer to measures relating to the use of green infrastructure for achieving its policy objectives. Second, relevant authorities have to be provided with sufficient financial resources to effectively apply the necessary measures to achieve the objectives.

To meet the first challenge, the EU guidance on drafting national River Basin Management Plans should be revised and complemented by a concept of how to apply water-related green infrastructure measures (including natural water retention measures). For the second, especially for effective management of floods and wetlands, coordination between Cohesion Policy investments and the measures under the Common Agricultural Policy must be enhanced, also to provide appropriate funding for ecological flood risk management under the Floods Directive. Moreover, the future EU Water Blueprint could foresee the systematic consideration of the opportunity costs of natural water retention measures and, where relevant, their translation into land acquisition, compensation or service payments.

This can be realised, among others, by fair water pricing, as requested by Article 9. Of the water Framework Directive, whereby authorities responsible for the development and implementation of River Basin Management Plans will have the responsibility for ensuring that the proceeds will be spent on securing the availability of water and improving its quality through appropriate creation and management of green infrastructure.

9.2.6 Climate change Policy

Green infrastructure can play a major role in both mitigation and adaptation strategies. An examination of sectoral strategies revealed that agriculture, forestry, biodiversity, water and coastal and marine areas are the sectors most relevant for the application of ecosystem-based approaches. This recently completed project identifies a clear need to raise awareness for the ecosystem based approach as one of the main barriers to their implementation identified is lack of awareness and understanding at all levels and recommends that a clear concept note be developed which would outline opportunities and links to different policy sectors (Naumann et al, 2011). While green infrastructure and, more specifically, ecosystem restoration can make ecosystems more resilient to climate change, it can also increase their carbon capture capacity of wetlands, forests, but also grasslands. In terms of adaptation strategies it is recommended to conduct an EU-wide research project to identify areas that are particularly vulnerable to climate change and at risk of loosing ecosystem services if no restoration is undertaken. This should support more targeted and effective action towards ecosystem-based adaptation in Europe, it will also raise the awareness of regional authorities on the role of ecosystem capacities in their own future adaptation approaches. Regional authorities will also have to be informed about the synergies green infrastructure bears in achieving different environmental objectives. While restoration of ecosystems might mostly be regarded under the perspective of protecting biodiversity, its potentials in adaptation could make actors make aware of numerous benefits that can be gained from implementing such concepts. In terms of mitigation, the crucial role of (well-functioning) ecosystems has to be recognised in relevant planning and management strategies. EU guidance will be needed on how innovative financing schemes such as Payments for Ecosystem Services (PES) can be created for involving the private sector in regional and local mitigation strategies.

9.2.7 Cohesion Policy

Territorial approaches to integrated planning for regional and urban development should be considerably enhanced with a view to exploit development opportunities based on natural capital assets but also in terms of identifying vulnerable infrastructures (both manmade and natural) to climate change impacts. The use of spatial mapping of green infrastructure assets needs to underpin the programming of expenditure and prevent undesired irreversible damages to nature, ecosystems and biodiversity. The programming and coordination of EU spending based on functional geographies (eg river basins, mountain ranges, etc.) and macro-regions should be strengthened in order to achieve higher connectivity and multi-functionality of ecosystem as well as foster cross-border partnerships, cooperation and exchange of good practices.

Green infrastructure is made a priority under the new thematic objectives of the CSF funds including Cohesion Policy. This requires two parallel steps, which are mutually reinforcing:

- Step up investment in green infrastructure through increasing the share of expenditure allocated under the ERDF and Cohesion Fund. The ESF should also be used to support awareness raising and capacity building of both managing authorities and beneficiaries to ensure that meaningful green infrastructure projects are developed and high level of absorption is ensured.
- Climate and biodiversity proof Cohesion Policy expenditure. This requires the development of governance mechanisms and instruments for ensuring that expenditure that is likely to have negative impacts on green infrastructure is discouraged throughout the project selection process or appropriate mitigation measures are put in place. Green infrastructure maps and valuation technics should be integrated in existing instruments such as CBA, ex-ante evaluations, SEA/EIA, project selection criteria, ex-ante conditionalities, performance framework, indicators, etc.

The scope of technical assistance (eg JASPERS) should be revised so as to help project promoters to develop green infrastructure projects and also integrate green infrastructure elements in the feasibility studies of smaller scale projects (eg water treatment and purification). Innovative financial instruments could be used for revenue-generating projects (eg green infrastructure-based energy efficiency) thereby offering alternative financial sources of financing and at the same time freeing up grant money for biodiversity, climate adaptation and nature conservation measures.

9.2.8 Transport and energy

The need to better take into account the requirements for preserving and enhancing Europe’s green infrastructure should fully reflect in the future provisions governing the functioning of the Connecting Europe Facility. In particular, all projects applications should be biodiversity and climate proofed and should include harmonised green infrastructure maps (ie meeting minimum requirements/standards). The EU share of co-financing should be variable depending on whether or not applicants for funding add to their project proposal a concrete plan to support the green infrastructure in close proximity to the proposed development. The EU should encourage MS to put aside a small proportion of road user fees for ex-post road infrastructure mitigation projects and programmes, thus further implementing the polluter pays principle.

9.2.9 Marine and Coastal Zones Policy

The future EMFF should support measures relying on green infrastructure, including restoration activities, to meet the objectives of the Marine Strategy Framework Directive (MSFD), in particular achieving good environmental status (GES) by 2020. Should the MSFD be revised, this should be used as an opportunity to include green infrastructure (actions) more explicitly and clarify what ‘green infrastructure’ would be in the context of the marine environment. Mapping of ecosystems and Marine Protected Areas could be added to the reporting requirements off the MSFD and indicators of green infrastructure benefits could be included. With regard to coastal zones, the revised ICZM recommendations should strongly encourage MS to include measures for the identification and protection of key green infrastructure and identify restoration areas in view to adapt to climate change and invest in coastal defence in their national Strategies for the integrated management of their coastal zones. EMFF money should be available to support such investment through particularly favourable co-financing rates for ecosystem based solutions.

9.3 Added value and limits/potentials of a green infrastructure Strategy for Europe

A wide range of policy initiatives currently exists, relying on a variety of tools, instruments and measures to support elements of Europe's green infrastructure at various scales of governance. While some are designed to deliver one particular objective, others contribute to meeting multiple objectives. The green infrastructure concept offers an opportunity to integrate and combine them across scales and maximise their potential to optimise the delivery of ecosystem services and biodiversity benefits at EU level.

The results of this study suggests that the objectives of the action to be taken, namely to establish a common framework for the protection and enhancement of the green infrastructure, cannot be sufficiently achieved by the Member States alone and without a coherent approach. Given the scale of the challenge that ecosystem degradation and loss of ecosystem services represents, its implications with respect to a wide range of EU level legislation and objectives and that some EU sectoral policies may contribute to exacerbating the problem or help mitigate ecosystem degradation processes, further integration of green infrastructure approaches into such policies is necessary. Thus, the EU may need to adopt policy measures, in accordance with the principle of subsidiarity.

Amongst the main barriers to green infrastructure approaches is a lack of awareness that ecosystem degradation results in problems that require both strategic and targeted policy interventions to be overcome, that taking appropriate measures is urgent and early action more cost-effective than ad-hoc solutions and that in many cases, appropriate and cost-effective responses may include green infrastructure measures or ecosystem based approaches (see also Naumann et al. 2011 (Forthcoming), the absence of convincing proof that green infrastructure measures will indeed achieve the desired results, the public and private implementation costs involved and the negative impacts on certain vested interests (whether perceived or real). The EU is in a position to influence all these factors, although some more than others.

Thus, one important role for the EU is the elaboration of a common vision and identification of strategic goals as regards green infrastructure implementation. A more recent study concerned with the project level also suggests that a clear framework at EU level, which would clarify the concept (possibly even provide a definition), typology of initiatives, objectives and targets would support the effective design of products adopting an integrated land use approach, encourage and facilitate the uptake of ecosystem based approaches and help integrate the concept into spatial planning processes (Naumann et al., 2011).

In addition, the EU can play an important role in further demonstrating that green infrastructure approaches deliver the benefits they have been adopted for. An increasing amount of examples can serve to demonstrate that the main elements of green infrastructure are widely accepted and are being incorporated into a range of implementing programmes. Awareness of growing problems in the delivery of ecosystem services and perceptions of green infrastructure can also be influenced, particularly if the message comes from European Commission DGs other than DG Environment. The target groups need to be clearly identified and their understanding of what green infrastructure tries to achieve must be fostered. Also, at EU level, alliances with key public and private stakeholders can be built which would aim to use cross-cutting instruments, particularly research, awareness-raising and the various financial instruments, especially in agriculture and regional development. A recent study focused on green infrastructure implementation at project level (Naumann et al., 2011) resulted in similar recommendations as it identified the main opportunities for EU policy actions on green infrastructure to lie in:

- The creation of a common legislative framework (eg EU Strategy with common vision an strategic goals, workable definition, typology of green infrastructure initiatives, etc)
- Increasing awareness and facilitating knowledge transfer across the EU MS states (eg campaigns targeted at specific stakeholders and sectors, highlight best-practice examples and demonstration projects, development and dissemination of tools etc.)
- Maximising efficiency of EU funding (eg better targeting of available funds, better identification of financial needs at EU level, increase support to public private partnerships and innovative financing, promote PES scheme development, etc)

This also resonates with some of the main roles for the EU with regard to green infrastructure which were identified by participants to an expert workshop on 'Green infrastructure projects and policies'[41], which took place in September 2011. According to the participants, some of the most important contributions of the EU could lie in:

- Providing a common vision/ strategic goals, including a clear definition and objectives (key indicators set at EU level so values are comparable), supporting promising/high visibility demonstration projects and which can then be used for communication purposes.
- Ensuring there is maximum coherence with regard to the promotion green infrastructure and the mitigation of impacts on it needs to be ensured.
- Providing technical assistance and training (funded by EU/MS) at regional and local levels
- Making resources (both human and financial) for green infrastructure implementation available

With regard to cost savings, the added value of a coordinated and integrated approach at EU level such as those presented in options 3 and 4 above, will depend on the degree to which these policies are taken up by Member States or the policy sectors at the EU level. Lessons from the implementation of the Water Framework Directive nonetheless imply that the co-ordinated approach is likely to result in cost savings, including through:

[41] Expert workshop on 'Green infrastructure projects and policies', URL: http://ecologic.eu/4286

- Improved co-ordination of different administrations at regional and national level regarding management and monitoring.
- Reduced costs of managing of ecosystems as whole units rather than in smaller segments as a result of lower fixed costs (see for example Armsworth et al, 2011).
- Setting of common definitions and standards facilitating a common approach.
- Action at an EU level could work to leverage greater private sector financing of green infrastructure initiatives, through, for example, payments from both public and private buyers for the provision of ecosystem services (Dickie et al, 2011).

A co-ordinated approach is most likely to be beneficiary at an EU level, as a result of ensuring of multiple policy objectives through existing funds, and at Member State level, through reduced operating costs as a result of a standard framework on which to co-operate with neighbouring Member States for overlapping ecosystems. The regional and local levels may also be directly impacted by a co-ordinated approach by being supported in delivering green infrastructure projects and measures in line with EU guidance and recommendations and being able to build on previous experience from across Europe, thus avoiding potentially costly experimentation with moderately effective approaches to green infrastructure implementation.

10 REFERENCES

Aaerstrup, K, Lucas, M C and Hansen, J A (2003) Efficiency of a nature-like bypass channel for sea trout (Salmo trutta) ascending a small Danish stream studied by PIT telemetry. Ecology of Freshwater Fish, No 12, pp160-168.

Adriaensen, F (2003) The application of 'least-cost' modelling as a functional landscape model.

Adriaensen, F.; Van Damme, S.; Van den Bergh, E.; Van Hove, D.; Brys, R.; Cox, T.; Jacobs, S.; Konings, P.; Maes, J.; Maris, T.; Mertens, W.; Nachtergale, L.; Struyf, E.; Van Braeckel, A.; Meire, P. (2005). Instandhoudingsdoelstellingen Schelde-estuarium. Report Ecosystem Management Research Group ECOBE, 05-R82. Universiteit Antwerpen: Antwerpen, Belgium. 249 + bijlagen pp

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, No 12, (3) pp374-390.

Allen, C R, Gunderson, L and Johnson, A R (2005) The use of discontinuities and functional groups to assess relative resilience in complex systems. Ecosystems, No 8, (8) pp958-966.

Alterra (2008) Restoring ecological networks across transports corridors in Bulgaria: Identification of bottleneck locations and practical solutions.

Anderson, M J, Crist, T O, Chase, J M, Vellend, M, Inouye, B D, Freestone, A L, Sanders, N J, Cornell, H V, Comita, L S, Davies, K F, Harrison, S P, Kraft, N J B, Stegen, J C and Swenson, N G (2011) Navigating the multiple meanings of beta diversity: a roadmap for the practicing ecologist. Ecology Letters, No 14, (1) pp19-28.

Ando, A, Camm, J, Polasky, S and Solow, A (1998) Species Distributions, Land Values, and Efficient Conservation. Science, No 279, (5359) pp2126-2128.

Angold, P G, Sadler, J P, Hill, M O, Pullin, A, Rushton, S, Austin, K, Small, E, Wood, B, Wadsworth, R, Sanderson, R and Thompson, K (2006) Biodiversity in urban habitat patches. Science of the Total Environment, No 360, pp196-204.

Aphekom (2011) Improving knowledge and communication for decision making on air pollution and health in Europe. Summary Report of the Aphekom project 2008-2011.

Armsworth, P R, Cantú-Salazar, L, Parnell, M, Davies, Z G and Stoneman, R (2011) Management costs for small protected areas and economies of scale in habitat conservation. Biological Conservation, No 144, pp423-429.

Aronson, J, Blignaut, J N, Milton, S J, Le Maitre, D, Esler, K J, Limouzin, A, Fontaine, C, De Wit, M P, Mugido, W, Prinsloo, P, Van Der Elst, L and Lederer, N (2010) Are socioeconomic benefits of restoration adequately quantified? A meta-analysis of recent papers (2000-2008) in Restoration Ecology and 12 other scientific journals. Restoration Ecology, No 18, (2) pp143-154.

Aronson, J, Milton, S J and Blignaut, J N (eds) (2007) Restoring Natural Capital: Science, Business, and Practice. Island Press, Washington DC.

Atanasiu, B. (2010) The role of bioenergy in the National Renewable Energy Action Plans: a first identification of issues and uncertainties. IEEP: London.

Bade, T, Middendorp, B v and Smid, G (2009) Nieuwe natuur, nieuwe economie. Arnhem, Kenniscentrum Triple E.

Badgley, C., Moghtader, J., Quintero, E., Zakem, E., Chappell, M.J., Aviles-Vazquez, K., et al. (2007). Organic agriculture and the global food supply. Renewable Agriculture and Food Systems, 22(2), 86-108.

Bailey, E (2010) The most important hill in Britain. Natural World, No Winter 2010, pp13-18, The Wildlife Trusts

Bailey, S (2007) Increasing connectivity in fragmented landscapes: An investigation of evidence for biodiversity gain in woodlands.

Bakkes, J A, Bosch, P R, Eerens, H C, Bouwman, A F, den Elzen, M G J, Isaac, M, Janssen, P H M, Klein Goldewijk, K, Kram, T, de Leeuw, F A A M, Olivier, J G J, van Oorschot, M, Stehfest, E E and van Vuuren, D P (2011) Background report to the OECD Environmental Outlook to 2030. Overviews, details, and methodology of model-based analysis. MNP Report 500113001/ 2008, MNP Netherlands Environmental Assessment Agency, Bilthoven.

Báldi, A (2008) Habitat heterogeneity overrides the species-area relationship. Journal of Biogeography, No 35, pp675-681.

Ballon, P (1985) First observations for proving the efficiency of wildlife passages across the motorway A36., in Routes Et Faune Sauvage, pp311-316.

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. Final Report (draft version as of 19 May 2008). ENV/070307/2007/486089/ETU/B2, University of Cambridge, Cambridge, UK.

Balmford, A, Rodriguez, 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. European Commission, Cambridge, UK.

Bank, F G, Irwin, C L, Evink, G L, Gray, M E, Hagood, S, Kinar, J R, Levy, A, Paulson, D, Ruediger, B, Sauvajot, R M, Scott, D J and White, P (2002) Wildlife Habitat Connectivity Across European Highways. American Trade Initiatives, Alexandria, VA, USA.

Banting, D, Doshi, H, Li, J, Missions, P, Au, A, Currie, B A and Verrati, M (2005) Report on the environmental benefits and costs of green roof technology for the city of Toronto. Ryerson University, Toronto.

Bartczak, Anna, Lindhjem, Henrik, Navrud, Ståle, Zandersen, Marianne and Zylicz, Tomasz (2008): Valuing forest recreation on the national level in a transition economy: The case of Poland, Forest Policy and Economics 10 7-8 : pp. 467-472.

Baskent, E and Keles, S (2008) Developing alternative forest management planning strategies incorporating timber, water and carbon values: an examination of their interactions. Environmental Modeling and Assessment, No 14, (4) pp467-480.

Bateman I., R. Brouwer, S. Ferrini, M. Schaafsma, D. Barton, A. Dubgaard, B. Hasler, S. Hime, I. Liekens, S. Navrud, L. De Nocker, Ščeponavičiūtė R., Semėnienė D., (2011b). Making Benefit Transfers Work: Deriving and Testing Principles for Value Transfers for Similar and Dissimilar Sites Using a Case Study of the Non-Market Benefits of Water Quality Improvements Across Europe. Environmental and Resource Economics, 50:365-387

Bateman Ian J, David Abson, Nicola Beaumont, Amii Darnell, Carlo Fezzi, Nick Hanley, Andreas Kontoleon, David Maddison, Paul Morling, Joe Morris, Susana Mourato, Unai Pascual, Grischa Perino, Antara Sen, Dugald Tinch, Kerry Turner and Gregory Valatin (2011 a), Economic Values from Ecosystems. In: The UK National Ecosystem Assessment Technical Report. UK National Ecosystem Assessment, UNEP-WCMC, Cambridge, 2011.

Beaufoy, G and Cooper, T (2008) Guidance Document to the Member States on the Application of the High Nature Value Indicator. Report for DG Agriculture.

Beaumont, N J, Austen, M C, Mangi, S C, Townsend, M (2008) Economic valuation for the conservation of marine biodiversity, Marine Pollution Bulletin, Volume 56, Issue 3, March 2008, Pages 386-396,

Begon, M, Townsend, C R and Harper, J L (2006) Ecology - From Individuals to Ecosystems. 4th ed. Blackwell Publishing, Malden, USA / Oxford / Carlton, Australia.

Begon, M., C. R. Townsend, and J. L. Harper. Ecology - From Individuals to Ecosystems. 4th ed. Malden, USA / Oxford / Carlton, Australia: Blackwell Publishing, 2006.

Beier, P and Noss, R F (1998) Do habitat corridors provide connectivity? Conservation Biology, No 12, (6) pp1241-1252.

Beier, P, Spencer, W, Baldwin, R F and McRae, B H (2011) Toward Best Practices for Developing Regional Connectivity Maps. Conservation Biology, No 25, (5) pp879-892.

Benayas, J M, Newton, A C, Diaz, A and Bullock, J M (2009) Enhancement of biodiversity and ecosystem services by ecological restoration: a meta-analysis. Science, No 325, (5944) pp1121-1124.

Bender, D J and Fahrig, L (2005) Matrix structure obscures the relationship between interpatch movement and patch size and isolation. Ecology, No 86, (4) pp1023-1033.

Bennett, A F (2003) Linkages in the landscape. The role of corridors and connectivity in wildlife conservation. IUCN, Gland, Switzerland / Cambridge, UK.

Bennett, A F, Henein, K and Merriam, G (1994) Corridor use and the elements of corridor quality: chipmunks and fencerows in a farmland mosaic. Biological Conservation, No 68, pp155-165.

Bennett, G and Mulongoy, K J (2006) Review of experience with ecological networks, corridors and buffer zones. 23, Secretariat of the Convention on Biological Diversity, Montreal.

Bennett, J and Scheufele, G, (2011), Valuing Ecosystem Resilience, Crawford School Research Paper ; Environmental Economics Research Hub (EERH) Research Reports No. 98. Available at SSRN: http://ssrn.com/abstract=1907462

Bennett, V J, Smith, W P and Betts, M G (2011) Toward understanding the ecological impact of transportation corridors. General Technical Report. Pacific Northwest Research Station, USDA Forest Service.

Berliner Wasserbetriebe (2011) Resource protection. URL: www.bwb.de/content/language2/html/956.php.

Bernatzky, A. (1983) The effects of trees on the urban climate. In: Trees in the 21st Century. Academic Publishers, Berkhamster, pp. 59–76

Bernhardt, E S, Palmer, M A, Allan, J D, Alexander, G, Barnas, K, Brooks, S, Carr, J, Clayton, S, Dahm, C, Follstad-Shah, J, Galat, D, Gloss, S, Goodwin, P, Hart, D, Hassett, B, Jenkinson, R, Katz, S, Kondolf, G M, Lake, P S, Lave, R, Meyer, J L, O'Donnell, T K, Pagano, L, Powell, B and Sudduth, E (2005) Synthesizing U.S. River Restoration Efforts. Science, No 308, (5722) pp636-637.

Biala, K, Terres, J-M, Pointereau, P and Paracchini, M L (2008) Low Input Farming Systems: an opportunity to develop sustainable agriculture, in Proceedings of the JRC Summer University

Ranco, 2-5 July 2007. Office for Official Publications of the European Communities, Luxembourg.

BIO Intelligence Service (2011, forthcoming), Estimating the economic value of the benefits provided by the tourism/recreation and Employment supported by Natura 2000, Provisional Final Report prepared for. European Commission - DG Environment

Birch, J C, Newton, A C, Aquino, C A, Cantarello, E, Echeverr+¡a, C, Kitzberger, T, Schiappacasse, I and Garavito, N T (2010) Cost-effectiveness of dryland forest restoration evaluated by spatial analysis of ecosystem services. Proceedings of the National Academy of Sciences, No 107, (50) pp21925-21930.

Bird, W (2004) Natural Fit: Can green space and biodiversity increase levels of physical activity?

Blekemolen, M, Gr, nend, k J M and de Ridder, A (2009) Meerjarenprogramma Ontsnippering (MJPO). Eindrapport evaluatie Meerjarenprogramma Ontsnippering. The Hague, Twynstra Gudde.

Blekemolen, M, Groenendijk, J M and de Ridder, A (2009) Meerjarenprogramma Ontsnippering (MJPO). Eindrapport evaluatie Meerjarenprogramma Ontsnippering. The Hague, Twynstra Gudde.

Blignaut, J, Mander, M, Schulze, R, Horan, M, Dickens, C, Pringle, C, Mavundla, K, Mahlangu, I, Wilson, A, McKenzie, M and McKean, S (2010) Restoring and managing natural capital towards fostering economic development: Evidence from the Drakensberg, South Africa. Ecological Economics, No 69, (6) pp1313-1323.

Bloomberg, M R and Holloway, C (2010) NYC Green Infrastructure Plan. A Sustainable Strategy for Green Waterways.

Bolund, P And Hunhammar, S (1999) Ecosystem services in urban areas. Ecological Economics, No 29, (2) pp293-301.

Botes, A, McGeoch, M A and van Rensburg, B J (2006) Elephant and human-induced changes to dung beetle coleoptera: scarabaedia assemblages in the maputaland centre of endemism. Biological Conservation, No 130, pp573-583.

Bowler, D E, Buyung-Ali, L, Knight, T M and Pullin, A S (2010) Urban greening to cool towns and cities: A systematic review of the empirical evidence. Landscape and Urban Planning, No 97, (3) pp147-155.

Bowyer, C. (2011) Anticipated indirect land use change associate with expanded use of biofuels and bioliquids in the EU - an analysis of the National Renewable Energy Action Plans (updated version of original 2010 report). IEEP: London.

Bradbury, R B, Stoate, C and Tollowin, J (2010) Lowland farmland bird conservation in the context of wider ecosystem service delivery. Journal of Applied Ecology, No 47, (5) pp986-983.

Bradshaw, C J A, Sodhi, N, Peh, K and Brook, B (2007) Global evidence that deforestation amplifies flood risk and severity in the developing world. Global Change Biology, No 13, (11) pp2379-2395.

Brander, L.M., Florax, R.J.G.M, and Vermat, J.E. (2006). The empirics of wetland valuation: a comprehensive summary and a meta analysis of the literature. Environmental and Resource Economics, 33: 223-250

Brander, L.M., Ghermandi, A., Kuik, O., Markandya, A., Nunes, P.A.L.D., Schaafsma and M., Wagtendonk, A. 2008. Scaling up ecosystem services values: methodology, applicability and a case study. Final Report, European Environment Agency, May 2008.

Brauman, K A, Daily, G C, Duarte, T K and Mooney, H A (2007) The nature and value of ecosystem services: an overview highlighting hydrologic services. Annual Review of Environment and Resources, No 32, pp67-98.

Bredenoord, H W B, Dirkx, G H P, VanEsbroek, M L P, Koomen, A J M and Weijschede, T J (2004) Beleidsevaluatie natuur en landschap. Achtergronddocument bij Natuurbalans 2004. Natuurplanbureau, vestiging Wageningen.

Brenneisen, S (2003) The benefits of biodiversity from green roofs: key design consequences. Proceedings of the 1st North American Green Roof Conference pp323-329.

Brenneisen, S (2006) Space for urban wildlife: Designing green roofs as habitats in Switzerland. Urban Habitats, No 4, (1) pp27-36.

Breure, A M, Mulder, C, Rombke, J and Ruf, A (2005) Ecological classification and assessment concepts in soil protection. Ecotoxicology and Environmental Safety, No 62, (211) 229.

Brink B.J.E.ten (2002) Biodiversity indicators for the OECD Environmental Outlook and Strategy: a feasibility study. Bilthoven, The Netherlands.

Broekx S, Smets S, Liekens I, Bulckaen D, Smets S, De Nocker L, Designing a long-term flood risk management plan for the Scheldt estuary using a risk based approach, Natural Hazards 2011, 57-2, p. 245-266. http://www.springerlink.com/content/e43138836415t02n/

Brouwer R, Hess S, Linderhof L (2007a) De Baten van Wonen aan Water, een Internet Keuze Experiment, IVM, University Amsterdam, research report E07-15, 2007

Brouwer, R. et al. (2007b) De Baten van Wonen aan Water: Een Hedonische Prijsstudie naar de Relatie tussen Huizenprijzen, Watertypen en Waterkwaliteit, IVM, Amsterdam.

Brouwer, R., Barton, D.N., Bateman, I.J., Brander, L., Georgiou, S., Martín-Ortega, J., Pulido-Velazquez, M., Schaafsma, M. and Wagtendonk, A. (2009). Economic Valuation of Environmental and Resource Costs and Benefits in the Water Framework Directive: Technical Guidelines for Practitioners. Institute for Environmental Studies, VU University Amsterdam, the Netherlands.

Bruhl, C A, Eltz, T and Linsenmair, K E (2003) Size does matter - effects of tropical rainforest fragmentation on the leaf litter ant community in Sabah, Malaysia. Biodiversity and Conservation, No 12, (7) pp1371-1389.

Bullock, J M, Aronson, J, Newton, A C, Pywell, R F and Rey-Benayas, J M (2011) Restoration of ecosystem services and biodiversity: conflicts and opportunities. Trends in Ecology & Evolution, No 26, (10) pp541-549.

Burel, F (1996) Hedgerows and their role in agricultural landscapes. Critical Reviews in Plant Sciences, No 15, pp169-190.

Butchart, S H M, Walpole, M, Collen, B, van Strien, A, Scharlemann, J P W, Almond, R E A, Baillie, J E M, Bomhard, B, Brown, C, Bruno, J, Carpenter, K E, Carr, G M, Chanson, J, Chenery, A M, Csirke, J, Davidson, N C, Dentener, F, Foster, M, Galli, A, Galloway, J N, Genovesi, P, Gregory, R D, Hockings, M, Kapos, V, Lamarque, J F, Leverington, F, Loh, J, McGeoch, M A, Mcrae, L, Minasyan, A, Morcillo, M H, Oldfield, T E E, Pauly, D, Quader, S, Revenga, C, Sauer, J R, Skolnik, B, Spear, D, Stanwell-Smith, D, Stuart, S N, Symes, A, Tierney, M, Tyrrell, T D, Vie, J C and Watson, R (2010) Global Biodiversity: Indicators of Recent Declines. Science, No 328, (5982) pp1164-1168.

CABE (2009) Making the invisible visible: The real value of park assets. CABE, London.

Cadotte, M W (2011) Beyond species: functional diversity and the maintenance of ecological processes and services.

Cadotte, M W (2011) Beyond species: functional diversity and the maintenance of ecological processes and services.

Cai, M, Pettenella, D and Gatto, P (2008) Report on linking agricultural biodiversity benefits and the type of farming. Report of the EXIOPOL Project. WP II.3.a-2.

Calabrese, J M and Fagan, W F (2004) A comparison-shopper's guide to connectivity metrics. Frontiers in Ecology and the Environment, No 2, (10) pp529-536.

Campbell, A, Kapos, V, Scharlemann, J P W, Bubb, P, Chenery, A, Coad, L, Dickson, B, Doswald, N, Khan, M S I, Kershaw, F and Rashid, M (2009) Review of the Literature on the Links between Biodiversity and Climate Change: Impacts, Adaptation and Mitigation. Technical Series No. 42, Secretariat of the Convention on Biological Diversity, Montreal.

Campbell, A, Miles, L, Lysenko, I, Hughes, A and Gibbs, H (2008) Carbon Storage in Protected Areas: Technical Report. UNEP-WCMC.

Cantú-Salazar, L and Gaston, K J (2010) Very Large Protected Areas and Their Contribution to Terrestrial Biological Conservation. Bioscience, No 60, (10) pp808-818.

Cao, Y, Elliott, J, McCracken, D, Rowe, K, Whitehead, J and Wilson, L (2009) Estimating the Scale of Future Environmental Land Management Requirements for the UK. Land Use Policy Group.

Carpenter, S R and Brock, W A (2006) Rising variance: a leading indicator of ecological transition. Ecology Letters, No 9, (3) pp308-315.

Carter, T And Butler, C (2008) Ecological impacts of replacing traditional roofs with green roofs in two urban areas. Cities and The Environment, No 1, (2)

Carter, T and Keeler, A (2008) Life-cycle cost-benefit analysis of extensive vegetated roof systems. Journal of Environmental Management, No 87, (3) pp350-363.

Carwardine, J, Wilson, K A, Watts, M, Etter, A, Klein, C J and Possingham, H P (2008) Avoiding Costly Conservation Mistakes: The Importance of Defining Actions and Costs in Spatial Priority Setting. PLoS ONE, No 3, (7) e2586.

Carwardine, J, Wilson, K A, Watts, M, Etter, A, Klein, C J and Possingham, H P (2008) Avoiding Costly Conservation Mistakes: The Importance of Defining Actions and Costs in Spatial Priority Setting. PLoS ONE, No 3, (7) e2586.

Cassman, K G, Wood, S, Choo, P S, Cooper, H D, Devendra, C, Dixon, J, Gaskell, J, Khan, S, Rattan, L, Lipper, L, Pretty, J, Primavera, J, Ramankutty, N, Viglizzo, E and Wiebe, K (2005) Cultivated systems, in Ecosystems and Human well-being: Current state and trends: findings of the condition and trends working group, pp745-793. Island Press, Washington Dc.

Castell, C. (2011) SITXELL Input and Results (Chapter in Report to EPSA 2011 Awards organized by the European Institute for Public Administration).

CEC (2009) Composite report on the conservation status of habitat types and species as required under Article 17 of the Habitats Directive. Report from the Commission to the Council and the European Parliament Composite, COM(2009)0358 final, 13.7.2009, Commission of the European Communities, Brussels.

CEC (2010) Accompanying document to the report from the Commission to the Council and the European Parliament: The 2010 Assessment of Implementing the EU Biodiversity Action Plan. COM(2010)1163 final, 8.10.2010,

CEC (2010) LIFE building up Europe's green infrastructure. Addressing connectivity and enhancing ecosystem functions. Publications office of the European Union, Luxembourg.

Chang, C R, Li, M R and Chang, S D (2007) A preliminary study on the local cool-island intensity of Taipei city parks. Landscape and Urban Planning, No 80, pp386-395.

Chapin III, F S, Zavaleta, E S, Eviner, V T, Naylor, R L, Vitousek, P M, Reynolds, H L, Hooper, D U, Lavorel, S,. SalaI, O E, Hobbie S E, Mack, M C, and Díaz S (2000) Consequences of changing biodiversity, Nature, Volume 405, May 2000, pp234-242

Chevassus-au-Louis B, Jean-Michel Salles , Jean-Luc Pujol,2009, Approche économique de la biodiversité et des services liés aux ecosystems, Contribution à la décision publique, Paris; Centre d'analyse stratégique La Documentation française (Rapports et documents , n° 18, 2009)

Christie, M, Hyde, T, Cooper, R, Fazey, I, Dennis, P, Warren, J, Colombo, S and Hanley, N (2011) Economic Valuation of the Benefits of Ecosystem Services delivered by the UK Biodiversity Action Plan. Defra Project SFFSD 0702. Aberystwythn University.

Church A, Burgess J and Ravenscroft N (2011), Cultural Services In: The UK National Ecosystem Assessment Technical Report. UK National Ecosystem Assessment, UNEP-WCMC, Cambridge, 2011.

Clevenger, A P and Waltho, N (2005) Performance indices to identify attributes of highway crossing structures facilitating movement of large mammals. Biological Conservation, No 121, (3) pp453-464.

Clevenger, A P and Wierzchowski, J (2006) Maintaining and restoring connectivity in landscapes fragmented by roads, in K R Crooks & M Sanjayan (eds) Connectivity Conservation, pp502-535. Cambridge University Press, Cambridge, UK.

Cohen, D A, Mckenzie, T L, Sehgal, A, Williamson, S, Golinelli, D and Lurie, N (2007) Contribution of public parks to physical activity. American Journal of Public Health, No 97, (3) pp509-514.

Conant, R T, Paustian, K and Elliott, E T (2001) Grassland management and conversion into grassland: effects on soil carbon. Ecological Applications, No 11, (2) pp343-355.

Connor, E F and McCoy, E D (1979) The Statistics and Biology of the Species-Area Relationship. The American Naturalist, No 113, (6) pp791-833.

Constanza, R, Pérez-Maqueo, O, Martinez, M L, Sutton, P, Anderson, S J and Mulder, K (2008) The value of coastal wetlands for hurricane protection. Ambio, No 37, (4) pp241-248.

Coombes, E, Jones, A P and Hillsdon, M (2010) The relationship of physical activity and overweight to objectively measured green space accessibility and use. Social Science and Medicine, No 70, (6) pp816-822.

Coombes, E, Jones, A P and Hillsdon, M (2010) The relationship of physical activity and overweight to objectively measured green space accessibility and use. Social Science and Medicine, No 70, (6) pp816-822.

Cooper, T, Hart, K and Baldock, D (2009) 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.

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. Report Prepared for DG Agriculture and Rural Development, Contract No 30-CE-0233091/00-28, IEEP, London.

Corlatti, L, Hackländer, K and Frey-Roos, F (2009) Ability of Wildlife Overpasses to Provide Connectivity and Prevent Genetic Isolation. Conservation Biology, No 23, (3) pp548-556.

Courchamp, F, Berec, L and Gascoigne, J (2009) Allele Effects in Ecology and Conservation. Oxford University Press, Oxford, UK.

COWI (2010) Changing city rooftops into green landscapes. Http://www.cowi.com/menu/newsandmedia/news/buildings/pages/cityrooftopsbecomelandscapes.aspx

Credoc (2008) Evolution économique et institutionnelle du programme Natura 2000: étude de cas sur la plaine de la Crau.

Crooks, K R and Sanjayan, M (2006) Connectivity conservation: maintaining connections for nature, in K R Crooks & M Sanjayan (eds) Connectivity Conservation, pp1-19. Cambridge University Press, Cambridge, UK.

Cullis-Suzuki, S and Pauly, D (2010) Marine protected area costs as 'beneficial' fisheries subsidies: a global evaluation. Coastal Management, No 38, pp113-121.

Davies, Z G and Pullin, A S (2007) Are hedgerows effective corridors between fragments of woodland habitat? An evidence-based approach. Landscape Ecology, No 22, pp333-351.

De Groot, R.S., Wilson, M., Boumans, R., (2002). A typology for the description, classification and valuation of Ecosystem Functions, Goods and Services, Ecological Economics Volume, 41 (3):393-408.

de Guenni, L B, Cardoso, M, Goldammer, J, Mata, L J, Ebi, K, House, J and Valdez, J (2005) Regulation of Natural Hazards: Floods and Fires, in R Hassan, R Scholes, & N Ash (eds) Ecosystems and Human Well-Being: Current State and Trends: Findings of the Condition and Trends Working Group, pp441-454. Island Press, Washington DC.

De Nocker L., S. Broekx, I. Liekens (2011) Economische waardering van verbetering ecologische toestand oppervlaktewater op basis van onderzoeksresultaten uit Aquamoney, Rapport voor Vlaamse Milieu Maatschappij, Vito 2011/RMA/R/248

De Vries, J G (1994) Faunal protective measures at roads in Baden-Wurttemberg. Rijkswaterstaat, dienstWeg- en Waterbouwkunde, Delft. Delft.

Department of Health (2004) At least five a week: the evidence on the impact of physical activity and its relationship to health. A report from the chief medical officer, Professor Sir Liam Donaldson. DP, London.

Diamond, J and May, R (1976) Island biogeography and the design of natural reserves, in R May (ed) Theoretical Ecology: Principles and Applications, pp163-186. Blackwell Scientific Publications, Oxford, UK.

Diaz, S and Cabido, M (2001) Vive la difference: plant functional diversity matters to ecosystem processes. Trends in Ecology & Evolution, No 16, (11) pp646-655.

Díaz, S, Tilman, D and Fargione, J (2005) Biodiversity regulation of ecosystem services, In R Hassan, R Scholes, & N Ash (Eds) Ecosystems and Human well-being: Current state and trends: findings of the Condition and Trends Working Group, Island Press, Washington, Covelo, London.

Dickie, I A, Gantioler, S, Cooper, G, McConville, A J, Dutton, A, Burrett, R, Duke, G and Treweek, J R (2011) Innovative use of financial instruments and approaches to enhance private sector finance of biodiversity. European Commission Directorate-General Environment.

Dobson, A P, Rodriguez, J P, Roberts, W M and Wilcove, D S (1997) Geographic Distribution of Endangered Species in the United States. Science, No 275, (5299) pp550-553.

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, No 317, pp810-813.

Donald, P F and Evans, A D (2006) Habitat connectivity and matrix restoration: the wider implications of agri-environment schemes. Journal of Applied Ecology, No 43, (2) pp209-218.

Dresner, S, Ekins, P, Mcgeevor, K and Tomei, J (2007) Forests and climate change: global understandings and possible responses, in P H Freer-Smith, S M J Broadmeadow, & J M Lynch (Eds) Forestry and Climate Change, pp38-48. Cabi, Cambridge, Ma.

Driver, D (2008) Restoration of open habitats from woods and forests in England: developing Government policy: evidence. The Forestry Commission, Bristol.

DTLGR (2002) Green spaces, better places: final report of the urban green spaces task force. Department of Transport, Local Government and the Regions, UK.

Dubgaard, A, Kallesøe, M F , Petersen, M L, Ladenburg, J (2002) Cost-benefit analysis of the Skjern River Project, Department of Economics and Natural Resources, Royal Veterinary and Agricultural University, Copenhagen.

Dudley, N (2008) Guidelines for Applying Protected Area Management Catagories. N Dudley (ed), IUCN, Gland, Switzerland.

Dudley, N and Stolton, S (2003) Running Pure: The Importance of Forest Protected Areas to Drinking Water. World Bank / WWF Alliance for forest conservation and sustainable use, Gland, Switzerland.

Dudley, N, Higgins-Zogib, L and Mansourian, S (2006) Beyond Belief: Linking Faiths and Protected Area Networks to Support Biodiversity Conservation. WWF International and Alliance on Religions and Conservation, Gland, Switzerland and Bath, UK.

Dudley, N, Stolton, S, Belokurov, A, Lopoukhine, N, MacKinnon, K, Sandwith, T and Sekhran, N (2010) Natural Solutions: Protected Areas Helping People Cope With Climate Change. TNC, UNDP, WCS, The World Bank and WWF, Gland, Switzerland, Washington DC and New York, USA.

Duffy, A., Jefferies, C., Waddell, G., Shanks, G., Blackwood, D. and Watkins A. (2008). A cost comparison of traditional drainage and SUDS in Scotland. Water Science and Technology 57 (9), 1451–1459.

Dupraz C, and Liagre, F. (2008). Agroforestrie: des arbres et des cultures. Ed. France Agricole, Paris, 413 p.

Dupraz C., Burgess P., Gavaland A., Graves A., Herzog F., Incoll L., Jackson N., Keesman K., Lawson G., Lecomte I., Liagre F., Mantzanas K., Mayus M., Moreno G., Palma J., Papanastasis V., Paris P., Pilbeam D., Reisner Y., Vincent G., Werf Van der W., (2005). Synthesis of the Silvoarable Agroforestry for Europe project. INRA-UMR System Editions, Montpellier, 254 p.

EASAC (2009) Ecosystem Services and Biodiversity in Europe. EASAC Policy Report 09, European Academies Science Advisory Council Secretariat, The Royal Society, London, UK.

Ebert, S, Hulea, O and Strobel, D (2009) Floodplain restoration along the lower Danube: A climate change adaptation case study, in Lessons for Climate Change Adaptation From Better Management of Rivers, pp212-219. vol. 1 Earthscan, EC (2006) LIFE and European forests. Office for Official Publications of the European Communities, Luxembourg.

EC (2010) Life Building up Europe's Green Infrastructure. Addressing connectivity and enhancing ecosystem functions. Publications Office of the European Union, Luxembourg.

EC (2011) Our life insurance, our natural capital: an EU biodiversity strategy to 2020. COM(2011)244 Final, 3.5.2011, European Commission, Brussels.

EC (2011). Communication on our life insurance, our natural capital: an EU biodiversity strategy to 2020, Commission staff working paper: Impact assessment, SEC(2011)540 evidence. Northwest Regional Development Agency.

Ecologic and ECI Oxford (2011) Draft Final Report of the project: Ecosystem-based approaches for climate change adaptation and mitigation. DG Environment.

Ecologic Institute and ECI (2011, forthcoming) Assessment of the potential of ecosystem-based approaches to climate change adaptation and mitigation in Europe. Draft Final Report to Service Contract No. 070307/2010/580412/SER/B2

Ecologic Institute. (2003). The EU Open Method of Co-ordination: Risks & Chances for Environmental Policy. Paper for the Conference 'Sustainable Development in an Enlarged Union – Linking National Strategies & Strengthening European Coherence' 27-29 April 2003 in Vienna, Austria.

Ecologic, IEEP and GHK (2011): Taking into account opportunity costs when assessing costs of biodiversity and ecosystem action. Final report submitted to the European Commission. March 2011

ECOTEC (2008) The economic benefits of Green Infrastructure: The public and business case for investing in Green Infrastructure and a review of the underpinning

Ecotec (2008) The economic benefits of green infrastructure: the public and business case for investing in green infrastructure and a review of the underpinning evidence. Northwest Regional Development Agency.

EEA (2004) High nature value farmland — characteristics, trends and policy challenges. UNEP/EEA , Report No 1/2004. European Environment Agency, Copenhagen.

EEA (2008) European forests - ecosystem conditions and sustainable use. European Environment Agency, Copenhagen.

EEA (2009) Distribution and targeting of the CAP budget from a biodiversity perspective, Report No 12/2009. European Environment Agency, Copenhagen.

EEA (2009) Progress Towards the European 2010 Biodiversity Target - Indicator Fact Sheets. The European Environment Agency, Copenhagen.

EEA (2010) 10 messages for 2010- Agriculture, European Environment Agency. Copenhagen

EEA (2010) EU 2010 Biodiversity Baseline. EEA Technical Report No 12/2010, European Environment Agency, Copenhagen.

EEA (2010) Forest: growing stock, increment and fellings (SEBI 017). European Environment Agency webpage. Data and Maps. http://www.eea.europa.eu/data-and-maps/indicators/forest-growing-stock-increment-and-fellings/forest-growing-stock-increment-and .

EEA (2010b) Assessing Biodiversity in Europe - the 2010 Report. EEA Technical Report No 5/2010, European Environment Agency, Copenhagen.

EEA (2010c) Forest: growing stock, increment and fellings (SEBI 017). European Environment Agency webpage. Data and Maps. http://www.eea.europa.eu/data-and-maps/indicators/forest-growing-stock-increment-and-fellings/forest-growing-stock-increment-and .

EEA (2011) Green infrastructure and territorial cohesion – The concept of green infrastructure and its integration into policies using monitoring systems, EEA Technical report No 18/2011, published 19 December 2011, ISSN 1725-2237, Copenhagen

EEA and FOEN (2011) Landscape Fragmentation in Europe. 2, European Environment Agency / Swiss Federal Office for the Environment, Copenhagen / Bern.

EFIMED, BOKU and CEPF (2008) Study on the Development and marketing of non-market forest products and services, Study for European Commission, DG Agriculture

Eftec (2008) Wallasea Island economic benefits study. Final report submitted to East of England Development Agency.

Eidgenössische Finanzkontrolle (2007) Normen und Standards betreffend Wildtierpassagen in Österreich. Separates Dokument im Rahmen des Berichts 'Protection de l'environnement et routes nationales: Evaluation des normes et standards pour les passages à faune'. Bern,

Elliman, K and Berry, N (2007) Protecting and restoring natural capital in New York City's Watersheds to safeguard water, in J Aronson, S J Milton, & J N Blignaut (eds) Restoring Natural Capital: Science, Business, and Practice, pp208-215. Island Press, Washington DC.

Elmqvist, T, Folke, C, Nyström, M, Peterson, G, Bengtsson, J, Walker, B and Norberg, J (2003) Response diversity, ecosystem change, and resilience. Frontiers in Ecology and the Environment, No 1, (9) pp488-494.

Emmanuel F., 2000. A renewed perspective on agroforestry concepts and classification. Comptes Rendus de l'Academie des Sciences - Series III - Sciences de la Vie, 323:1009-1017

Erz, W. and Klausnitzer, B. (1998). 'Fauna', In: Sukopp, H. and Wittig, R., (eds.), Stadtökologi, 2nd revised edition, Gustav Fischer Verlag, Stuttgart, 1998, pp. 266–315.

EUCC (2010) Carbon sequestration and biodiversity. EAF supported implementation of biodiversity objectives that can contribute to emission reduction aims. Final Report of the project EUCC's contribution to EU marine policy and EU climate change policy / carbon sequestration and biodiversity, Coastal & Marine Union.

European Bird Census Council (2007) Bird Census News. Newsletter of the European Bird Census Council. Volume 20, number 2, A Anselin (ed), INBO, Brussels.

European Commission, (2011). Natura 2000, European Commission Nature and Biodiversity Newsletter, 30.

Evans, K L, Rodrigues, A S L, Chown, S L and Gaston, K J (2006) Protected areas and regional avian species richness in South Africa. Biology Letters, No 2, pp184-186.

Evink, G L (2002) NCHRP synthesis 305 - Interaction between roadways and wildlife ecology. National Cooperative Highway Research Program, Transportation Research Board, National Research Council, Washington, D.C

Ewers RM, Didham RK, Habitat fragmentation: panchreston or paradigm?, Trends Ecological Evolution, 2007, Vol:22, Pages:511-511.

Fahrig, L (2003) Effects of habitat fragmentation on biodiversity. Annual Review of Ecology, Evolution, and Systematics, No 34, (1) pp487-515.

FAO (2002) Fish Passes - Design, Dimensions and Monitoring. Food and Agriculture Organisation of the United Nations, in assosication with Deutscher Verband für Wasserwirtschaft und Kulturbau e.V. (DVWK), Rome.

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, London.

Feld, C K, de Bello, F, Bugter, R, Grandin, U, Hering, D, Lavorel, S, Mountford, O, Pardo, I, Partel, M, Römbke, J, Martins da Silva, P, Sousa, J P and Jones, K B (2007) Assessing and Monitoring Ecosystems - Indicators, Concepts and their Linkage to Biodiversity and Ecosystem Services. The RUBICODE project — Rationalising Biodiversity Conservation in Dynamic Ecosystems.

Fernández, M., Moreno, V., Picazo, I., Torres, A. & Martínez, B. 2008. Valoración de los costes indirectos de gestión de la Red Natura 2000 en España. Dirección General de Medio Natural y Política Forestal, Ministerio de Medio Ambiente y Medio Rural y Marino. Madrid. Unpublished

Ferraro, P J and Pattanayak, S K (2006) Money for Nothing? A Call for Empirical Evaluation of Biodiversity Conservation Investments. PLoS Biol, No 4, (4) e105.

Fingal County Council (2010) Fingal Biodiversity Action Plan 2010 - 2015. Draft for consultation.

Fischer, J, Lindenmayer, D B and Manning, A D (2006) Biodiversity, ecosystem function, and resilience: Ten guiding principles for commodity production landscapes. Frontiers in Ecology and The Environment, No 4, (2) pp80-86.

Fischer, R A and Fischenich, J C (2000) Design Recommendations for Riparian Corridors and Vegetated Buffer Strips. EMRRP.

Fisher, B., Costanza, R., Turner, R.K. and Morling, P., (2007). Defining and classifying ecosystem services for decision-making. Ecological Economics, in DEFRA. An introductory guide to valuing ecosystem services. London, UK

Fjortoft I. The natural environment as a playground for children: The impact of outdoor play activities in pre-primary school children. Early Childhood Education Journal. 2001;29:111–117.

Forest Europe, UNECE and FAO (2011) State of Europe's forests 2011. Status and trends in sustainable forest management in Europe.

Forest Research (2010) Benefits of Green Infrastructure. Report to Defra and CLG. Forest Research, Farnham.

Forman, R T T and Alexander, L E (1998) Roads and Their Major Ecological Effects. Annual Review of Ecology and Systematics, No 29, pp207-231.

Forman, R T T, Bissonette, J, Clevenger, A, Cutshall, C, Dale, V, Fahrig, L, Goldman, C, Heanue, K, Jones, J, Sperling, D, Swanson, F, Turrentine, T and Winter, T (2002) Road Ecoloy: Science and Solutions. Island Press, Washington DC.

Forman, R T T, Sperling, D and Bissonette, J (2003) Road Ecology: Science and Solutions. Island Press, Washington, D.C.

Förster, J (2010) Peatlands restoration in Germany – a potential win-win-win solution for climate protection, Biodiversity Conservation And Land Use. http://www.eea.europa.eu/atlas/teeb/peatland-restoration-for-carbon-sequestration-germany-1

Foster, J, Lowe, A and Winkelman, S (2011) The value of green infrastructure for urban climate adaptation. The Center for Clean Air Policy, Washington.

Fuller, R A, McDonald-Madden, E, Wilson, K A, Carwardine, J, Grantham, H S, Watson, J E M, Klein, C J, Green, D C and Possingham, H P (2010) Replacing underperforming protected areas achieves better conservation outcomes. Nature, No 466, (7304) pp365-367.

Gallai, N., Salles, J.-M., Settele, J. and Vaissiere, B. (2009) Economic valuation of the vulnerability of world agriculture confronted with pollinator decline, Ecological Economics, vol 68, pp810–821

Gantioler S., Tucker G. and Kettunen M., (2007). Identification and Classification of the main agricultural biodiversity values. Final Draft to Exiopol: Work Stream II3: Valuation of biodiversity in land areas currently under agriculture.

Gantioler S., Tucker G., Kettunen M. (2008) Identification and classification of the main agricultural and biodiversity values, Report of the EXIOPOL project

Gantioler, S, Rayment, M, Bassi, S, Kettunen, M, McConville, A, Landgrebe, R, Gerdes, H and ten Brink, P (2010) Costs and Socio-Economic Benefits associated with the Natura 2000 Network. Final Report to the European Commission, DG Environment on Contract ENV.B.2/SER/2008/0038, Institute for European Environmental Policy / GHK / Ecologic, Brussels.

Gardner, R. H., R. V. O'Neill, M. G. Turner, and V. H. Dale. (1989). Quantifying scale-dependent effects of animal movement with simple percolation models. Landscape Ecology: 217-227.

Gaston, K J, Charman, K, Jackson, S F, Armsworth, P R, Bonn, A, Briers, R A, Callaghan, C S Q, Catchpole, R, Hopkins, J, Kunin, W E, Latham, J, Opdam, P, Stoneman, R, Stroud, D A and Tratt, R (2006) The ecological effectiveness of protected areas: The United Kingdom. Biological Conservation, No 132, (1) pp76-87.

Gehl, J and Gemzoe, L (1998) Public Spaces – Public Life, Copenhagen, 1998

GEN Consulting (2006) Glasgow Green Renewal Benefits Analysis. A report to Glasgow City Council November 2006

Genecon LLP (2010) Building natural value for sustainable economic development: The green infrastructure valuation toolkit user guide. Creative Commons Attribution – NonCommercial 3.0 Unported License. www.bit.ly/givaluationtoolkit

Georgi, B., Zisenis, M., Richard, D., Gregor, M., Kleeschulte, S., Simon, A., Schutyser, F., Uhel, R. and Pereira Martins, I. (2010) 10 Messages for 2010 – Urban Ecosystems. European Environment Agency, Copenhagen, Denmark.

Getzner, M (2009) Economic and cultural values related to protected areas. Part A: Valuation of ecosystem services in Tatra (PL) and Slovensky Raj (SK) national parks. Final report, WWF-DCP, Vienna, Austria.

Ghermandi, A.; Paulo A L D Nunes (2011), A Global Map of Costal Recreation Values: Results From a Spatially Explicit Based Meta-Analysis, Fondazione Eni Enrico Mattei Working Papers (2011) Volume: 590

GHK (2010) Collection of information and data to support the Impact Assessment study of the review of the EIA Directive – Final report; URL: http://ec.europa.eu/environment/eia/pdf/collection_data.pdf

GHK and eftec (2011) Costing potential actions to offset the impact of development on biodiversity – Final Report to defra, On Defra website, URL: www.defra.gov.uk/environment/natural/biodiversity/uk/offsetting/

GHK Consulting, 2006, Social and Economic Benefits of the Natural Environment: Review of Evidence, GHK Consulting, 2006.

GHK Consulting, Christie M, ADAS, IEEP, Minter R and the Research Box (2011) Benefits of Sites of Special Scientific Interest. Final Report to DEFRA, London, UK. http://randd.defra.gov.uk/Document.aspx?Document=finalreportsssis-benefits.pdf

Gilbert-Norton, L, Wilson, R, Stevens, J R and Beard, K H (2010) A meta-analytic review of corridor effectiveness. Conservation Biology, No 24, (3) pp660-668.

Gill, S, Handley, J, Ennos, A and Pauleit, S (2007) Adapting cities for climate change: the role of the greenspace. Built Environment, No 33, (1) pp115-133.

Gillies, C S and Cassady St Clair, C (2008) Riparian Corridors Enhance Movement of a Forest Specialist Bird in a Fragmented Tropical Forest. Proceedings of the National Academy of Sciences, No 105, (50) pp19774-19779.

Girvan, M and Newman, M E J (2002) Community structure in social and biological networks. Proceedings of the National Academy of Sciences of the United States of America, No 99, (12) pp7821-7826.

Good, J A (1998) The potential role of ecological corridors for habitat conservation in Ireland: A review. No. 2.

Goode, D (2006) Green infrastructure report to the Royal Commission on Environmental Pollution. Royal Commission on Environmental Pollution, London.

Goodwin, B J and Fahrig, L (2002a) Effect of landscape structure on the movement behaviour of a specialized goldenrod beetle, Trirhabda borealis. Canadian Journal of Zoology-Revue Canadienne de Zoologie, No 80, (1) pp24-35.

Goodwin, B J and Fahrig, L (2002b) How does landscape structure influence landscape connectivity? Oikos, No 99, (3) pp552-570.

Götmark, F and Thorell, M (2003) Size of nature reserves: densities of large trees and dead wood indicate high value of small conservation forests in southern Sweden. Biodiversity and Conservation, No 12, (6) pp1271-1285.

Grahn P, Martensson F, Lindblad B, Nilsson P, Ekman A. UTE pa DAGIS, Stad & Land nr. 93/1991 Sveriges lantbruksuniversitet, Alnarp 1997

Grahn, P and Stigsdotter, U A (2003) Landscape planning and stress. Urban Forestry and Urban Greening, No 2, (1) pp1-18.

Grahn, P and Stigsdotter, U A (2003) Landscape planning and stress. Urban Forestry and Urban Greening, No 2, (1) pp1-18.

Grashof-Bokdam, C J (2009) The synergistic effect of combining woodlands and green veining for biodiversity.

Green Infrastructure North West (2011) Building natural value for sustainable economic development: the green infrastructure valuation toolkit user guide.

Green Infrastructure North West (2011) Building natural value for sustainable economic development: The green infrastructure valuation toolkit user guide.

Greiber T, van Ham C, Jansse G and Gaworska M (2009) Final report study on the economic value of groundwater and biodiversity in European forests, IUCN and CEPF, Brussels, 2009

Gren, I M (1995) Costs and benefits of restoring wetlands. Two Swedish case studies. Ecological Engineering, No 4, (2) pp153-162.

Gren, I-M, Groth, K-H and Sylvén, M (1995) Economic values of Danube floodplains. Journal of Environmental Management, No 45, (4) pp333-345.

Greve, M, Chown, S L, van Rensburg, B J, Dallimer, M and Gaston, K J (2011) The ecological effectiveness of protected areas: a case study for South African birds. Animal Conservation, No 14, pp295-305.

Griffen, B D and Drake, J M (2009) Environment, but not migration rate, influences extinction risk in experimental metapopulations. Proceedings of the Royal Society B-Biological Sciences, No 276, (1677) pp4363-4371.

Gulati, R D (2002) Lakes in the Netherlands, their origin, eutrophication and restoration: state-of-the-art review.

Gunderson, L H (2000) Ecological resilience - in theory and application. Annual Review of Ecology and Systematics, No 31, pp425-439.

Gürlük, S (2006) The estimation of ecosystem services' value in the region of Misi Rural Development Project: Results from a contingent valuation survey, Forest Policy and Economics, Volume 9, Issue 3, 1 December 2006, Pages 209-218, ISSN 1389-9341, 10.1016/j.forpol.2005.07.007.

Haapalehto, T O (2011) The Effects of Peatland Restoration on Water-Table Depth, Elemental Concentrations, and Vegetation: 10 Years of Changes.

Handley, J and Carter, J (2006) Adaptation Strategies for Climate Change in the Urban Environment. ASCCUE Draft final report to the National Steering Group, Centre for Urban and Regional Ecology, University of Manchester, Manchester.

Hansen, M J and Clevenger, A P (2005) The influence of disturbance and habitat on the presence of non-native plant species along transport corridors. Biological Conservation, No 125, (2) pp249-259.

Hanski, I (1998) Metapopulation dynamics.

Harmer, R and Kiewitt, A (2006) Restoration of lowland conifer PAWS. The Forestry Commission, London.

Harrison, P A, Vandewalle, M, Sykes, M T, Berry, P M, Bugter, R, de Bello, F, Feld, C K, Grandin, U, Harrington, R, Haslett, J R, Jongman, R H G, Luck, G W, Martins da Silva, P, Moora, M, Settele, J, Sousa, J P and Zobel, M (2010) Identifying and prioritising services in European terrestrial and freshwater ecosystems. Biodiversity and Conservation, No 19, (10) pp2791-2821.

Hart, K, Baldock, D, Tucker, G, Allen, B, Calatrava, J, Black, H, Newman, S, Baulcomb, C, McCracken, D and Gantioler, S (2011) Costing the Environmental Needs Related to Rural Land Management. Report prepared for DG Environment, Contract No ENV.F.1/ETU/2010/0019r, Institute for European Environmental Policy, London.

Hart, K, Baldock, D, Weingarten, P, Osterburg, B, Povellato, A, Vanni, F, Pirzio-Biroli, C and Boyes, A (2011a) What tools for the European agricultural policy to encourage the provision of public goods. Report prepared for the European Parliament, Directorate General for internal policies. Policy department B: structural and cohesion policies. IP/B/AGRI/IC/2010_094, Institute for European Environmental Policy, London.

Hartridge, O and Pearce, D.W. 2001. Is UK Agriculture Sustainable? Environmentally Adjusted Economic Accounts For UK Agriculture. Economics, University College London, mimeo.

Harzman, U (2002) German green roofs, in Proceedings of the Annual Green Roof Construction Conference, Chicago, IL. Roofscapes, Inc.,

Hatzopoulos, Vassilis. (2007). Why the Open Method of Coordination Is Bad For You: A Letter to the EU. European Law Journal, Vol. 13, No. 3, May 2007. 320.

HEAL and HCWH (2010) Acting now for better health: a 30% reduction for EU Climate policy. Health and Environment Alliance and Health Care without Harm Europe.

Heath, M F and Evans, M I (eds) (2000) Important Bird Areas in Europe: Priority Sites for Conservation. BirdLife International, Cambridge.

Heller, N E and Zavaleta, E S (2009) Biodiversity management in the face of climate change: A review of 22 years of recommendations. Biological Conservation, No 142, (1) pp14-32.

Hermy, M (1999) An ecological comparison between ancient and other forest plant species of Europe, and the implications for forest conservation.

Herrick, J E (2000) Soil quality: an indicator of sustainable land management? Applied Soil Ecology, No 15, pp75-83.

Heywood, V. (1996) The Importance of Urban Environments in Maintaining Biodiversity'. In:, di Castri, F. and Younès, T., (eds.), Biodiversity, Science and Development: Towards a New Partnership. CAB International, Wallingford, Oxon, in association with the International Union of Biological Sciences, 1996, pp. 543–550.

Hilty, J A and Merenlender, A M (2004) Use of Riparian Corridors and Vineyards by Mammalian Predators in Northern California. Conservation Biology, No 18, (1) pp126-135.

Hodgson, J A, Moilanen, A, Wintle, B A and Thomas, C D (2011) Habitat area, quality and connectivity: striking the balance for efficient conservation. Journal of Applied Ecology, No 48, (1) pp148-152.

Hoffmann, C C and Baattrup-Pedersen, A (2007) Re-establishing freshwater wetlands in Denmark. Ecological Engineering, No 30, (2) pp157-166.

http://ec.europa.eu/environment/eia/pdf/Costs%20and%20benefits%20of%20the%20EIA%20Directive.pdf

Hulea, O, Ebert, S and Strobel, D (2009) Floodplain restoration along the Lower Danube: A climate change adaptation case study. IOP Science, No 6, (402002) 1.

Hussain, S S, Winrow-Giffin, A, Moran, D, Robinson, L A, Fofana, A, Paramor, O and Frid, C L J (2010) An ex ante ecological economic assessment of the benefits arising from marine protected areas designation in the UK. Ecological Economics, No 69, (4) pp828-838.

Huston, M A (1994) Biological Diversity: the Coexistence of Species in Changing Landscapes. Cambridge University Press, Cambridge.

IEEP & 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, London.

IEEP (2011) What tools for the European Agricultural Policy to Encourage the Provision of Public Goods, A Study for the European Parliament Policy Department B: Structural and Cohesion Policies.

IEEP and Ecologic Institute. (2005). Exploration of options for the Implementation of the Open Method of Coordination for Environmental Policy. Final Report - Executive Summary.

IEEP, Ecologic and GHK (2010) Costs and Socio-Economic Benefits associated with the Natura 2000 Network. Draft report to DG Environment, ten Brink et al. (2012)

IEEP, GHK, Ecologic, Metroeconomica and Eftec (2011, forthcoming) Estimating the Overall Economic Value of the Benefits provided by the Natura 2000 Network. Final Report to the European Commission, DG Environment on Contract COMMISSION CONTRACT 07.0307/2010/581178/SER/B3, Institute for European Environmental Policy, Brussels, Belgium.

Ioja, C I, Patroescu, M, Rozylowicz, L, Popescu, V D, Verghelet, M, Zotta, M I and Felciuc, M (2010) The efficacy of Romania's protected areas network in conserving biodiversity. Biological Conservation, No 143, (11) pp2468-2476.

Iremonger, S, Gittings, T, Smith, G F, Wilson, M W, Oxbrough, A, Coote, L, Pithon, J, O'Donoghue, S, McKee, A-M, O'Halloran, J, Kelly, D L, Giller, P S, O'Sullivan, A, Neville, P, Mitchell, F J G, O'Donnell, V, Kelly, T C and Dowding, P (2006) Investigation of experimental methods to enhance biodiversity in plantation forests. BIOFOREST Project Final Report.

IVM (2007) Costs and Benefits of the EIA Directive - Final report for DG Environment under specific agreement no. 07010401/2006/447175/FRA/G1; URL:

Jackson, S F, Walker, K and Gaston, K J (2009) Relationship between distributions of threatened plants and protected areas in Britain. Biological Conservation, No 142, (7) pp1515-1522.

Jacobs et al. (2004) Environment Group Research Report: An Economic Assessment of the Costs and Benefits of Natura 2000 Sites in Scotland, 2004 Final Report, The Scottish Government. 75 pp URL: http://www.scotland.gov.uk/Resource/Doc/47251/0014580.pdf

Jaeger, J A G (2000) Landscape division, splitting index, and effective mesh size: new measures of landscape fragmentation. Landscape Ecology, No 15, (2) pp115-130.

Jehle, R and Arntzen, J W (2000) Post-breeding migrations of newts Triturus cristatus and T. marmoratus with contrasting ecological requirements. Journal of Zoology, No 251, pp297-306.

Jim, C Y and Chen, W Y (2008) Assessing the ecosystem service of air pollutant removal by urban trees in Guangzhou (China). Journal of Environmental Management, No 88, (4) pp665-676.

JNCC (1998) A Statement on Common Standards Monitoring. Joint Nature Conservation Committee, Peterborough.

Jongeneel, R, Polman, N and Slangen, L (2008) Cost-benefit Analysis of the Dutch Nature Conservation Policy: Direct and Indirect Effects and Transaction Costs of the Ecological Main Structure in the Netherlands. European Association of Agricultural Economists, Ghent.

Jungwirth, M, Schmutz, S and Weiss, S (1998) Fish Migration and Fish Bypasses. Fishing News Books, Blackwell Science, Oxford, UK.

Kaczynski, A and Henderson, K (2007) Environmental correlates of physical activity: a review of evidence about parks and recreation. Leisure Sciences, No 29, (4) pp315-354.

Kaden, D, Meienberger, C and Beerli, P (1993) Erfolgskontrolle der okologischen Massnahment an der Neubaustrecke der N7. Bericht im Auftrag des Tiefbauamtes des Kantons Thurgau. Buro fur Okologie und EDV, Frauenfeld, Switzerland.

Kantelhardt, J.; Osinski, E.; Heissenhuber, A.; (2003), Is there a reliable correlation between hedgerow density and agricultural site conditions?; Agriculture, Ecosystems and Environment 98 (2003) 517–527

Kaphengst, T, Bassi, S, Davis, M, Gardner, S, Herbert, S, Lago, M, Naumann, S, Pieterse, M and Rayment, M (2010) Taking into account opportunity costs when assessing costs of biodiversity and ecosystem action. A report for DG Environment..

Kattge, J (2011) TRY - a global database of plant traits.

Kazmierczak, A and Carter, J (2010) Adaptation to climate change using green and blue infrastructure. A database of case studies. University of Manchester.

Kerkhoff, A J and Enquist, B J (2007) The implications of scaling approaches for understanding resilience and reorganization in ecosystems. Bioscience, No 57, (6) pp489-499.

Kettunen, M, Baldock, D, Gantioler, S, Carter, O, Torkler, P, Arroyo Schnell, A, Baumueller, A, Gerritsen, E, Rayment, M, Daly, E and Pieterse, M (2011) Assessment of the Natura 2000 co-financing arrangements of the EU financing instrument. A project for the European Commission - final report. 138 pp. + Annexes, Institute for European Environmental Policy, Brussels, Belgium.

Kettunen, M, Bassi, S, Gantioler, S and ten Brink, P (2009) Assessing Socioeconomic Benefits of Natura 2000 - a Toolkit for Practitioners. Output of the European Commission project Financing Natura 2000: Cost estimate and benefits of Natura 2000 (Contract No.: 070307/2007/484403/MAR/B2)., Institute for European Environmental Policy (IEEP), Brussels.

Kettunen, M, Terry, A, Tucker, G and Jones, A (2007) Guidance on the maintenance of landscape connectivity 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, Brussels.

Kindlmann, P and Burel, F (2008) Connectivity measures: a review. Landscape Ecology, No 23, (8) pp879-890.

Kirby, K, Jefferson, R, Larwood, J, Russell, D, Le Bas, B and Wright, R (2010) What has the SSSI improvement programme achieved for nature conservation in England? British wildlife, No 22, (1) pp16-25.

Kleijn, D, Baquero, R A, Clough, Y, Diaz, M, Esteban, J, Fernandez, F, Gabriel, D, Herzog, F, Holzschuh, A, Johl, R, Knop, E, Kruess, A, Marshall, E J P, Steffan-Dewenter, I, Tscharntke, T, Verhulst, J, West, T M and Yela, J L (2006) Mixed biodiversity benefits of agri-environment schemes in five European countries. Ecology Letters, No 9, (3) pp243-254.

Klein, A., Vaissière, B. E., Cane, J. H., Steffan-Dewenter, I., Cunningham, S. A., Kremen, C., & Tscharntke, T. (2007) Importance of pollinators in changing landscapes for world crops. Proceedings of the Royal Society of London B 274: 303-313.

Kleyer, M, Bekker, R M, Knevel, I C, Bakker, J P, Thompson, K, Sonnenschein, M, Poschlod, P, van Groenendael, J M, Klimes, L, Klimesova, J, Klotz, S, Rusch, G M, Hermy, M, Adriaens, D, Boedeltje, G, Bossuyt, B, Dannemann, A, Endels, P, Gotzenberger, L, Hodgson, J G, Jackel, A K, Kuhn, I, Kunzmann, D, Ozinga, W A, Romermann, C, Stadler, M, Schlegelmilch, J, Steendam, H J, Tackenberg, O, Wilmann, B, Cornelissen, J H C, Eriksson, O, Garnier, E and Peco, B (2008) The LEDA Traitbase: a database of life-history traits of the Northwest European flora. Journal of Ecology, No 96, (6) pp1266-1274.

Klimkowska, A, Van Diggelen, R, Bakker, J P and Grootjans, A P (2007) Wet meadow restoration in Western Europe: A quantitative assessment of the effectiveness of several techniques. Biological Conservation, No 140, (3-4) pp318-328.

Koch, E W, Barbier, E B, Silliman, B R, Reed, D J, Perillo, G M E, Hacker, S D, Granek, E F, Primavera, J H, Muthiga, N, Polasky, S, Halpern, B S, Kennedy, C J, Kappel, C V and lanski, E (2009) Non-linearity in ecosystem services: temporal and spatial variability in coastal protection. Frontiers in Ecology and the Environment, No 7, (1) pp29-37.

Kovács-Hostyánszki, A., Körösi, Á. Orci, K.M. et al. (2011) Set-aside promotes insect and plant diversity in a Central European country. Agriculture, Ecosystems and Environment 141:296-301.

Kremen, C, Williams, N M, Aizen, M A, Gemmill-Herren, B, LeBuhn, G, Minckley, R, Packer, L, Potts, S G, Roulston, T, Steffan-Dewenter, I, Vázquez, D P, Winfree, R, Adams, L, Crone, E E, Greenleaf, S S, Keitt, T H, Klein, A-M, Regetz, J and Ricketts, T H (2007) Pollination and other ecosystem services produced by mobile organisms: a conceptual framework for the effects of land-use change. Ecology Letters, No 10, pp299-314.

Kretschemer, B, Watkins, E, Baldock, D, Allen, B, Keenleyside, C and Tucker, G (2011) Securing Biomass for Energy - Developing an Environmentally Responsible Industry for the UK Now and into the Future. Institute for European Environmental Policy, London, UK.

Kroes, M J, Gough, P, Schollema, P P and Wanningen, H (2006) From sea to source: Practical guidance for restoration of fish migration in European rivers.

La Greca, P., La Rosa, D., Martinico, F. & Privitera, R. (2011) Agricultural and green infrastructures: The role of non-urbanised areas for eco-sustainable planning in a metropolitan region. Environmental Pollution. 159:2193-2202.

Laguna, E, Deltoro, V I, Pèrez-Botella, J, Pèrez-Rovira, P, Serra, L I, Olivares, A and Fabregat, C (2004) The role of small reserves in plant conservation in a region of high diversity in eastern Spain. Biological Conservation, No 119, (3) pp421-426.

Lahti, D C (2001) The ''edge effect on nest predation'' hypothesis after twenty years. Biological Conservation, No 99, pp365-374.

Lal, R (2008) Soil carbon stocks under present and future climate with specific reference to European ecoregions. Nutrient Cycling in Agroecosystems, No 81, (2) pp113-127.

Laliberte, E, Wells, J A, DeClerck, F, Metcalfe, D J, Catterall, C P, Queiroz, C, Aubin, I, Bonser, S P, Ding, Y, Fraterrigo, J M, McNamara, S, Morgan, J W, Merlos, D S, Vesk, P A and Mayfield, M M (2010) Land-use intensification reduces functional redundancy and response diversity in plant communities. Ecology Letters, No 13, (1) pp76-86.

Lande, R (1995) Mutation and Conservation. Conservation Biology, No 9, (4) pp782-791.

Landscape Institute (2009) Green infrastructure: connected and multifunctional landscapes http://www.landscapeinstitute.org/PDF/Contribute/GreenInfrastructurepositionstatement13May09.pdf

Larinier, M and Marmulla, G (2003) Fish Passes: Types, Principles and Geographic Distribution - an Overview, in R L Welcomme & T Petr (eds) Proceedings of the Second International Symposium on the Management of Large Rivers for Fisheries, 11.2.2003, Phomh Penh, Kingdom of Cambodia.

Larue, M A (2008) Modelling potential dispersal corridors for cougars in midwestern North America using least-cost path methods.

Lavelle, P, Decaëns, T, Aubert, M, Barot, S, Blouin, M, Bureau, F, Margerie, P, Mora, P and Rossi, J-P (2006) Soil invertebrates and ecosystem services. European Journal of Soil Biology, No 42, (Supplement 1) S3-S15.

Lavelle, P, Decaëns, T, Aubert, M, Barot, S, Blouin, M, Bureau, F, Margerie, P, Mora, P and Rossi, J-P (2006) Soil invertebrates and ecosystem services. European Journal of Soil Biology, No 42, (Supplement 1) S3-S15.

Lavelle, P, Dugdale, R, Scholes, R, Berhe, A A, Carpenter, E, Codispoti, L, Izac, A-M, Lemoalle, J, Luizao, F, Treguer, P and Ward, B (2005) Nutrient cycling, in R Hassan, R Scholes, & N Ash (eds) Ecosystems and Human Well-Being: Current State and Trends: Findings of the Condition and Trends Working Group, Island Press, Washington, Covelo, London.

Lawton, J H, Brotherton, P N M, Brown, V K, Elphick, C, Fitter, A H, Forshaw, J, Haddow, R W, Hilborne, S, Leafe, R N, Mace, G M, Southgate, M P, Sutherland, W J, Tew, T E, Varley, J and Wynne, G R (2010) Making Space for Nature: a review of England's wildlife sites and ecological network. Report to Defra.

Laycock, H F, Moran, D, Smart, J, Raffaelli, D and White, P (2009) Evaluating the cost-effectiveness of conservation: The UK Biodiversity Action Plan. Biological Conservation, No 142, (12) pp3120-3127.

Layke, C (2009) Measuring Nature's Benefits: A Preliminary Roadmap for Improving Ecosystem Service Indicators. WRI Working Paper, World Resources Institute, Washington DC.

le Gear, J 2006. A review of the methodologies used for restoring active blanket bog in the West of Ireland. Forestry Management University of Central Lancashire.

Liljenstolpe C (2011) Valuation of environmental impacts of the Rural Development Program. - A hedonic model with application of GIS. Swedish University of Agricultural Sciences, Upsulla , Sweden

Liekens I., De Nocker L., Schaafsma M., Wagtendonk A., Gilbert A., Broekx S., Brouwer R., 2009. AQUAMONEY Case Study Report International Scheldt Basin, Vrije universiteit Amsterdam (IVM), October 2009.

Liekens I., Schaafsma M., Brouwer R. , Broekx Steven, Aertsens Joris, Staes Jan, Meire Patrick, De Nocker L. 2010. Spatial elements in a valuation function for nature development. Proceedings of 12th Annual BIOECON conference "From the Wealth of Nations to the Wealth of Nature: Rethinking Economic Growth" , Venice, Italy, September 27-28, 2010

Linstead, C, Barker, T, Maltby, E, Kumar, P, Mortimer, M, Plater, A and Wood, M (2008) Reviewing Targets and Indicators for the Ecosystem Approach. Final Report. Defra Project Code NR0119.

Loreau, M, Naeem, S, Inchausti, P, Bengtsson, J, Grime, J P, Hector, A, Hooper, D U, Huston, M A, Raffaelli, D, Schmid, B, Tilman, D and Wardle, D A (2001) Ecology - Biodiversity and ecosystem functioning: current knowledge and future challenges. Science, No 294, pp804-808.

Losey, J. E. and Vaughan, M. (2006) The economic value of ecological services provided by insects, BioScience, vol 56, pp311–323

Lowrance, R, Todd, R, Fail, J, Hendrickson, O, Leonard, R and Asmussen, L (1984) Riparian forests as nutrient filters in agricultural watersheds. Bioscience, No 34, (6) pp374-377.

Lucas, M C and Baras, E (2001) Migration of Freshwater Fishes. Blackwell Science Ltd., Oxford, UK.

Luck, G W, Daily, G C and Ehrlich, P R (2003) Population diversity and ecosystem services. TRENDS in Ecology and Evolution, No 18, (7) pp331-336.

Lundqvist, H, Rivinoja, P, Leonardsson, K and McKinnell, S (2008) Upstream passage problems for wild Atlantic salmon (Salmo salar L.) in a regulated river and its effect on the population. Hydrobiologia, No 602, pp111-127.

Luttik, J. en M. Zijlstra (1997). Woongenot heeft een prijs: het waardeverhogend effect van een groene en waterrijke omgeving op de huizenprijs. SC_DLO rapport nummer 562. Dienst Landbouwkundig Onderzoek, Wageningen.

Maas, J, Verheij, R A, Groenewegen, P P, De Vries, S and Spreeuwenberg, P (2006) Green space, urbanity and health: how strong is the relation? Journal of Epidemiology and Community Health, No 60, (7) pp587-592.

MacArthur, R H and Wilson, E O (1967) The Theory of Island Biogeography. Princetown University Press, Princetown, New Jersey, USA.

Machtans, C S, Villard, M and Hannon, S J (1996) Use of Riparian Buffer Strips as Movement Corridors by Forest Birds. Conservation Biology, No 10, (5) pp1366-1379.

Maclean, N (2010) Silent Summer. The State of Wildlife in Britain and Ireland. Cambridge University Press, Cambridge, UK.

Madureira, L., Rambonilaza, T., Karpinski, I., (2007) Review of methods and evidence for economic valuation agricultural non-commodity outputs and suggestions to facilitate its application to broader decisional contexts, Ecosystems and Environment 120, pp.5–20.

Maes, J, Paracchini, M L and Zulian, G (2011) A European Assessment of the Provision of Ecosystem Services. Towards an Atlas of Ecosystem Services. JRC Scientific and Technical Reports, Publications Office of the European Union, Luxembourg.

Maiorano, L, Falucci, A, Garton, E O and Boitani, L (2007) Contribution of the Natura 2000 Network to Biodiversity Conservation in Italy. Conservation Biology, No 21, (6) pp1433-1444.

Mallarach, J M (2008) A Comprehensive Evaluation of the Protected Areas System in Catalonia, Spain, in S Stolton (ed) Assessment of Management Effectiveness in European Protected Areas: Sharing Experience and Promoting Good Management, BfN (German Federal Agency for Nature Conservation), Bonn, Germany.

Manchester, S J, McNally, S, Treweek, J R, Sparks, T H and Mountford, J O (1999) The cost and practicality of techniques for the reversion of arable land to lowland wet grassland - an experimental study and review. Journal of Environmental Management, No 55, pp91-109.

Mansergh, I and Scotts, D J (1989) Habitat Continuity and Social Organization of the Mountain Pygmy-Possum Restored by Tunnel. The Journal of Wildlife Management, No 53, (3) pp701-707.

Marghescu, T (2006) An example for Europe, Presentation at the occasion of het opening seminar of the Hoge Kempen National Park, Genk, 2006.

Markland, J (2002) Final Report on Financing Natura 2000. Working Group on Article 8 of the Habitats Directive. European Commission, Brussels.

Martinez-Salgado, M M, Gutiérrez-Romero, V, Jannsens, M and Ortega-Blu, R (2010) Biological soil quality indicators: a review, in A Méndez-Vilas (ed) Current Research, Technology and Education Topics in Applied Microbiology and Microbial Biotechnology, vol. 1 FORMATEX, Badajoz, Spain.

Martín-López B, García-Llorente M, Palomo I, Montes C. (2011) The conservation against development paradigm in protected areas: Valuation of ecosystem services in the Doñana social-ecological system (southwestern Spain). Ecological Economics70(2011)1481–1491

Maskell, L C, Smart, S M, Bullock, J M, Thompson, K and Stevens, C J (2010) Nitrogen deposition causes widespread loss of species richness in British habitats. Global Change Biology, No 16, (2) pp671-679.

Mata, C, Hervàs, I, Herranz, J, Suárez, F and Malo, J E (2003) Effectiveness of wildlife crossing structures and adapted culverts in a highway in Northwest Spain, in C L Irwin, P Garrett, & K P McDermott (eds) Proceedings of the 2003 international conference on ecology and transportation, pp265-276. Center for Transportation and the Environment, North Carolina State University, Raleigh, North Carolina, USA.

Mata, C, Hervàs, I, Herranz, J, Suàrez, F and Malo, J E (2005) Complementary use by vertebrates of crossing structures along a fenced Spanish motorway. Biological Conservation, No 124, pp397-405.

Mata, C, Hervàs, I, Herranz, J, Suàrez, F and Malo, J E (2007) Are motorway passages worth building? Vertebrate use of road--crossing structures on a Spanish motorway. Journal of Environmental Management, No 88, pp407-415.

McCollin, D (2000) Editorial: Hedgerow policy and protection - changing paradigms and the conservation ethic. Journal of Environmental Management, No 60, pp3-6.

McDonald, A G, Bealey, W J, Fowler, D, Dragosits, U, Skiba, U, Smith, R I, Donovan, R G, Brett, H E, Hewitt, C N and Nermitz, E (2007) Quantifying the effect of urban tree planting on concentrations and depositions of PM10 in two UK conurbations. Atmospheric Environment, No 41, pp8455-8467.

Mclaren, B E (1994) Wolves, Moose, and Tree-Rings on Isle Royale.

McPherson, E G, Nowak, D J And Rowntree, R A (1994) Chicago's urban forest ecosystem: results of the Chicago Urban Forest Climate Project. United States Department of Agriculture.

McPherson, E G, Nowak, D J and Rowntree, R A (1994) Chicago's urban forest ecosystem: results of the Chicago urban forest climate project. United States Department of Agriculture.

Mcrae, B H and Beier, P (2007) Circuit theory predicts gene flow in plant and animal populations. Proceedings of the National Academy of Sciences of the United States of America, No 104, (50) pp19885-19890.

McVittie, A and Moran, D (2010) Valuing the non-use benefits of marine conservation zones: An application to the UK Marine Bill, Ecological Economics, 70, issue 2, p. 413-424.

MEEDDM (2009) Evaluation des benefices environnementaux des zones humides dans le cadre du Grenelle Environnement,

Mentens, J, Raes, D and Hermy, M (2006) Green roofs as a tool for solving the rainwater runoff problem in the urbanized 21st century? Landscape and Urban Planning, No 77, (3) pp217-226.

Merlo, M., Croitoru, L. (2005) Valuing Mediterranean Forests – Towards Total Economic Value. CABI Publishing.

Millenium Ecosystem Assessment (2005) Ecosystems and Human Well-being: Biodiversity Synthesis. World Resources Institute, Washington, DC.

Mills, J, Courtney, P, Gaskell, P, Reed, M and Ingram, J (2010) Estimating the Incidental Socio-economic Benefits of Environmental Stewardship Schemes. Final Report. Countryside and Community Research Institute.

Mills, L S (1993) The Keystone-Species Concept in Ecology and Conservation.

Ministère de l'Environnement, du développement durable et de la Mer (MEEDDM) (2009) Etude d'Impact : Projet de loi portant engagement national pour l'environnement, URL : http://www.legrenelle-environnement.fr/IMG/pdf/etude_impact_loi_environnement.pdf.

Ministerie van Verkeer en Waterstaat (2011) Meerjarenprogramma ontsnippering (MJPO). MIRT projectenboek 2011. Ministerie van Verkeer en Waterstaat, The Hague.

Ministry of Environment and Energy (2011) Environmental Impact of Watercourse Rehabilitation, in River Restoration - Danish Experience and Examples, pp80-89. National Environmental Research Institute, Denmark.

Ministry of Environment and Water (2002) Bulgaria: Wetlands Restoration and Pollution Reduction Project. Projects Appraisal Document.

Mitchell, R and Popham, F (2007) Greenspace, urbanity and health: relationships in England. Journal of Epidemiology and Community Health, No 61, pp681-683.

Mondelaers, K., Aertsens, J., Van Huylenbroeck, G. (2009), "A meta-analysis of the differences in environmental impacts between organic and conventional farming", British Food Journal; Volume: 111 (10); pp. 1098-1119; http://www.emeraldinsight.com/10.1108/00070700910992925

Morris, J. and Camino, M, 2011, Economic Assessment of Freshwater, Wetland and Floodplain (FWF) Ecosystem Services, Working Paper, Background report to UK NEA Economic Analysis Report, School of Applied Sciences, Cranfield University, Bedford, February 2011

Mortelliti, A, Amori, G, Capizzi, D, Cervone, C, Fagiani, S, Pollini, B and Boitani, L (2011) Independent effects of habitat loss, habitat fragmentation and structural connectivity on the distribution of two arboreal rodents. Journal of Applied Ecology, No 48, (1) pp153-162.

Mouissie, A M (2005) Estimating adhesive seed-dispersal distances: field experiments and correlated random walks.

Mourato S., Giles Atkinson, Murray Collins, Steve Gibbons, George MacKerron and Guilherme Resende (2010), Economic Analysis of Cultural Services, Background report to UK NEA Economic Analysis Report, Department of Geography and Environment , London School of Economics and Political Science London, 2010

Mulongoy, K J and Gidda, S B (2008) The Value of Nature: Ecological, Economic, Cultural and Social Benefits of Protected Areas. Secretariat of the Convention on Biological Diversity, Montreal.

Munchmeyer T., Fogleman V., Mazza L., and Mudgal S. (2009) Implementation Effectiveness of the Environmental Liability Directive (ELD) and related Financial Security Issues. Bio Intelligence Service, Report for the European Commission (DG Environment), URL: http://ec.europa.eu/environment/legal/liability/pdf/ELD%20Study%20November%202009.pdf

Murdoch, W, Ranganathan, J, Polasky, S and Regetz, J (2010) Using return on investment to maximize conservation effectiveness in Argentine grasslands. Proceedings of the National Academy of Sciences, No 7, (49) pp20855-20862.

Murphy, P (2008) Restoring Active Blanket Bog in Ireland. LIFE Technical Final Report. LIFE02 NAT/IRL/8490.

Mustafa, A, Scholz, M, Zhang, L, Harrington, R and Carroll, P (2008) The long-term performance of a representative integrated constructed wetland for treating farmland runoff, in BHS 10th National Hydrology Symposium, Exeter, 2008, pp445-451.

Naiman, R J, Décamps, H and Pollock, M (1993) The Role of Riparian Corridors in Maintaining Regional Biodiversity. Ecological Applications, No 3, (2) pp209-212.

National Trust (2006): Valuing our Environment – Economic Impact of the National Parks of Wales, Great Britain.

Natural England (2009) River Wensum restoration strategy. Natural England, Norwich.

Natural England (2010) Lost Life: England's Lost and Threatened Species. Natural England, Peterborough, UK.

Naumann, S, McKenna, D, Kaphengst, T, Pieterse, M, and Rayment, M (2011): Design, implementation and cost elements of Green Infrastructure projects. Final report. Service Contract No. 070307/2010/577182/ETU/F.1

Nellemann, C and Corcoran, E (2010) Dead Planet, Living Planet. Biodiversity and ecosystem restoration for sustainable development, A rapid response assessment. UNEP, GRID-Arendal.

NERA, 2007. The Benefits of Water Framework Directive Programmes of Measures in England and Wales, A Final Report to DEFRA re CRP Project 4b/c.

Neville, H, Dunham, J and Peacock, M (2006) Assessing connectivity in salmonid fisheries with DNA microsatellite markers, in K R Crooks & M Sanjayan (eds) Connectivity Conservation, pp318-342. Cambridge University Press, Cambridge, UK.

New York City Government (2010) NYC Green Infrastructure Plan: A sustainable strategy for clean waterways.

Ng, S, Dole, J W, Sauvajot, R M, Riley, S P D and Valone, T (2004) Use of highway undercrossings by wildlife in southern California. Biological Conservation, No 115, pp499-507.

Niemelä, J, Saarela, S-R, Söderman, T, Kopperoinen, L, Yli-Pelkonen, V, Väre, S and Kotze, D J (2010) Using the ecosystem services approach for better planning and conservation of urban green spaces: a Finland case study. Biodiversity and Conservation, No 19, (11) pp3225-3243.

Nisbet, T R and Thomas, H (2008) Restoring floodplain woodland for flood alleviation. Final report for the Department for Environment, Food and Rural Affairs. Project SLD2316, DEFRA, London.

Nolte, C, Leverington, F, Kettner, A, Marr, M, Nielsen, G, Bomhard, B, Stolton, S, Stoll-Kleemann, S and Hockings, M (2011) Protected Area Management Effectiveness Assessments in Europe. A review of application, methods and results. Bundesamt für Naturschutz (BfN), Bonn, Germany.

Noss, R.F. & Daly, K.M. (2006) Incorporating connectivity into broad-scale conservation planning. Connectivity Conservation (eds K.R. Crooks & M. Sanjayan), pp. 587–619. Cambridge University Press, Cambridge.

Nowak, D J, Crane, D E and Stevens, J C (2006) Air pollution removal by urban trees and shrubs in the United States. Urban Forestry and Urban Greening, No 4, pp115-123.

O' Gorman S. and Bann C., 2008. Valuing England's Terrestrial Ecosystem Services, a report to Defra.

Oberndorfer, E, Lundholm, J, Bass, B, Coffman, R R, Doshi, H, Dunnett, N, Gaffin, S, Koehler, M, Liu, K K Y and Rowe, B (2007) Green roofs as urban ecosystems: ecological structures, functions, and services. Bioscience, No 57, (10) pp823-833.

O'Brien, L, Williams, K and Stewart, A (2010) Urban health and health inequalities and the role of trees, woods and forests in Britain: a review. Forest Research.

Odum E P (1953) Fundamentals of ecology. W.B.Saunders, Philadelphia.

OECD (2004) Handbook for market creation for biodiversity. Issues in implementation. OECD publications, Paris, France.

O'Gorman, E J, Yearsley, J M, Crowe, T P, Emmerson, M C, Jacob, U and Petchey, O L (2011) Loss of functionally unique species may gradually undermine ecosystems. Proceedings of the Royal Society B-Biological Sciences, No 278, (1713) pp1886-1893.

Olsson, M P O, Widen, P and Larkin, J L (2008) Effectiveness of a highway overpass to promote landscape connectivity and movement of moose and roe deer in Sweden. Landscape and Urban Planning, No 85, pp133-139.

Paetzold, A, Warren, P H and Maltby, L L (2010) A framework for assessing ecological quality based on ecosystem services. Ecological Complexity, No 7, (3) pp273-281.

Paine, R T (1969) A Note on Trophic Complexity and Community Stability.

Paracchini, M L, Petersen, J-E, Hoogeveen, Y, Bamps, C, Burfield, I and van Swaay, C (2008) High Nature Value Farmland in Europe - An Estimate of the Distribution Patterns on the Basis of Land Cover and Biodiversity Data. JCR Scientific and Technical Reports EUR 23480 EN, Office for Official Publications of the European Union, Luxembourg.

Parrott, L (2010) Measuring ecological complexity. Ecological Indicators, No 10, (6) pp1069-1076.

Pascual-Hortal, L and Saura, S (2006) Comparison and development of new graph-based landscape connectivity indices: towards the priorization of habitat patches and corridors for conservation. Landscape Ecology, No 21, (7) pp959-967.

Persic, A, Arico, S, Calvo, G and Ishwaran, N (2008) Ecosystems and human well-being: UNESCO Biosphere Reserves as learning laboratories for sustainable development, in L Janishevski, K Noonan-Mooney, S B Gidda, & K J Mulongoy (eds) Protected Areas in Today's World: Their Values and Benefits for the Welfare of the Planet, Secretariat of the Convention on Biological Diversity, Montreal.

Petchey, O L and Gaston, K J (2002) Functional diversity (FD), species richness and community composition. Ecology Letters, No 5, (3) pp402-411.

Peterken, G F (2000) Reversing the Habitat Fragmentation of British Woodlands. WWF, Godalming, UK.

Pettenella, D and Kloehn, S (2007) Mediterranean mushrooms: how to market them, in N Berrahmouni, X Escuté, P Regato, & C Stein (eds) Beyond Cork - a Wealth of Resources for People and Nature, pp52-68. WWF Mediterranean and IPADE, Madrid.

Pettenella, D, Ciccarese, L, Dragoi, S, Hegedus, A, Hingston, A, Klöhn, S, Matilainen, A, Posavec, S and Thorfinnsson, T (2006) NWFP&S marketing: Lessons learned from case studies in Europe, in A Niskanen (ed) Issues Affecting Enterprise Development in the Forest Sector in Europe. Research Notes 169, pp367-403. Faculty of Forestry, University of Joensuu,

Pettenella, D, Klöhn, S, Brun, F, Carbone F., Venzi, L, Cesaro, L and Ciccarese, L (2005) Italy's country report. In: Cost E30. Economic integration of urban consumers' demand and rural forestry production. Acta Silvatica and Lignaria Hungarica.Special Edition pp383-435.

Pittock, J (2008) Water for life: Lessons for climate change adaptation from better management of rivers for people and nature. WWF, Switzerland.

Posthumus, J, Rouquette, J R, Morris, J, owing, D J G and ess, T M (2010) A framework assessment for the assessment of ecosystem goods and services; a case study on lowland floodplains in England. Ecological Economics, No 69, (7) pp1510-1523.

Potchter, O, Cohen, P and Bitan, A (2006) Climatic behaviour of various urban parks during hot and humid summer in the mediterranean city of Tel Aviv, Israel. International Journal of Climatology, No 26, pp1695-1711.

Powe, N A and Willis, G K (2002) Social & environmental benefits of forestry phase 2: mortality and morbidity benefits of air pollution absorption by woodland. Report to the Forestry Commission, Centre for Research in Environmental Appraisal & Management University of Newcastle.

Pretty J.N.; Brett C.; Gee D.; Hine R.E.; Mason C.F.; Morison J.I.L.; Raven H.; Rayment M.D.; van der Bijl G., 2000, An assessment of the total external costs of UK agriculture, Agricultural Systems 65 (2), August 2000 , pp. 113-136.

Pulido-Santacruz P., Renjifo, L.M. (2011). Live fences as tools for biodiversity conservation: a study case with birds and plants; Agroforestry Systems 81 (1) pp. 15-30.

Pywell, R F, Warman, E A, Hulmes, L, Hulmes, S, Nuttall, P, Sparks, T H, Critchley, C N R and Sherwood, A (2006) Effectiveness of new agri-environment schemes in providing foraging resources for bumblebees in intensively farmed landscapes. Biological Conservation, No 129, (2) pp192-206.

Raedeke, K (1989) Streamside management: riparian wildlife and forestry interactions. Contribution Number 59. Institute of Forest Resources, University of Washington, Seattle, Washington, USA.

Rayment M, Pirgmaier E, De Ceuster G, Hinterberger F, Kuikd O, Leveson Gower H, Polzin,

Varmaa A (2009). The economic benefits of environmental policy. A project under the Framework contract for economic analysis ENV.G.1/FRA/2006/0073 - 2nd

Read, C F (2011) Surprisingly fast recovery of biological soil crusts following livestock removal in southern Australia.

Regeneris (2009) The economic contribution of the Mersey Forest's Objective one-funded investments.

Rein, F A (1999) An economic analysis of vegetative buffer strip implementation. Case study: Elkhorn Slough, Monterey Bay, California. Coastal Management, No 27, (4) pp377-390.

Rey Benayas, J M, Bullock, J and Newton, A C (2008) Creating woodland islets to reconcil ecological restoration, conservation, and agricultural land use. Frontiers in Ecology and the Environment, No 6, (6) pp329-336.

Rey-Benayas, J M, Newton, A C, Diaz, A and Bullock, J (2009) Enhancement of Biodiversity and Ecosystem Services by Ecological Restoration: A Meta-Analysis. Science, No 325, pp1121-1124.

Ricketts, T H (2001) The Matrix Matters: Effective Isolation in Fragmented Landscapes. The American Naturalist, No 158, (1) pp87-99.

Sundseth, K. and Raeymaekers, G. (2006) Biodiversity and Natura 20000 in urban areas – Nature in cities across Europe: a review of key issues and experiences, IBGE/BIM, Brussels, 2006.

Ricketts, T H, Regetz, J, Steffan-Dewenter, I, Cunningham, S A, Kremen, C, Bogdanski, A, Gemmill-Herren, B, Greenleaf, S S, Klein, A-M, Mayfield, M M, Morandin, L A, Ochieng, A and Viana, B F (2008) Landscape effects on crop pollination services: are there general patterns? Ecology Letters, No 11, pp499-515.

Ricklefs, R E and Schluter D (1993) Species Diversity in Ecological Communities. The University of Chicago Press.

Ries, L, Fletcher Jr., R J, Battin, J and Sisk, T D (2004) Ecological Responses to Habitat Edges: Mechanisms, Models and Variability Explained. Annual Review of Ecology, Evolution, and Systematics, No 35, pp491-522.

Roberts, C M, Bohnsack, J A, Gell, F, Hawkins, J P and Goodridge, R (2001) Effects of Marine Reserves on Adjacent Fisheries. Science, No 294, (1920) 1923.

Roncin, N, Alban, F, Charbonnel, E, Crechriou, R, de la Cruz Modino, R, Culioli, J-M, Dimech, M, Gong, R, Guala, I, Higgins, R, Lavisse, E, Le Direach, L, Luna, B, Marcos, C, Maynou, F, Pascual, J, Person, J, Smith, P, Stobart, B, Szelianszky, E, Vallek, K, Vasellio, S and Boncoeur, J (2008) Uses of ecosystem services provided by MPAs: How much do they impact the local economy? A southern Europe perspective . Journal for Nature Conservation, No 16, (4) pp256-270.

Rosell, C, Alvarez, G, Cahill, S, Campeny, R, Rodriguez, A and Sieler, A (2002) Habitat fragmentation due to transportation infrastructure in Spain. COST 341. Ministerio del Medio Ambiente, Madrid.

Rowe, D B (2011) Green roofs as a means of pollution abatement. Environmental Pollution, No 159, pp2100-2110.

RSPB (2011) Active Blanket Bog in Wales. R Farmer (ed), RSPB.

RSPB (2011) High nature value farming: how diversity in Europe's farm systems delivers for biodiversity. Royal Society for the Protection of Birds.

RSPB, CCW, Forestry Commission Wales, Environment Agency and Welsh Assembly Government (2011) Restoring active blanket bog in the Berwyn and Migneiny SACs in Wales. Layman's Report. Project code: LIFE06 NAT/UK/000134, LIFE Project Office, Powys.

Ruijgrok, E C M (2006) Kentallen Waardering Natuur, Water, Bodem En Landschap. Hulpmiddel Bij Mkba's. Witteven en Bos, Rotterdam.

Sandhu, Harpinder S.; Wratten,Stephen D.; Cullen,Ross; Case,Brad, 2008, The future of farming: The value of ecosystem services in conventional and organic arable land. An experimental approach, Ecological Economics 64 (4), pp. 835-848.

Saura, S, Estreguil, C, Mouton, C and Rodriguez-Freire, M (2011) Network analysis to assess landscape connectivity trends: Application to European forests (1990-2000). Ecological Indicators, No 11, (2) pp407-416.

Schaafsma, M., Brouwer, R. (2006) Overview of existing guidelines and manuals for the economic valuation of environmental costs and benefits. Amsterdam, IVM.

Scheffer, M and Carpenter, S R (2003) Catastrophic regime shifts in ecosystems: linking theory to observation. Trends in Ecology & Evolution, No 18, (12) pp648-656.

Scheufele, G, and Bennett, J (2011) Valuing Ecosystem Resilience. Crawford School Research Paper ; Environmental Economics Research Hub (EERH) Research Reports No. 98. Available at SSRN: http://ssrn.com/abstract=1907462

Schils, R, Kuikman, P, Liski, J, Van Oijen, M, Smith, P, Webb, J, Alm, J, Somogyi, Z, Van der Akker, J, Billett, M, Emmett, B, Evans, C, Lindner, M, Palosuo, T, Bellamy, P, Jandl, R and Hieder, R (2008) Review of Existing Information on the Interrelations between Soil and Climate Change (ClimSoil). Final Report. European Commission, Brussels.

Schoener, T W (1976) The species area relation within archipelagos: models and evidence from island land birds, in H J Frith & J H Calaby (eds) Proceedings 16th International Ornithological Conference, pp629-642. Australian Academy of Science, Canberra.

Schops I, Biodiversiteit en landschapszorg als hefboom voor Biodiversiteit en economische ontwikkeling, presentation in the context of the Steps project (no date)

Scottish Natural Heritage (2011) Cost/Benefit Analysis of Habitat Restoration. http://www.snh.org.uk/salmonlifeproject/pdf/MarkBilsby.pdf

SDC (2008) Health, place and nature. How outdoor environments influence health and well-being: a knowledge base. Sustainable Development Commission, UK.

Sen, A., Darnell, A., Crowe, A., Bateman, I.J. and Munday, P. (2011) Economic Assessment of the Value of Open-Access Recreation in UK Ecosystems: A Scenario Analysis, Report to the UK National Ecosystem Assessment, Centre for Social and Economic Research on the Global Environment (CSERGE), School of Environmental Sciences, University of East Anglia.

Shéhérazade Aoubid et Hélène Gaubert, 2010; valuation économique des services rendus par les zones humides, Etudes et documents No 23, (2010), URL :

Sills, N and Hirons, G (2011) From carrots to cranes: the creation of RSPB Lakenheath Fen, Suffolk. British wildlife, No 22, (6) pp381-390.

Simberloff, D, Farr, J A, Cox, J and Mehlman, D W (1992) Movement Corridors: Conservation Bargains or Poor Investments? Conservation Biology, No 6, (4) pp493-504.

Sitzia, T (2007) Hedgerows as corridors for woodland plants: a test on the Po Plain, northern Italy. Plant Ecology, No 188, pp235-252.

Smith, P (2004) Soils as carbon sinks - the global context. Soil Use Management, No 20, pp 212-218.

Spellerberg, I F (1998) Ecological Effects of Roads and Traffic: A Literature Review. Global Ecology and Biogeography Letters, No 7, (5) pp317-333.

Stacey, P B, Johnson, V A and Taper, M L (1997) Migration within metapopulations: the impact upon local population dynamics, in I A Hanski & M E Gilpin (eds) Metapopulation Biology: Ecology, Genetics, and Evolution, pp267-291. Academic Press, San Diego, CA, USA.

Stanturf, J A and Madsen, P (2002) Restoration concepts for temperate and boreal forests of North America and Western Europe. Plant Biosystems, No 136, (2) pp143-158.

Stevens, C J, Thompson, K, Grime, J P, Long, C J and Gowing, D J G (2010) Contribution of acidification and eutrophication to declines in species richness of calcifuge grasslands along a gradient of atmospheric nitrogen deposition. Functional Ecology, No 24, (2) pp478-484.

Stolton, S, Maxted, N, Ford-Lloyd, B, Kell, S and Dudley, N (2006) Food Stores: Using Protected Areas to Secure Crop Diversity. WWF and University of Birmingham, Gland, Switzerland and Birmingham, UK.

Stolton, S, Maxted, N, Ford-Lloyd, B, Kell, S and Dudley, N (2006) Food stores: using protected areas to secure crop diversity. WWF and University of Birmingham, Gland, Switzerland and Birmingham, UK.

Strife S. and Downey L. (2009) Childhood Development and Access to Nature, A New Direction for Environmental Inequality Research, Organ Environ. 2009 March; 22(1): 99–122

Susca, T., Gaffin, S.R. and Dell'Osso, G.R. (2011). Positive effects of vegetation: Urban heat island and green roofs. Environmental Pollution. 159: 2119-2126.

Swift, M J, Andren, O, Brussaard, L, Briones, M, Couteax, M M, Ekschmitt, K, Kjoller, A, Loiseau, P and Smith, P (1998) Global change, soil biodiversity, and nitrogen cycling in terrestrial ecosystems: three case studies. Global Change Biology, No 4, pp729-743.

Taylor, P D, Fahrig, L and With, K A (2006) Landscape connectivity: a return to the basics, in K R Crooks & M Sanjayan (eds) Connectivity Conservation, pp29-43. Cambridge University Press, Cambridge, UK.

Taylor, P D, Fahrig, L, Heinen, K and Merriam, G (1993) Connectivity is a vital element of landscape structure. Oikos, No 90, pp7-19.

TEEB (2009) TEEB Climate Issues Update.

TEEB (2010) The Economics of Ecosystems and Biodiversity – Ecological and Economic Foundations. Edited by Pushpam Kumar. Earthscan, London and Washington.

TEEB (2011) The Economics of Ecosystems and Biodiversity in National and International Policy Making. Edited by Patrick Ten Brink. Earthscan, London and Washington.

TEEB (ed) (2011) The Economics of Ecosystems and Biodiversity in National and International Policy Making. Edited by Patrick Ten Brink. Earthscan, London and Washington.

ten Brink P., Badura T., Bassi S., Ding H., Gantioler S., Kettunen M, Markandya A., Nunes P.A.L.D., Rayment M., Tinch R . (Forthcoming) Estimating the Overall Economic Value of the Benefits provided by the Natura 2000 Network. Final Synthesis Report to the European Commission, DG Environment on Contract ENV.B.2/SER/2008/0038. Institute for European Environmental Policy / GHK / Ecologic, Brussels and London.

Tewksbury, J J, Levey, D J, Haddad, N M, Sargent, S, Orrock, J L, Weldon, A, Danielson, B J, Brinkerhoff, J, Damschen, E I and Townsend, P (2002) Corridors affect plants, animals, and their interactions in fragmented landscapes. Proceedings of the National Academy of Sciences, No 99, (20) pp12923-12926.

The Landscape Institute (2009) Green infrastructure: connected and multifunctional landscapes. Position statement. The Landscape Institute, London.

The World Bank (2010) Convenient Solutions to an Inconvenient Truth: Ecosystem Based Approaches to Climate Change. The International Bank for Reconstruction and Development, Washington.

Thierrien, J and Bourgeois, G (2000) Fish Passage at Small Hydro Sites. International Energy Agency (IEA) Technical Report. International Energy Agency (IEA).

Thomas, C D and Harrison, S (1992) Spatial dynamics of a patchily distributed butterfly population. Journal of Animal Ecology, No 61, (2) pp437-446.

Thomas, C D and Jones, T M (1993) Partial recovery of a skipper butterfly (Hesperia comma) from population refuges: lessons for conservation in a fragmented landscape. Journal of Animal Ecology, No 63, (3) pp472-481.

Thomas, C D, Thomas, J A and Warren, M S (1992) Distributions of occupied and vacant butterfly habitats in fragmented landscapes. Oecologia, No 92, pp563-567.

Thrush, S F, Hewitt, J E, Dayton, P K, Coco, G, Lohrer, A M, Norkko, A, Norkko, J and Chiantore, M (2009) Forecasting the limits of resilience: integrating empirical research with theory. Proceedings of the Royal Society B-Biological Sciences, No 276, (1671) pp3209-3217.

Tischew, S, Mann, S, Schecher, K and Jager, U (2008) Restoration of Fallow Dry Grasslands in Cooperation with Local Farmers.

Tiwary, A, Sinnett, D, Peachey, C J, Chalabi, Z, Vardoulakis, S, Fletcher, T, Leonardi, G, Grundy, C, Azapagic, A and Hutchings, T R (2009) An integrated tool to assess the role of new planting in PM10 capture and the human health benefits: A case study in London. Environmental Pollution, No 157, pp2645-2653.

Trocmé, M., Cahill, S., de Vries, J.G., Farrall, H., Folkeson, L.G., Hichks, C. and Peymen, J. (eds) (2003) COST 341 - Habitat fragmentation due to transportation infrastructure: the European review. Office for official publications of the European Communities, Luxembourg, http://www.iene.info/cost-341/european-review

Trubek, David M.; Cottrell, Patrick; Nance, Mark. (2005). „Soft Law," „Hard Law," and European Integration: Toward a Theory of Hybridity. University of Wisconsin, Madison.

Trust for Public Land (2008) How much value does the City of Philadelphia receive from its parks and recreation system? Trust for Public Land Center for City Park Excellence, Philadelphia.

Tubelis, D P, Lindenmayer, D B and Cowling, A (2004) Novel patch-matrix interactions: patch width influences matrix use by birds. Oikos, No 107, (3) pp634-644.

Tucker, G.M., Kettunen, M., McConville, A.J. and Cottee-Jones, E. (2010) Valuing and conserving ecosystem services: a scoping case study in the Danube basin. Report prepared for WWF. Institute for European Environmental Policy, London.

Tyrvainen, L., Miettinen, A. (2000). Property prices and urban forest Amenities. Journal of Environmental Economics and Management 39: 205-223.

Tzoulas, K, Korpela, K, Venn, S, Yli-Pelkonen, V, Kazmierczak, A, Niemela, J and James, P (2007) Promoting ecosystem and human health in urban areas using green infrastructure: a literature review. Landscape and Urban Planning, No 81, (3) pp167-178.

Tzoulas, K, Korpela, K, Venn, S, Yli-Pelkonen, V, Kazmierczak, A, Niemela, J and James, P (2007) Promoting ecosystem and human health in urban areas using Green Infrastructure: A literature review. Landscape and Urban Planning, No 81, (3) pp167-178.

UK NEA (2011) Chapter 23: Health values from ecosystems, in UK National Ecosystem Assessment: technical report, UNEP-WCMC, Cambridge.

UK NEA (2011) Synthesis of the Key Findings, URL: http://uknea.unep-wcmc.org/LinkClick.aspx?fileticket=ryEodO1KG3k%3d&tabid=82

UK NEA (2011) The UK National Ecosystem Assessment. Synthesis of the Key Findings. UNEP-WCMC, Cambridge.

UK NEA (2011) The UK National Ecosystem Assessment: Technical Report. Chapter 18 Status and Changes in the UK's ecosystems and their services to society: a synthesis for Northern Ireland.

Upmanis, H, Eliasson, I and Lindqvist, S (1998) The influence of green areas on nocturnal temperatures in a high latitude city (Göteborg, Sweden). International Journal of Climatology, No 18, (6) pp681-700. URL: http://138.102.82.2/appli/pmb/exemplaires/expl_SIAFEE003956.pdf

Vallina, S M and Le Quere, C (2011) Stability of complex food webs: Resilience, resistance and the average interaction strength. Journal of Theoretical Biology, No 272, (1) pp160-173.

Van den Bergh, E.; Van Damme, S.; Graveland, J.; De Jong, D.; Baten, I.; Meire, P. (2005), Ecological Rehabilitation of the Schelde Estuary (The Netherlands-Belgium); Northwest Europe): Linking Ecology, Safety against Floods, and Accessibility for Port Development, Restoration Ecology, Vol. 13, no. 1, pp. 204-214

Van der Maarel, E. (2005) Vegetation Ecology. Blackwell Publishing.

van der Ree, R v d R, Jaeger, J A G, van der Grift, E A and Clevenger, A P (2011) Effects of Roads and Traffic on Wildlife Populations and Landscape Function: Road Ecology is Moving toward Larger Scales. Ecology and Society, No 16, (1) van der Ree, R, Gulle, N, Holland, K, van der Grift, E, Mata, C and Suarez, F (2007) Overcoming the Barrier Effects of Roads - How Effective are Mititgation Strategies?, in C I Leroy, D Nelson, & K P McDermott (eds) International Conference on Ecology and Transportation, 2007 International Conference on Ecology and Transportation. Center for Transportation and the Environment, North Carolina State University, USA.

van der Ree, R, Heinze, D, McCarthy, M and Mansergh, I (2009) Wildlife Tunnel Enhances Population Viability. Ecology and Society, No 14, (2) 7.

Van der Ree, R., D.T. Clarkson, K. Holland, N. Gulle, M. Budden (2008) Review of mitigation measures used to deal with the issue of habitat fragmentation by major linear infrastructure, Report for Department of Environment, Water, Heritage and the Arts (DEWHA), Contract No. 025/2006, Published by DEWHA.

Van Der Windt, H J and Swart, J A A (2008) Ecological corridors, connecting science and politics: the case of the Green River in the Netherlands. Journal of Applied Ecology, No 45, pp124-132.

Van Diggelen, R. (2006). Landscape: spatial interactions. In: Restoration Ecology: A European Perspective (eds. J. van Andel & J. Aronson), chapter 3. Blackwell Science, Oxford.

Van Kleunen A, Sierdsema H and Loos W B (2005) Aanvullende natuurlijke referentie-waarden en actuele waarden van broedvogels voor het opstellen van natuurgraadmeters. Sovon-onderzoeksrapport 2005/01.

Van Nes, E H and Scheffer, M (2005) Implications of spatial heterogeneity for catastrophic regime shifts in ecosystems. Ecology, No 86, (7) pp1797-1807.

Van Nes, E H and Scheffer, M (2007) Slow recovery from perturbations as a generic indicator of a nearby catastrophic shift (Vol 169, pg 738, 2007). American Naturalist, No 170, (4) 660.

Van Rensburg, T M, Kelley, H and Yadav, L (2009) Socio-economics of farming for conservation in the Burren. Working Paper No. 153, NUIG. Report prepared for the BurrenLIFE Project.

Van Teeffelen, A J A, Cabeza, M, Pöyry, J, Raatikainen, K and Kuussaari, M (2008) Maximizing conservation benefit for grassland species with contrasting management requirements. Journal of Applied Ecology, No 45, (5) pp1401-1409.

van Wieren, S E and Worm, P B (2001) The use of a motorway wildlife overpass by large mammals. Netherlands Journal of Zoology, No 51, (97) 105.

van Zeijts, H, Overmars, K, van der Bilt, Schulp, N, Notenboom, J, Westhoek, H, Helming, J, Terliun, I and Janssen, S (2011) Greening the Common Agricultural Policy: impacts on farmland biodiversity on an EU scale. PBL Netherlands Environmental Assessment Agency, The Hague, The Netherlands.

Vandewalle, M, Sykes, M T, Harrison, P A, Luck, G W, Berry, P, Bugter, R, Dawson, T P, Feld, C K, Harrington, A, Haslett, J R, Hering, D, Jones, K B, Jongman, R, Lavorel, S, Martins da Silva, P, Moora, M, Paterson, J, Rounsevell, M D A, Sandin, L, Settele, J, Sousa, J P and Zobel, M (2010) Review paper on concepts of dynamic ecosystems and their services. The RUBICODE project - Rationalising Biodiversity Conservation in Dynamic Ecosystems.

Vassant, J and Brandt, S (1998) Eude de la fréquentation par le grand gibier de deux passages pour la faune sur l´autoroute A5 pendant 7 ans, in pp157-170. Actes Des 3e Rencontres "Routes Et Faune Sauvage", 30 Septembre-2 Octobre, 30.9.1998,

Vellak, A, Tuvi, E-L, Reier, Ü, Kalamees, R, Roosaluste, E, Zobel, M and Pärtel, M (2009) Past and present effectiveness of Protected Areas for conservation of naturally and anthropogenically rare plant species. Conservation Biology, No 23, (3) pp750-757.

Venkatachalam, L (2004) The contingent valuation method: a review, Environmental Impact Assessment Review, Volume 24, Issue 1, January 2004, Pages 89-124

Vergano, L and Nunes, P (2006) Analysis and Evaluation of Ecosystem Resilience: An Economic Perspective, Working Papers 2006.25, Fondazione Eni Enrico Mattei

Villeger, S (2008) New multidimensional functional diversity indices for a multifaceted framework in functional ecology.

Virah-Sawmy, M, Gillson, L and Willis, K J (2009) How does spatial heterogeneity influence resilience to climatic changes? Ecological dynamics in southeast Madagascar. Ecological Monographs, No 79, (4) pp557-574.

Virkkala, R and Toivonen, H (1999) Maintaining Biological Diversity in Finnish Forests. The Finnish Environment 278. The Finnish Environment Institute, Helsinki.

Vlaams Overleg Regionale Landschappen, Tamás Marghescu, An example for Europe, presentation at the occasion of het opening seminar of the Hoge Kempen National Park, Genk, 2006. http://www.regionalelandschappen.be/rlalgemeen.html

Walker, B, Holling, C S, Carpenter, S R and Kinzig, A (2004) Resilience, adaptability and transformability in social-ecological systems. Ecology and Society, No 9, (2) on line.

Walker, B., C. S. Holling, S. R. Carpenter, and A. Kinzig. (2004). Resilience, adaptability and transformability in social–ecological systems. Ecology and Society 9(2): 5. [online] URL: http://www.ecologyandsociety.org/vol9/iss2/art5/

Walker, K J, Stevens, P A, Stevens, D P, Mountford, J O, Manchester, S J and Pywell, R F (2004) The restoration and re-creation of species-rich lowland grassland on land formerly managed for intensive agriculture in the UK. Biological Conservation, No 119, pp1-18.

Wätzold, F, Lienhoop, N, Drechsler, M and Settele, J (2008): Estimating optimal conservation in the context of agri-environmental schemes. Ecological Economics 68 (2008) 295 – 305

Wätzold, F, Mewes, M, van Apeldoorn, R, Varjopuro, R, Chmielewski, T, Veeneklaas, F and Kosola, M L (2010) Cost-effectiveness of managing Natura 2000 sites: an exploratory study for Finland, Germany, the Netherlands and Poland. Biodiversity and Conservation, No 19, (7) pp2053-2069.

Webb, N R (1990) Changes on the Heathlands of Dorset, England, Between 1978 and 1987. Biological Conservation, No 51, (4) pp273-286.

Werner, P. and Zahner, R. (2009). Biologische Vielfalt und Städte: Eine Übersicht und Bibliographie, (Biological Diversity and Cities: A review and Bibliography). BfN-Skripten, Vol. 245, Bundesamt für Naturschutz, Bonn, 2009.

WHO (2007) Steps to health: a European framework to promote physical activity for health. World Health Organisation Regional Office for Europe, Copenhagen.

Wiens, J A (1989) The Ecology of Bird Communities: Foundations and Patterns, 1. Cambridge University Press, Cambridge.

Wiersma, Y F and Nudds, T D (2009) Efficiency and effectiveness in representative reserve design in Canada: The contribution of existing protected areas. Biological Conservation, No 142, (8) pp1639-1646.

Wilson, L, Wilson, J, Holden, J, Armstrong, A, Johnstone, I and Morris, M (2011) Monitoring the impacts of peatland drain blocking, in CLAD Annual General Meeting: Restoration & Drainage in Peatlands, 12.1.2011, Glasgow. Carbon Landscapes and Drainage, Glasgow.

Winkel, G.; Kaphengst, T.; Herbert, S.; Robaey, Z.; Rosenkranz, L.; Sotirov, M. (2009). EU policy options for the protection of European forests against harmful impacts. Part of the tender: Implementation of the EU forestry Strategy: "How to protect EU forests against harmful impacts?"

Witt, A B R and Samways, M J (2004) Influence of agricultural land transformation and pest management practices on the arthropod diversity of a biodiversity hotspot, the cape floristic region, South Africa. African Entomology, No 12, pp89-95.

Wittig, R. (2005) The origin and development of the urban flora in Central Europe, Urban Ecosystems, Vol. 7, 2005, pp. 323–339.

Wolters, M, Garbutt, A and Bakker, J P (2005) Salt-marsh restoration: evaluating the success of de-embankments in north-west Europe. Biological Conservation, No 123, (2) pp249-268.

WWF (2008) Water for Life: Lessons for Climate Change Adaptation from Better Management of Rivers for People and Nature. WWF International, Gland, Switzerland.

WWF and IEEP (2009) Innovative use of EU funds to finance management measures and activities in Natura 2000 sites. Output of the project Financing Natura 2000: Cost estimate and benefits of Natura 2000. Final report. Output of the EC project Contract No. 070307/2007/484403/MAR/B2, WWF, Brussels, Belgium.

Young, A, Boyle, T and Brown, T (1996) The population genetic consequences of habitat fragmentation for plants. Trends in Ecology & Evolution, No 11, (10) pp413-418.

Young, J, Watt, A, Nowicki, P, Alard, D, Clitherow, J, Henle, K, Johnson, R, Laczko, E, McCracken, D, Matouch, S, Niemela, J and Richards, C (2005) Towards sustainable land use: identifying and managing the conflicts between human activities and biodiversity conservation in Europe. Biodiversity and Conservation, No 14, (7) pp1641-1661.

Yu, C and Hien, W N (2006) Thermal benefits of city parks. Energy and Buildings, No 38, pp105-120.

Zandersen, M. and R.S.J. Tol (2009), A meta-analysis of forest recreation values in Europe, Journal of Forest Economics, Volume 15, Issues 1-2, January 2009, pp109-130.

Zerbe, S., Maurer, U., Schmitz, S. and Sukopp, H. (2003) Biodiversity in Berlin and its potential for nature conservation, Landscape and Urban Planning, Vol. 62, 2003, pp. 139–148.

Zhang, W, Ricketts, T H, Kremen, C, Carney, K And Swinton, S M (2007) Ecosystem services and dis-services to agriculture. Ecological Economics, No 64, (2) pp253-260

Zipperer, W C, Sisinni, S M, Pouyat, R V and Foresman, T W (1997) Urban tree cover: an ecological perspective. Urban Ecosystems, No 1, (4) pp229-246.

Zisenis, M, Richard, D, Condé, S, Sharry, B M, Opermanis, O and Sipkova, Z (2010) 10 Messages for 2010 - Protected Areas. 2, European Environment Agency, Copenhagen, Denmark.

ANNEXES

Separate electronic files