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A spatial assessment of ecosystem services in Europe: Methods, case studies and policy analysis - phase 2

Joachim Maes, Jennifer Hauck, Maria Luisa Paracchini, Outi Ratamäki, Mette Termansen, Marta Perez-Soba, Leena Kopperoinen, Katri Rankinen, Jan Philipp Schägner, Peter Henrys, Iwona Cisowska, Marianne Zandersen, Kurt Jax, Alessandra La Notte, Niko Leikola, Eija Pouta, Simon Smart, Berit Hasler, Tuija Lankia, Hans Estrup Andersen, Carlo Lavalle, Tommer Vermaas, Mohammed Hussen Alemu, Paul Scholefield, Filipe Batista, Richard Pywell, Mike Hutchins, Morten Blemmer, Anders Fonnesbech-Wulff, Adam J. Vanbergen, Bernd Münier, Claudia Baranzelli, David Roy, Vincent Thieu, Grazia Zulian, Mikko Kuussaari, Hans Thodsen, Eeva-Liisa Alanen, Benis Egoh, Peter Borgen Sørensen, Leon Braat, Giovanni Bidoglio

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Summary

Mainstreaming ecosystem services in EU decision making processes requires a solid conceptual and methodological framework for mapping and assessing ecosystem services that serve the multiple objectives addressed by policies. The PRESS-2 study (PEER Research on EcoSystem Services – Phase 2) provides such an analytical framework which enables the operationalization of the present scientific knowledge base of environmental data and models for application by the EU and Member States for mapping and assessment of ecosystem services. This study is structured along three strands of work: policy and scenario analysis, mapping and valuation. Linking maps of ecosystem services supply to monetary valuation allows an analysis of the expected impact of policy measures on benefits derived from ecosystem services.

The first case study looks at water purification and demonstrates the three-step assessment cycle, investigating the impacts of agricultural and water policy scenarios on the capacity of ecosystems to purify water and on the benefits that are derived from improved water quality at different spatial scales. In general, the conclusion is that greening the CAP, would improve water quality and increase the benefits to society as measured via monetary valuation. Yet, reduction rates differed between the different levels (EU and basin scale) suggesting that the assessment of policy measures is scale-dependent, which, in turn, justifies our multi-scale assessment approach.

The second case study (recreation) presents evidence that millions of people visited forests several times per year and they expressed their willingness to pay to continue doing so. The visitor statistics that are used in this study confirm the usefulness of the ROS approach (Recreation Opportunity Spectrum) to identify areas in terms of their accessibility and potential to provide recreation services. In addition, PRESS-2 presents a spatial analysis of city population density and green urban areas.

The third case study regards pollination. Pollination services offered by insects such as wild bees and bumblebees are essential to maintain crop production, in particular of fruits and vegetables. PRESS-2 demonstrates that the coverage and resolution of current datasets are already sufficient to map the potential of ecosystems to provide this ecosystem service. However, future research should contribute to better ecological observations of key pollinator species to include important drivers of pollinators abundance in modelling and mapping approaches.

Europe has ambitious biodiversity and ecosystem services targets. Much of the ambition incorporated in the targets rests on the premise that ecosystem services are dependent on biodiversity for which there is indeed a substantial amount of evidence. Achieving biodiversity targets requires prioritizing investments and making them cost effective based on a sound knowledge base and assessment methods, which PRESS has contributed to. Our approaches show that the inclusion of the ecosystem services concept into policies would allow a systematic review of the consequences of policy measures for services beyond conventional environmental assessments. In order to be able to react and adapt to new circumstances, consequences of policies must be continuously monitored and flexible in design. Therefore, it is necessary to quantify goals and determine baseline levels describing what the situation was before the measure against which progress is verifiable. However, research is only one element of the necessary efforts to restore natural ecosystems and to preserve biodiversity in Europe. Therefore, the PRESS-2 team reiterates the conclusion of the first report and calls for a broad collaboration of all stakeholders involved, including researchers, policy makers, stakeholder groups and citizens, in an integrated ecosystem services approach.

PART 1. SYNTHESIS REPORT

1. Introduction

The policy context

The concept of ecosystem services (ESS) is now integrated in current biodiversity policies at global and European level (CBD 2010; EC 2011a). The policies describe how ecosystems and biodiversity are to be incorporated into public and business decision making, and indicate where natural resources are currently undervalued, and sometimes neglected. The inclusion of ESS into biodiversity policies is largely the result of the Millennium Ecosystem Assessment (MA 2005) and the TEEB initiative (The Economics of Ecosystems and Biodiversity 2010a,b). These studies have led to political acknowledgement (at the level of the United Nations) of the concept of ESS and advocate for a better understanding of the links between biodiversity, ecosystem functions, ecosystem services, their benefits and associated social and economic values as part of human well-being.

In particular, the EU Biodiversity Strategy to 2020 (EC 2011a) integrates the sustainable use of ecosystem services as underpinning element of human economies which complements the non-utilitarian conservation approach to biodiversity, thus contributing to the Europe 2020 targets[1], in particular through the "resource efficiency" flagship initiative[2]. This initiative aims at building smart, sustainable and inclusive growth for Europe. It establishes resource efficiency as the guiding principle for EU policies on energy, transport, climate change, industry, commodities, agriculture, fisheries, biodiversity and regional development. In addition, the ecosystem service concept has been identified as one of the pillars of the assessment of impacts in the preparation of the 2012 European Commission's Blueprint to Safeguard Europe's Water Resources (EC 2012). Furthermore, restoring and preserving ecosystem services is one of six priorities identified by the rural development pillar in the new proposal for the EU's Common Agricultural Policy (EC 2011i). Importantly, the EU's regional and cohesion policy now recognizes the importance of investing in natural ecosystems as a source of economic development aligning regional development targets with the Europe 2020 agenda (EC 2011j).

Much of the ambition incorporated in the targets and actions of the EU Biodiversity Strategy to 2020 rests on the premise that ecosystem services are dependent on biodiversity. And there is indeed a substantial amount of evidence demonstrating the dependency of "specific" ecosystem services on "specific" aspects of biodiversity. However, there is still much to be researched and validated, both at the experimental level and at the field observation and measurement level (see e.g. Cardinale et al., 2012). Much of the discussion on the relationships between biodiversity, ecosystem functions and ecosystem services is confused because the relationships are considered at the level of these so-called container concepts. Attempts to depict such relationships end up as a cloud of dots in a scatter plot. Another part of the confusion stems from the often undisclosed assumption that biodiversity is best represented

1 http://ec.europa.eu/europe2020/targets/eu-targets/index_en.htm

2 http://ec.europa.eu/resource-efficient-europe/

by species richness, and subsequently sufficiently represented by aboveground species only, and then mostly vertebrates.

In Braat and Ten Brink (2008) it was suggested that "mean species abundance" of a cross section of species of the ecosystem considered could usefully represent its potential to provide ecosystem services, with provisioning services having often only one, and occasionally a few, targeted species above-ground determining the service levels, and the associated economic values. But of course hundreds, if not thousands of species, did their work, usually not recognized, below the surface (insects, nematodes, fungi, bacteria). The regulating services are by definition dependent on the functional dimensions of ecosystems, and thus on the biological diversity of functional traits, and on key species in production and recycling, and in providing structure and spatial heterogeneity. Finally, species richness is of course a very important element of the cultural services, both as visible diversity components in space and through time, and as identifiable carriers of useful information, the common denominator of this class of services. Some of these contentions have been substantiated by now (see Maes et al., 2012), others are still being tested.

When mapping ecosystem services, the definition of the service flow, its source stock and production process, the choice of indicators, and by that the "visualisation" of the aspects of biological diversity of the service producing system will have to become part of the meta-data of the maps (and possibly in the legend). This is a still a major endeavour for most ecosystem services!

In the recent past it has become more evident to policy makers that nature-based solutions for social and economic problems and challenges, e.g. using wetland ecosystems for water purification, flood protection or carbon storage, may indeed be more cost-effective and resource efficient than technical infrastructures for enhancing resilience. Taking into consideration a probable future of decreasing resource availability in Europe and worldwide, the protection of the flow of services provided by ecosystems would contribute to delivering a sustainable, low carbon society and help progress towards the Europe 2020 targets on climate and energy. Assimilation of the ecosystem service concept calls for the economic valuation of ecosystem services and for a transparent incorporation into policy processes and decision-making. This implies placing ecosystems and biodiversity at the centre of sectoral policies, integrating them into the spatial planning of water and land, and making explicit the costs of ecosystem service degradation and biodiversity loss as well as the benefits from conservation and sustainable use of natural resources.

The PRESS study

Mainstreaming natural capital and ecosystem services into policy and decision making requires a scientifically sound knowledge base, which should provide a better understanding of the complex consequences of decision making of the private and public sector at different geographical policy levels. Furthermore, a better understanding is needed of the ecological production functions and their specific relationships with aspects of biodiversity, which are at the basis of ecosystem services. The PRESS (PEER Research on EcoSystem Services) project was conceived during the TEEB meetings in 2009 and started in early 2010 to contribute to this knowledge base by advancing methods to map, assess and valuate ecosystem services at multiple spatial scales[3]. The project has addressed some of the knowledge gaps which stand in the way of performing a spatially-explicit, biophysical, monetary and policy assessment

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3 PEER is the Partnership for European Environmental Research, a network of Institutes which includes Alterra Wageningen UR (the Netherlands), CEH (U.K.), Irstea (France), DCE – Danish Centre for Environment and Energy at Aarhus University (Denmark), SYKE (Finland), Helmoltz Centre for Environmental Research – UFZ (Germany) and the European Commission's JRC-IES

of ecosystem services. The focus has been on Europe, the Member States of the EU and sub-national regions. The starting point was the need to upgrade the knowledge base on land-use mapping to reflect the existing knowledge about ecosystem services and their social and economic values, and to better inform policy design and decision making processes.

In the PRESS - phase 1 report (Maes et al. 2011) we demonstrated methodologies to map ecosystem services. In particular, this report delivered models for mapping at different spatial scales the role of ecosystems as providers of recreation to citizens and the function of river networks in providing clean water. It demonstrated how the introduction of ecosystem services into biodiversity policy has resulted in synergies and trade-offs with other policies regulating agriculture, fisheries or forestry, each of which has strong impacts on biodiversity and conservation. The report includes an analysis of policy options, which shows that the perception of which services are provided by ecosystems varies according to the respondents, the geographical characteristics of the regions and the scales of decision making. This suggests then the type of assessment that territorial managers need to carry out. Finally, we pointed to the need for the development of hierarchical sets of ecosystem service indicators, following the SEBI-2010 example (Streamlining European Biodiversity Indicators; EEA, 2010), but geographically explicit and linked to the EU Biodiversity Strategy 2011-2020, and in particular the supporting Action 5 (under Target 2) which calls on the EU Member States to map, assess and value ecosystem services on their national territory.

Outline of the PRESS Phase 2 Synthesis report

This Synthesis report contains the results of the second phase of the PRESS project which has extended the mapping and policy analysis with scenarios and monetary valuation.

Water purification (chapter 2) relates to the role ecosystems play in the filtration and decomposition of organic wastes and pollutants in water, and the assimilation and detoxification of compounds through sediment, soil and subsoil processes. In particular, this case study examines how scenarios of land use change (as a result of a change in agricultural policy) and of river and wetland restoration affect the biophysical flow and the monetary value of this service.

Both natural and managed ecosystems provide a source of *outdoor recreation* as people enjoy walking in forests, watching birds in wetlands or hiking and camping in the outdoors. The recreation case study (chapter 3) builds on maps that express the recreation opportunity spectrum which combines recreation potential with accessibility to sites. The case study explores a scenario of expected demographic changes and makes an assessment of the service flows.

Pollination services are mainly delivered by bees and bumblebees when transferring pollen between flower parts increasing the probability of fertilization. Many crops are, to various degrees, dependent on pollination to produce fruits. This case study (chapter 4) quantifies the relative abundance of pollinators and estimates the contribution of ecosystems to crop pollination.

A literature based *policy analysis* (chapter 5) explores how EU policies and their implications at Member State and local level affect the supply of ecosystem services or may lead to trade-offs.

With these three case studies and the policy analysis we aim to illustrate how current knowledge and data on land cover, water resources, ecosystem properties, nutrient dynamics and climate can be combined to estimate biophysical flows of ecosystem services and their associated benefits and social and economic values. It is important to note that when we refer to biodiversity in this report, we do not only mean species richness, but do imply all functional and structural aspects of the biological diversity of the ecosystem discussed. As such, the PRESS project contributes to on-going initiatives that aim to increase our knowledge on ecosystems and to integrate them into the common implementation framework (CIF) of the EU Biodiversity Strategy to 2020.

This Synthesis report of the main results and achievements of this study is accompanied by a Technical report which presents and documents the different approaches and methodologies that have been used and reports extensively on the results.

2 Mapping and assessment of water purification services at multiple spatial scales

Policy messages

Water purification is a crucial ecosystem service as the self-cleaning capacity of wetlands, rivers, streams and lakes results in the provision of clean water for multiple uses. This service averts costs for society, since the treatment of mainly diffuse pollution is difficult using technological solutions only.

The water purification study demonstrates the full assessment cycle by investigating the impacts of agricultural and water policy scenarios on the capacity of ecosystems to purify water and on the benefits that are derived from improved water quality at different spatial scales.

Biodiversity cleans streams: the more biodiversity a river holds, the faster nitrogen is removed from the water (Cardinale, 2011). Although this PRESS study was not able to upscale this experimentally derived observation to the scale of river catchments, biodiversity was considered at ecosystem level, since the high nitrogen removal rates of wetlands are accounted for in the models.

The scenarios of greening of the Common Agricultural Policy, introducing measures to reduce fertilizer application and the restoration of wetlands, resulted in positive effects on water purification services, improved water quality and increased the benefits to society as measured via monetary valuation.

Yet, reduction rates differed between the different levels (EU and basin scale) suggesting that the assessment of policy measures is scale-dependent, which in turn justifies our multi-scale assessment approach.

Introduction

Freshwater aquatic ecosystems, and more specifically the biotic communities in lakes, rivers and floodplains, interacting with the waterlogged soils, have the capacity to retain, process and remove pollutants, sediments and excess nutrients. This water purification service reduces the quantity of pollutants of downstream waters and more importantly to the human settlements in the region, it contributes to the availability of clean water for multiples uses.

In this chapter, we present four case studies which cover different spatial scales to illustrate how benefits from water purification services can be accounted for using nitrogen as a common water quality indicator (Figure 2.1).

The starting point of the assessment is a policy change with a focus on the new Common Agricultural Policy (CAP; EC 2011i) and on a new water policy at EU scale (Blueprint to Safeguard Europe's Water Resources; EC 2012). A number of specific policy measures (greening measures under the CAP, nitrogen reduction measures and river and wetland restoration) were analysed using scenarios of land use change as a consequence of the policy measures relative to a baseline. Biophysical models were used to estimate how changing land use affected water purification as indicated by nitrogen retention. Finally, the economic value of the improved water quality, due to the nitrogen removal, was assessed via costs saved for downstream water treatment and by willingness to pay for clean water.

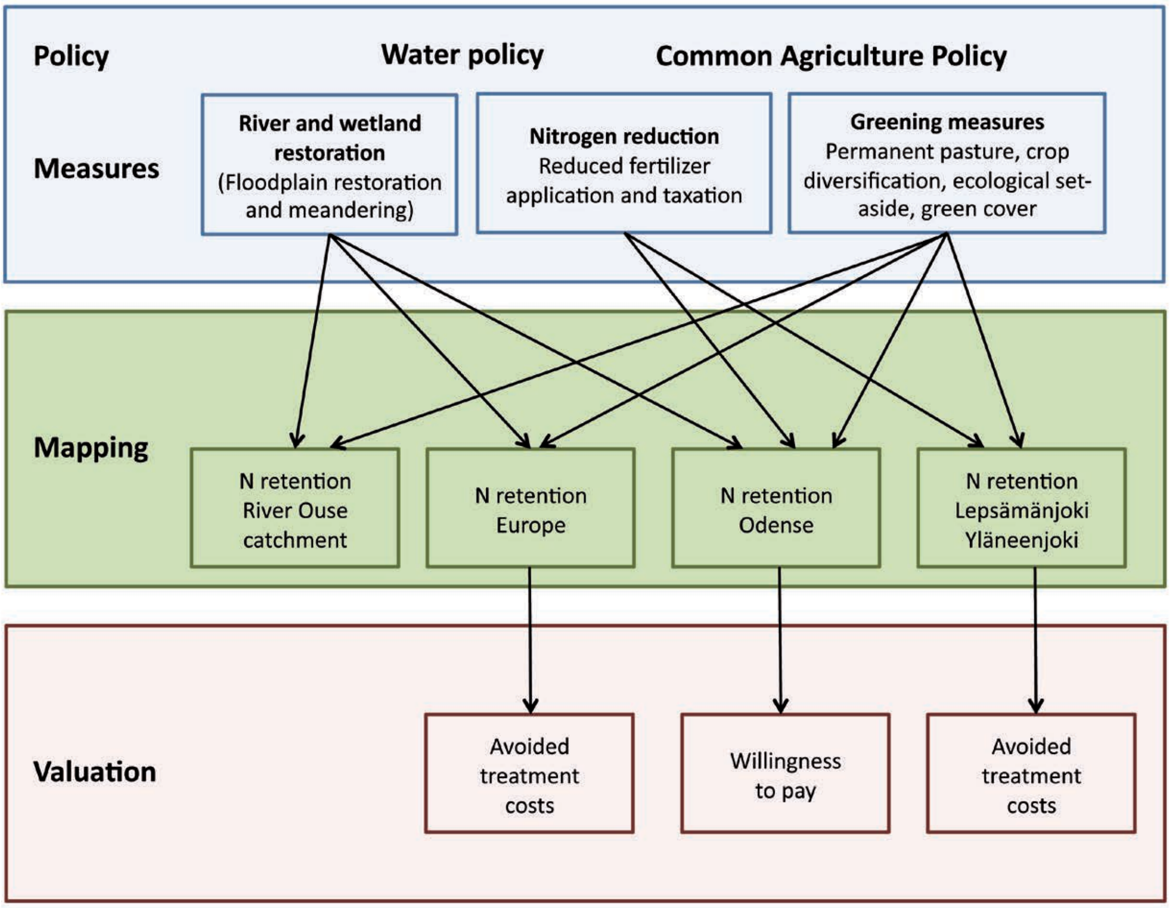


Figure 2.1. Scenario-based approach for the assessment of water purification services at different spatial scales in Europe. Nitrogen (N) was used as a common water-quality metric.

Results

Table 2.1 summarizes the most important results of the study by showing the direction of change of water purification services delivered by the aquatic ecosystems in a range of scenarios of land use change as a consequence of the policy measures. The overall conclusion was that greening the CAP, introducing measures to reduce fertilizer application, and the restoration of wetlands all resulted in increased levels of the water purification services, improved water quality and increased benefits to society as measured via monetary valuation.

Table 2.1. Direction of change in water purification following the implementation of different scenarios in four different case study areas.

<table>
<tr><th colspan="2">Scenarios and measures</th><th>Europe</th><th>UK
Ouse catchment</th><th>FI
Lepsämänjoki
Yläneenjoki
catchments</th><th>DK
Odense
catchment</th></tr>
<tr><td rowspan="4">Greening direct payments (CAP)</td><td>Permanent grassland</td><td rowspan="3">➔</td><td>↗</td><td></td><td></td></tr>
<tr><td>Crop rotation/ diversification</td><td></td><td>↘</td><td></td></tr>
<tr><td>Ecological set-aside
(ecological focus areas)</td><td>↗</td><td>↗</td><td>↗</td></tr>
<tr><td>Green cover</td><td></td><td></td><td>↗</td><td></td></tr>
<tr><td colspan="2">Reduced fertilizer application</td><td></td><td></td><td>↗</td><td>↗</td></tr>
<tr><td colspan="2">River restoration</td><td></td><td>➔</td><td></td><td></td></tr>
<tr><td colspan="2">Wetland restoration</td><td>↗</td><td></td><td></td><td>↗</td></tr>
</table>

➔: change in nitrogen retention less than 5%; ↘: 5% decrease in nitrogen retention; ↗: 5% increase in nitrogen retention

Greening of the CAP

The difference in effects between a generic European scenario on greening direct payments relative to the catchment specific scenarios is apparent. At European scale, losses in arable land and certain crops in one area are predicted to be compensated for in other areas, since EU food demand is not expected to change substantially. As a result, the overall change in land use, nitrogen input and nitrogen retention is relatively small. It follows that the benefits (avoided treatment costs) at aggregated EU scale (arising from reduced nitrogen application) were equally small (see Figure 2.2). At the catchment scale, however, the greening measures were predicted to result in increased benefits. Figure 2.3 illustrates this for the Finnish case.

This suggests that local and regional implementation of EU legislation may enable a more rigid enforcement of measures without considering the impacts on other areas, explaining why greening measures result in increased local benefits but may have negative effects on other regions.

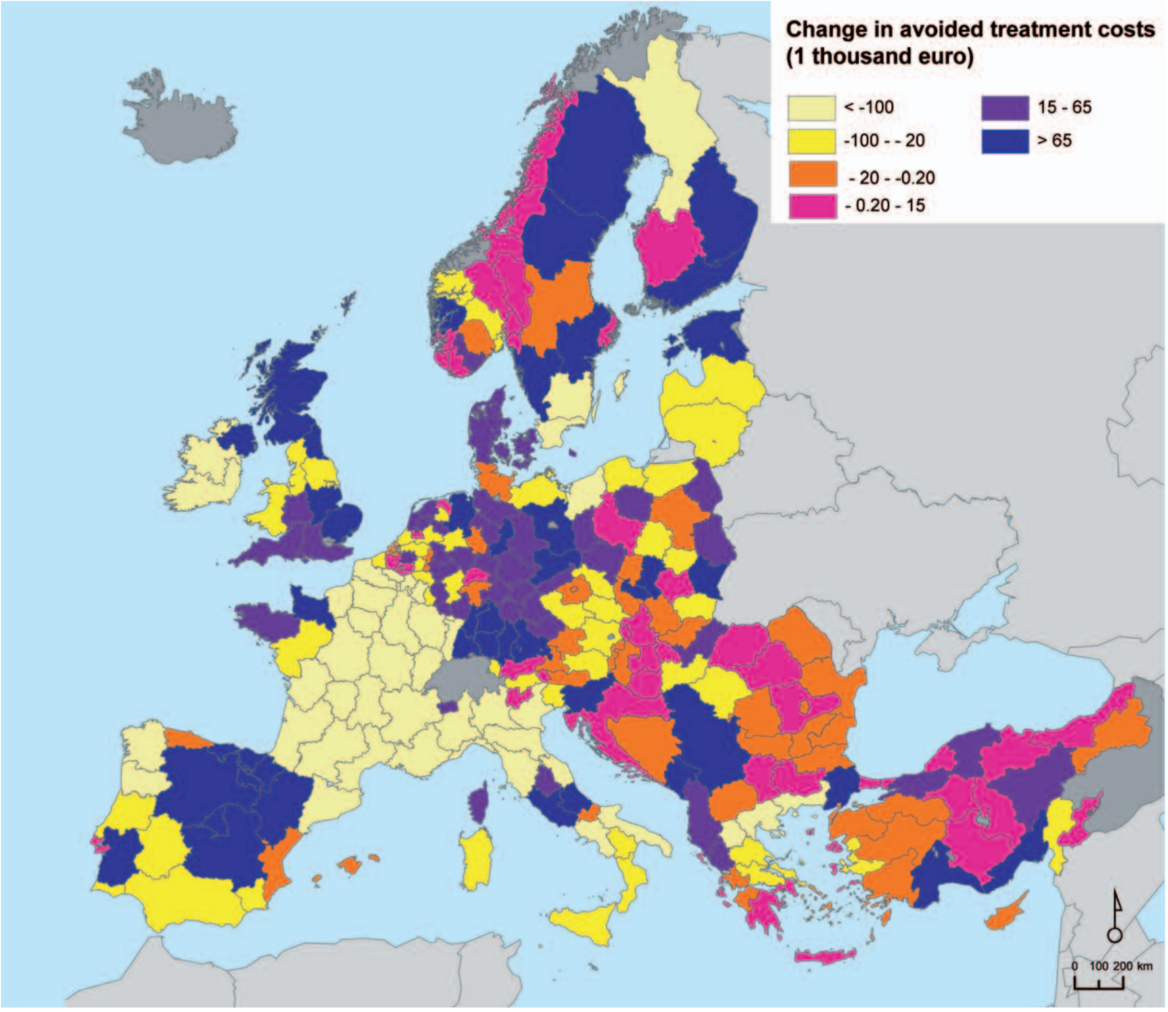


Figure 2.2. Assessment of avoided treatment costs comparing the EU-GREENCAP scenario relative to the EU-BAU (Business as Usual).

(1) The UK study (Table 2.2) includes two measures: an area measure, the Environmentally Sensitive Area scheme and a *pro constraint*, a farm-level compulsory rate of ecological set-aside. They are predicted to have significant beneficial effects as measured by the effectiveness (the ratio between output load for each scenario relative to the baseline).

Table 2.2. Scenario assessment of basin-wide nitrate-N fluxes and concentrations for the river Ouse catchment.

	Diffuse sources (ton year^{-1})	River retention (ton year^{-1})	River retention (%)	Output load (ton year^{-1})	N at outlet (mg l^{-1})	Effectiveness (%)
Baseline	8961	783	8.17	8798	4.67	
Environmentally Sensitive Area	8263	723	8.13	8160	4.33	7.25
20% set-aside	8044	707	8.16	7956	4.22	9.57

(2) The Danish scenarios (Table 2.3) are characterised by significant average reductions in fertilizer application relative to the baseline, in particular in those scenarios that involve taxation of fertilizer. This results in lower nitrogen loads to lakes and to the coastal zone and yields benefits measured by willingness to pay (WTP) to achieve a better ecological status (based on the quality criteria of the Water Framework Directive).

Table 2.3. Changes in average fertiliser application, N-retention and the benefits in terms of water quality improvements predicted for the scenarios of the Danish case study.

Scenario	Fertiliser reduction (kg/ha)	N load to Fjord (ton)	N retention (ton)	P reduction to lakes (kg)	Water quality Fjord	Water quality Lake	WTP Million € year[1]
Baseline model		1838		n/a	Poor	Poor	
Low fertilizer tax	79	1479	359	n/a	Moderate	n/a	31.3
High fertilizer tax	101	1404	434	n/a	Moderate	n/a	31.3
Set-aside 15%	12	1715	123	342	Poor	Good	34.4
Set-aside 25%	24	1570	268	538	Poor	Very Good	27.9
Wetland restoration		1747	91	n/a	Poor	n/a	

(3) The Finnish scenario is based on the greening measures as proposed by the new CAP proposal: ecological set aside area increase up to 10-15% of the total crop area; crop diversification with at least 3 crops cultivated and spring cereals cover <40% of field area; grass cover >10% of field area. This scenario differs from the EU scenario in that it includes an additional measure of 50% of total crop area under wintertime vegetation. The scenario with fertilizer reduction assumes 100% of the area under reduced fertilization with a nitrogen balance decreased to 20 kg N ha-1 and manure spreading allowed only during the growing season. Reduced fertilizer application, vegetation cover during winter, and ecological set aside are predicted to result in additional benefits. Crop diversification is, contrary to general findings, predicted to increase nitrogen application (as a result of case specific conditions) and will invoke costs (Figure 2.3).

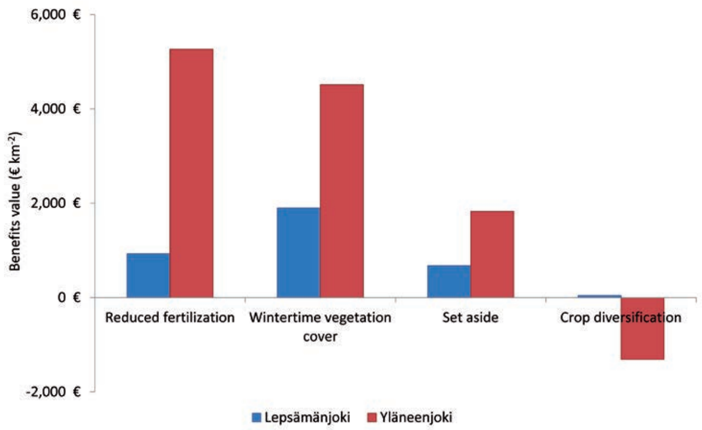


Figure 2.3. Value (€ ha^{-1}) generated by water purification services for four different measures (Finnish case study)

Wetland and floodplain restoration

Biodiversity was not included explicitly in the models used in this study. Yet, more and more it becomes clear that biodiversity positively influences ecosystem functions that are essential to provide ecosystem services. For instance, Cardinale (2011) showed that a higher diversity of the community of algal species increased the nitrogen uptake capacity justifying efforts to protect and conserve aquatic biodiversity. Upscaling parameters that describe the biodiversity-ecosystem function relationships to landscape level in order to make inferences on ecosystem services still requires basic research, which was not possible in this study (Cardinale et al. 2012). However, biodiversity can be considered at ecosystem level as well and in the study we demonstrate that wetland and floodplain restoration are shown to contribute significantly to the reduction of nitrogen in surface waters and decrease the loading to European coastal zones. This was also confirmed by the Danish case study. Additional benefits that are derived from wetland restoration but which were not valuated in this study, are flood protection, increased habitat for species, in particular birds, and enhanced opportunities for particular forms of recreation.

3 Mapping and assessment of outdoor recreation at multiple spatial scales

Policy messages

Recreation in nature (outdoor recreation) is likely one of the most clearly perceived benefits of ecosystems to people. Many people have experienced the sheer enjoyment of walking in forests, seeing beautiful flowers and animals in the outdoors or picnicking with the family on a lakeshore. This is shown by the high visitation rates of forests and natural areas. The visitor statistics that were used in this study confirm the usefulness of the ROS approach (Recreation Opportunity Spectrum) to identify areas in terms of their accessibility and potential to provide recreation services.

Biodiversity is an important variable in the modelling approach. In the recreation study, biodiversity is approximated in an explicit way using spatial data on naturalness but also implicitly by including the Natura2000 network layer.

Millions of people have visited forests several times per year and they expressed their willingness to pay to continue doing so. The magnitude of estimates provided by the case study areas proves that such value may easily be in a range of billions of euros, and may increase if the avoided cost for health care due to recreation restorative and stress reduction capacity is included.

A spatial analysis of city population density and green urban areas is used to bring nature closer to citizens. The analysis can identify where investment in nature will increase the capacity of ecosystems to provide this essential service to people taking into account demographic evolution, urbanization and modes of transport.

Though the issue is not yet addressed in literature under the umbrella of ecosystem services, the restorative and stress reduction capacity of ecosystems would be a major theme for research. It is in fact reported that wilderness and the natural environment in general do have restorative capacities on humans. Accessibility to these areas is therefore important also from this point of view.

Introduction

Cultural ecosystem services are defined as non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experience. In all these forms of cultural services, the essential process is the flow of information from ecosystems, while humans have to invest in obtaining that information through developing accessibility to the ecosystems, and exposing themselves to the information.

This section shows how ecosystems can provide recreation (the re-creating process within humans) as a benefit to citizens. More specifically, the type of recreation addressed here relates to the benefits obtained in daily life, ranging from e.g. the pleasure of reading a newspaper while sitting in the closest green urban area, a bike ride after work, to a day trip to a nature area. All ecosystems are considered to be potential providers of the service, irrespective of their conservation status (biodiversity level), though the type and level of service provision changes accordingly. Tourism and long distance (>100 km) travel were not included in this study, as this would have required a different approach.

The mapping and assessment of recreation services offered by ecosystems was structured along the ecosystem services cascade model (Haines-Young and Potschin 2010; De Groot et al. 2010; Figure 3.1). Firstly, we mapped for different case studies the potential of different ecosystems, including urban ones, to provide recreation. The ROS approach (Recreation Opportunity Spectrum) presented in the first PRESS report (Maes et al. 2011) has been refined and applied at the EU level and at the national level for Finland. A local scale study was carried out on green urban areas, as these are an increasingly important source of recreation given the growing share of human populations in towns and cities. Secondly, we reported on the efforts to assess the number people that recreate in nature by evaluating a number of visitor statistics based on surveys or analysis of existing data. Thirdly, the monetary value of the benefits of the recreation services was estimated based on travel costs. Finally, a scenario of land use change, including demographic projections to 2030, shows how the provision of recreation may consequently change.

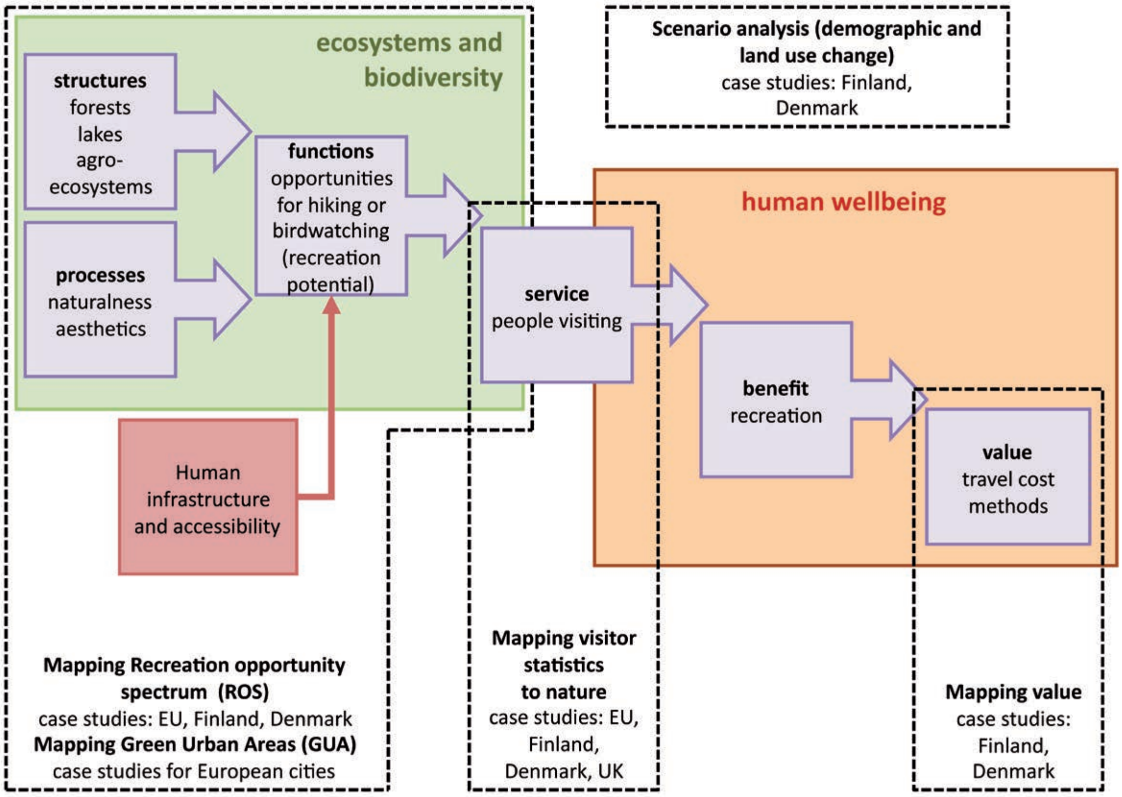


Figure 3.1. Application of the ecosystem services cascade model as an analytical framework to map and assess recreation in nature.

Results

The usefulness of the ROS concept

A first conclusion of this study regards the usefulness of the ROS concept to map the potential of ecosystems to provide recreation (Figure 3.2). The survey data of the different case studies confirm the assumption that the environments where people like to recreate are linked to the quality of the natural area and the presence of water. In particular the Danish approach concludes that forests which are receiving more than half a million visits per year are those that are categorised in the ROS model with predominantly high recreation opportunity provision while forests categorised as medium recreation opportunity provision received less than half a million visitors.

Another important confirmation of the validity of the ROS model is coming from the analysis of travelled distance. A main assumption in the EU-wide exercise was that all ecosystem types had to be analysed as potential sources for recreation, and not only the most valuable ones in terms of the quality of the natural area and biodiversity. In fact, if someone wants to recreate in nature shortly after work, or bring the children for a stroll, he or she does not have a wide selection of ecosystems available to go to in the limited area surrounding his or her home. It is therefore important to understand what the characteristics of current provision are, to be able to improve it. Results from 23 analysed EU countries show that on average 35% of the population can easily reach sites with a high potential for recreation. Areas with a relatively high degree of naturalness (forests are considered as such) provide multiple ecosystem services (Maes et al. 2011), some of which have positive effects on human health (i.e. air quality regulation).

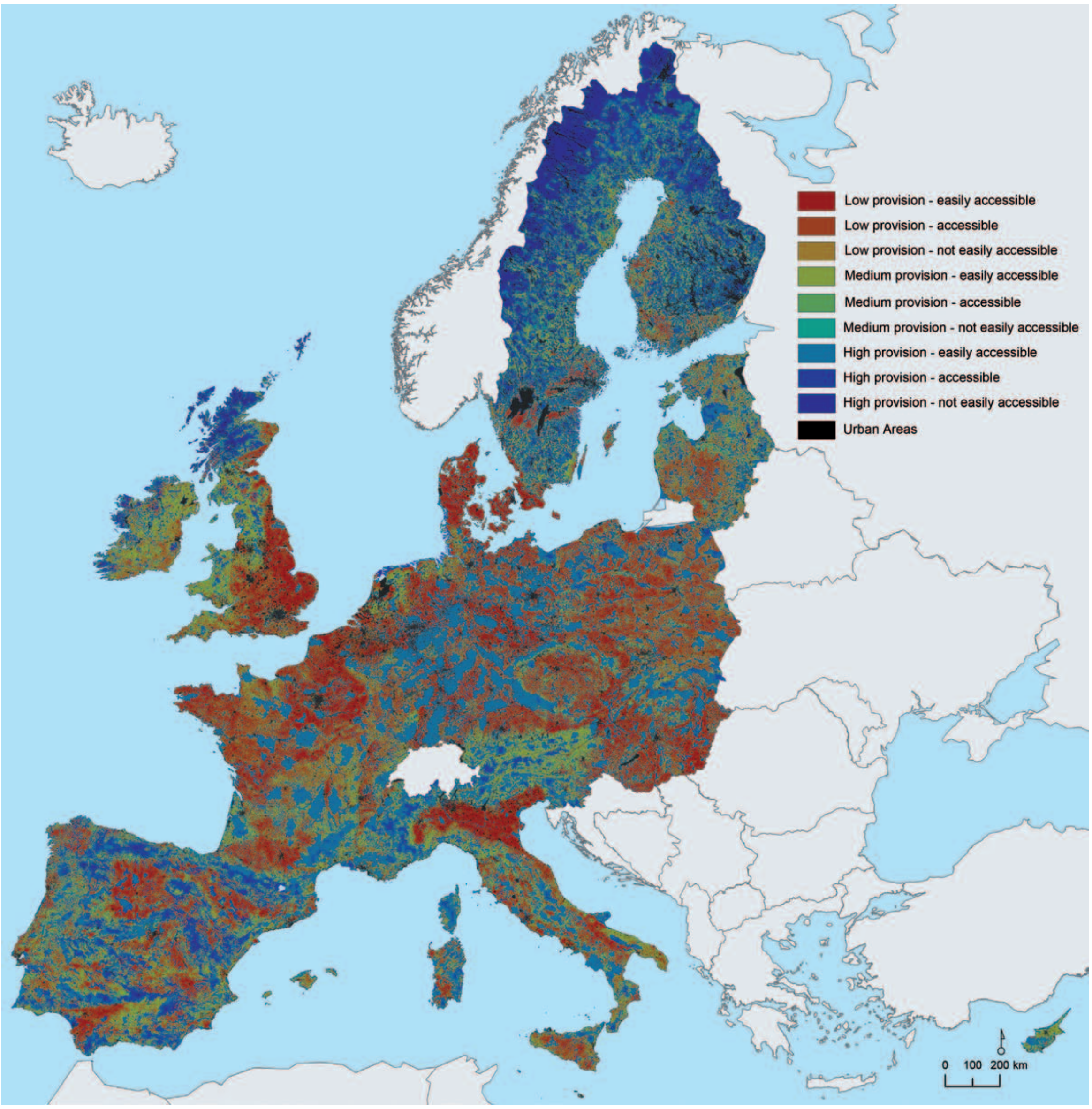


Figure 3.2. The Recreation Opportunity Spectrum (ROS) for Europe classifies ecosystems in three classes of accessibility and three classes of recreation potential.

Accessibility

The analysis made at country level provides some ideas on how accessibility can be granted. Some countries have an inherent high provision of recreation potential. For instance, in Sweden and Finland the boreal environment is characterised by a high degree of naturalness. In countries where this provision is lower due to intensive agriculture (for instance Germany, United Kingdom, France, Italy) the network of protected areas is a major element in ensuring potential recreation provision. Intensive agriculture mostly takes place in lowlands, where many major European cities are also located and millions of people live. In Italy, a high recreation potential is mostly provided by areas in the hills and mountains, which are further away from millions of citizens than the average distance of close-to-home trips. On the contrary, countries like Germany show a more evenly distributed network of protected areas on the national territory.

Surrounding environment

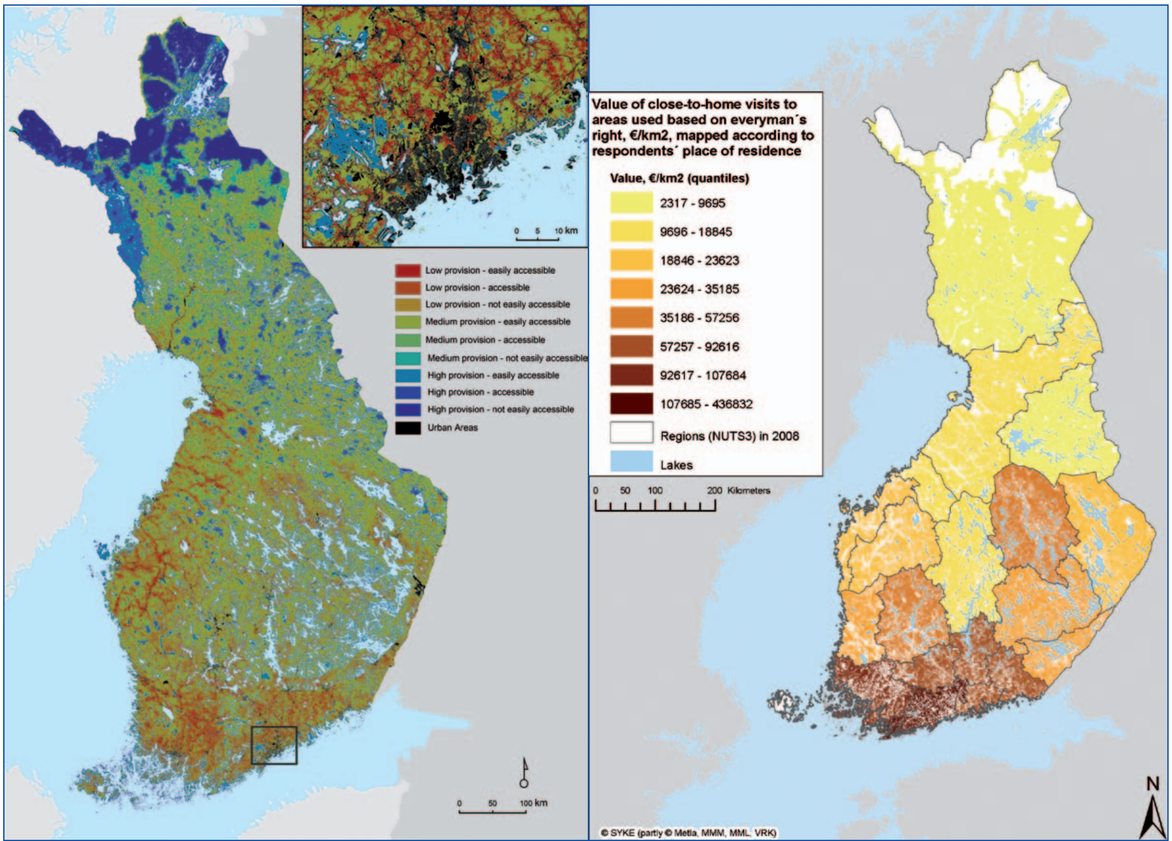
The fact that the surrounding environment is crucially important is demonstrated by the Finnish survey (Figure 3.3), which shows the importance of the *everyman's right* (the right to have public access to the land). About 80% of close-to-home trips are made to this type of environment. The total number of close-to-home trips accounts for over 500 million trips per year. The Danish survey provides high estimates for trips to nearby forests, estimated at over 26 million per year in the Copenhagen and Frederiksborg regions only (Figure 3.4). The fact that the surroundings are important in recreation analysis highlights the role of urban green areas (Figure 3.5). Also in this case spatial distribution matters, and has the double effect of providing a higher number of residents with recreation potential, and of diminishing visitor pressure on each area. Statistics in the Netherlands show that availability of green urban areas to people living in a 500 m surrounding range from 14 to 56 m^2, with an average around 30 m^2.

Economic valuation

In the Finland case, the analysis of consumer surplus estimates per trip, shows that leisure homes in general and in Northern Finland as a region stand out from the others. Furthermore, the value of a trip to State owned land in Northern Finland is calculated to be almost twice as high as the value of a trip to State owned land in other parts of the country. Trips to *everyman's right area* in Northern Finland provide a consumer surplus that is about 45% higher than trips to the same type of site elsewhere in Finland. The total value of the recreation service is estimated at several hundreds of M€ for the capital city. The Danish study on forests in the Copenhagen and Frederiksborg regions concludes that the willingness to pay for car access ranges from 1 to 12 million € per site. There were 52 forests analysed so the total value is exceeding 50 million € for just one type of ecosystem.

Scenario analysis

The scenario analysis links land use modelling, a population growth scenario and recreation provision. The scenario applied on Finland is a Business as Usual scenario towards 2030. Results show that under current conditions changes are very small. Results of the Danish case indicate that with an increase of 240 000 of the population living in the municipality of Copenhagen over a 20-year period, forests closest to Copenhagen would receive between 106 000 and 1 million additional trips (equivalent to 10-32% increase). Changes in the value of car access show in some locations a reduction of € 134 000 per year while in other locations recreation services would yield as much as € 2.8 million.



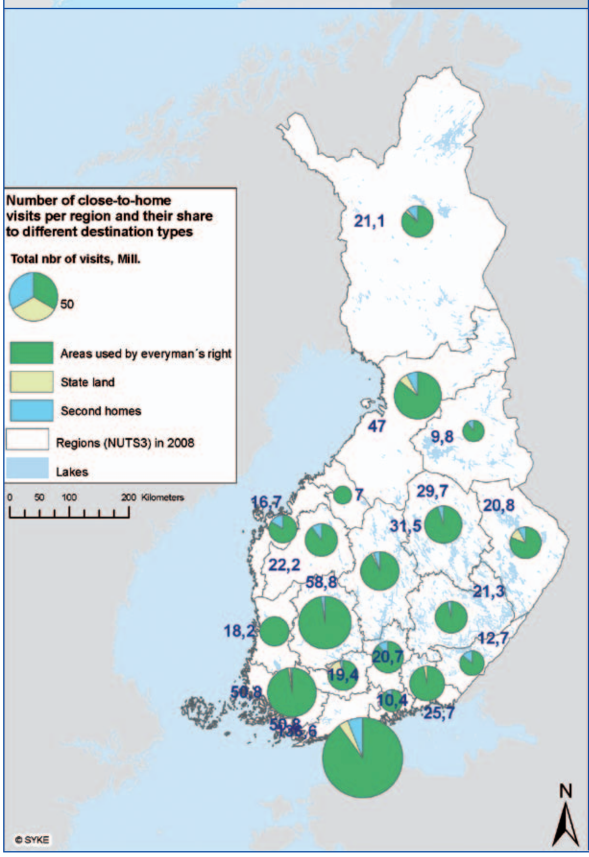


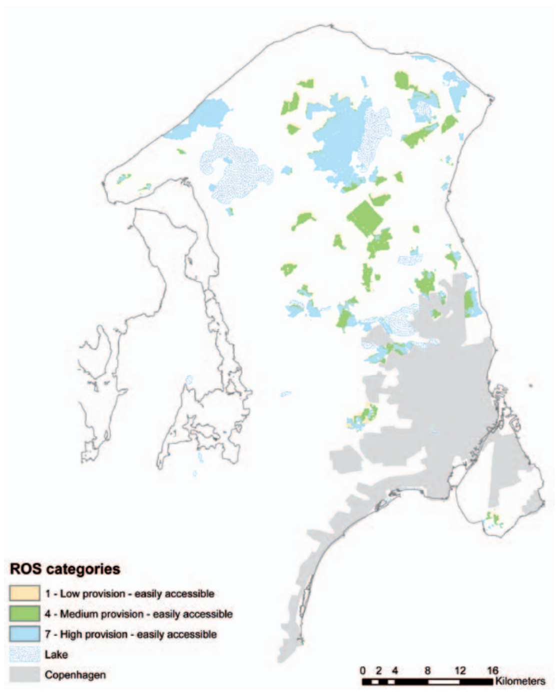
Figure 3.3. Finnish case study results.

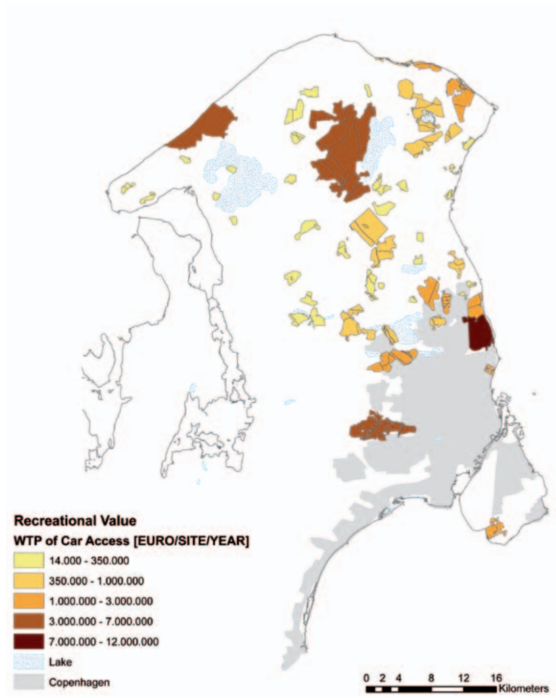
The Finnish case study is based on data from the national outdoor recreation demand inventory (LVVI2) by the Finnish Forest Research Institute.

Top Left: An improved ROS map for Finland with inclusion of the everyman's right areas (areas owned by private landowners, municipalities or State where the use is based on public access to the land).

Bottom left. Survey statistics show that areas of everyman's right are very important for recreation by Finnish population and that second homes (summer cottages) also play a relevant role in recreation activities. In Finland, 80% of respondents travel a maximum of 8 km for recreation highlighting the importance of the potential provision of recreation by ecosystems in the surroundings of places of residence.

Top Right. The value (million € km^{-2}) of close-to-home visits to areas under everyman´s right
Source: Metla/LVVI2 data





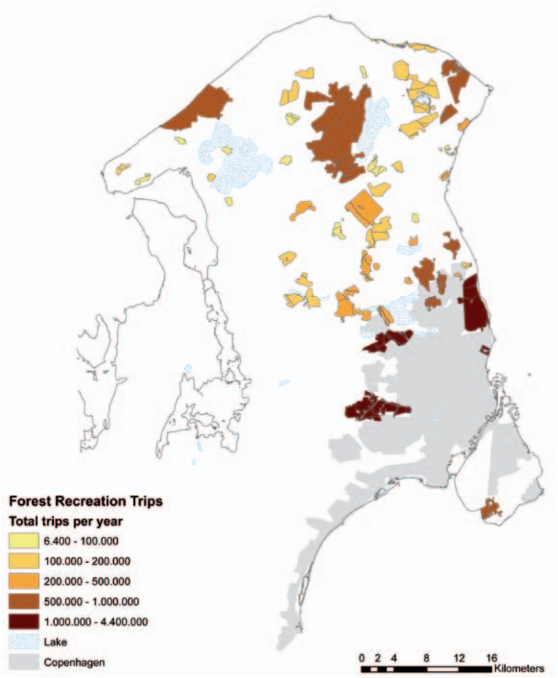


Figure 3.4. Danish case study results.

The Danish case study is based on a national household survey from 1994 used to estimate how many trips per year people make to forests for recreation in the regions of Copenhagen and Frederiksborg (North Zealand), totalling 662 people.

Top Left: ROS categorisation of forest sites included in the case study.

Bottom left. Total number of forest recreation day trips per site. Based on these statistics it is estimated that the total of yearly car trips to the 52 forests amounts to 14.5 million and trips with other means of transport sum to 12.1 million trips. On average, each adult in the region makes 23.5 trips per year to these forests.

Top Right. The willingness to pay for car access to forests (million € per site per year). The most valuable site (Willingness to Pay for car access close to 12 million € per year) is a former royal hunting forest and is today the most visited natural area in Denmark.

It is premature to draw EU-wide conclusions from this study on the value of recreation as ecosystem service. Nevertheless, the magnitude of estimates provided by the case study areas proves that such value may easily be in a range of billions of euros, and may increase if the avoided cost for health care due to recreation restorative and stress reduction capacity is included.

The potential of Green Urban Areas (GUAs) to provide recreation ecosystem services

Surveys clearly show the strong relation between recreational activities and the origin of recreational trips (the places of residence of people recreating). Under this perspective, the role of Green Urban Areas (GUAs) cannot be neglected. GUAs are in fact main sources of recreation provision by ecosystems for populations living in urban centres.

Using *the potential number of people per GUA for the urban zones* as a proxy to value the potential of Green Urban Areas to provide recreation services, Figure 3.5 shows for the city of The Hague, lying at the Dutch coast, that both the green areas situated in the city centre and the dune areas in the urban periphery provide potential recreational services to many people within a 500m distance. Compared to The Hague, recreational services in the city of Amsterdam are provided more by small GUA's in the city centre (Figure 3.6). A second proxy to value the potential of GUA to provide recreation ecosystem services is the *amount of green area per person*. The dune areas in The Hague provide a higher service in terms of area per person than the green areas in the city centre.

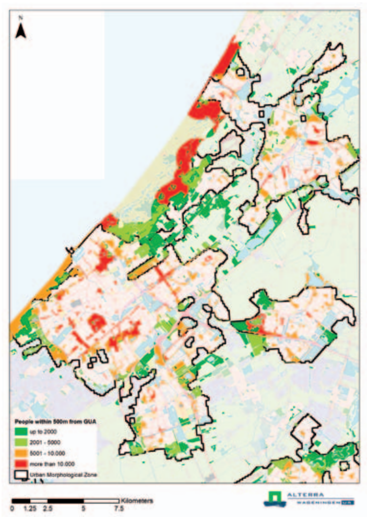


Figure 3.5. *Number of people within 500m of GUAs in the Dutch city of The Hague*

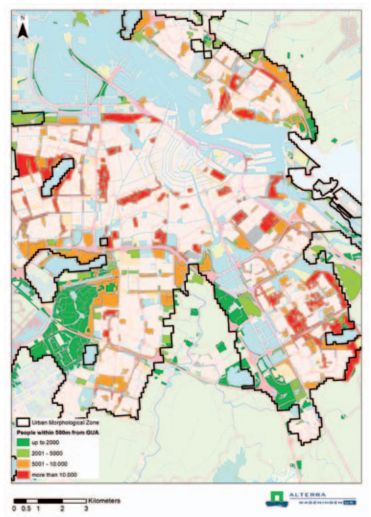


Figure 3.6. *Number of people within 500m of GUAs in the Dutch city of Amsterdam*

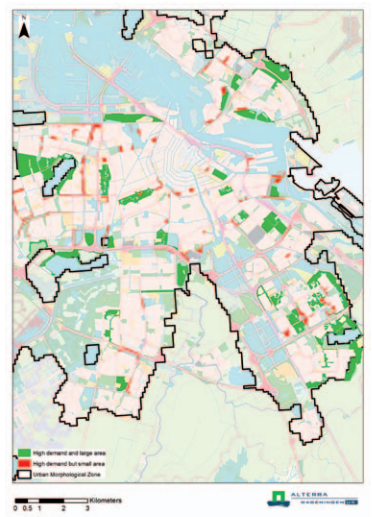


Figure 3.7. *Demand/supply ratios for GUAs in the Dutch city of Amsterdam*

Considering *the number of people within 500 m of a GUA* as the demand for recreation, and the area of that GUA as the supply, a selection of GUAs can be made. In Figure 3.7 the areas with high demand and high supply (thus potentially providing a high amount of green space to many people) are marked in green, high demand and low supply (thus potentially providing a low amount of green space to many people) are marked in red. Compared to Figure 3.6, showing the number of people within 500 m of GUAs, this map provides a different interpretation of recreation provision. Some sites like the dune areas, for example, provide recreation potential to many more residents than the smaller green areas in the city, which may therefore be less congested.

Using available datasets in a simple and transparent way that can be applied at European level, recreation ecosystem services provided by green urban areas can be analysed effectively. The calculations do not take into account people working only in the cities, relevant in many European city centres. The distance of 500 m was based on the assumption that people will walk to the GUA, while in some countries cycling, or going by car or public transport will be more common.

4. Mapping and stakeholder assessment of pollination services at multiple spatial scales

Policy messages

Pollination services offered by insects such as wild bees and bumblebees are essential to maintain crop production, in particular of fruit and vegetables. PRESS demonstrated that the coverage and resolution of current datasets are already sufficient to map the potential of ecosystems to provide this ecosystem service.

Importantly, this study shows how functional traits of pollinator biodiversity can be used to map pollination potential of ecosystems.

The concept of ecosystem services was expressed to be useful by interviewed stakeholders, but it has opened up new questions about responsibilities and liabilities. Many stakeholders feel they have all the relevant information. Instead, operationalization of scientific information and development of good social practices were identified as key concerns, and they think informal practices and codes of conduct are also an important aspect of pollinator conservation.

However, better ecological observations of key pollinator species are needed to include important drivers of pollinator-abundance in modelling and mapping approaches which were not included in the study, for instance the use of pesticides or the presence of pollinator-supporting habitats in the landscape.

Introduction

The productivity of many agricultural crops, in particular of fruits and vegetables, depends on the presence of pollinating insects. The dependence of several European crops on pollination and the high monetary value associated with crop pollination makes it relevant to society to delineate places where nature has the potential to provide pollination services.

This study presents a mapping approach to assess the relative importance of pollination to European agricultural crops. The approach is based on the evidence that different habitats, but in particular forest edges, grasslands rich in flowers and riparian areas, offer suitable sites to host populations of wild pollinator insects such as solitary bees, bumblebees or hoverflies. Pollination as an ecosystem service was studied in four case studies across Europe.

Results

EU level

At the European scale, a map of pollination potential was produced (Figure 4.1). Spatial data of land cover and land use were transformed into indicators for nesting suitability and floral resource availability. Next, these indicators were combined with climate data to simulate pollinator activity and map the relative pollination abundance at a landscape scale. The mapping method was based on the InVEST model of the Natural Capital Project (Kareiva et al. 2011).

The relative pollinator abundance is modelled to increase from northern to southern Europe corresponding to the modelled temperature-dependent activity rate of bees and bumblebees. Given temperature, pollination potential is expected to be low in areas where the dominant land use is arable land used for production of cereals, such as the east of the United Kingdom, areas in France surrounding the capital, areas in central Spain, the Po plain in Italy, areas in northern Germany, Poland and Slovakia and the along the borders of the Danube in Bulgaria and Romania. These areas are assumed to have low pollinator nesting suitability and to offer limited resources for foraging due to an absence of plants with flowers carrying nectar. At aggregated EU level, 23.6% of the total production of crops which depend on pollination could be assigned to insect pollination. This figure corresponds to a production deficit if no pollination services were offered by insects. This value decreases to 1% if all crop production is considered, including the large share crops that are not dependent on pollination.

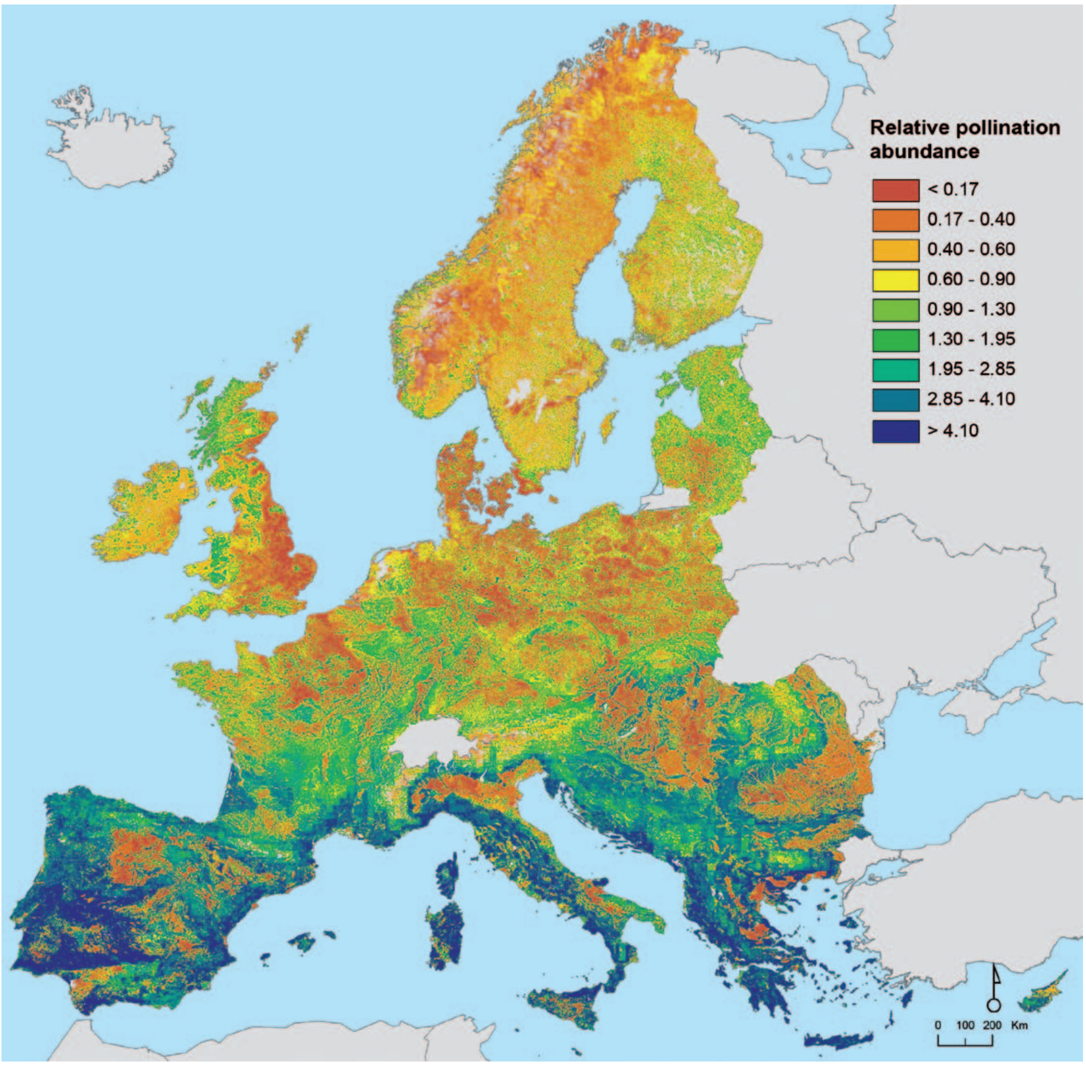


Figure 4.1. Relative pollinator abundance across Europe.

The Finland case

The Finnish case study is based on a similar mapping approach but the spatial scale of assessment was finer. Maps of the relative pollinator abundance at different spatial scales have been compared to maps of pollination demand indicated by the distribution of insect-pollinated crops. The availability of pollination services was generally highest in the north and lowest in the south-east, whereas the demand for insect pollination had just the opposite pattern (Figure 4.2). These patterns are better seen in the scale of the 10 km grid than in the smaller grid sizes and they are largely due to the differences in land cover by forest and arable land between the northern and southern parts. In the northern part cultivated fields tend to be smaller and thereby the distances to forest edges with high pollination availability tend to remain small, whereas in the southern part arable fields constitute much larger cultivated open areas with low availability of pollination services and the distribution of insect-pollinated crops follow the general distribution of arable areas.

The Finnish high resolution maps (grid size of 25 m) are useful in the local planning of the implementation of agri-environmental measures, because they can help identify localities where pollination demand is high but pollination services are scarce, and where practical mitigation measures are needed. These maps also illustrate that even small patches of woodland in the middle of large field parcels can potentially act as important pollinator source habitats in agricultural landscapes. This stresses again the importance of green infrastructure elements as a way of providing multiple services, including pollination.

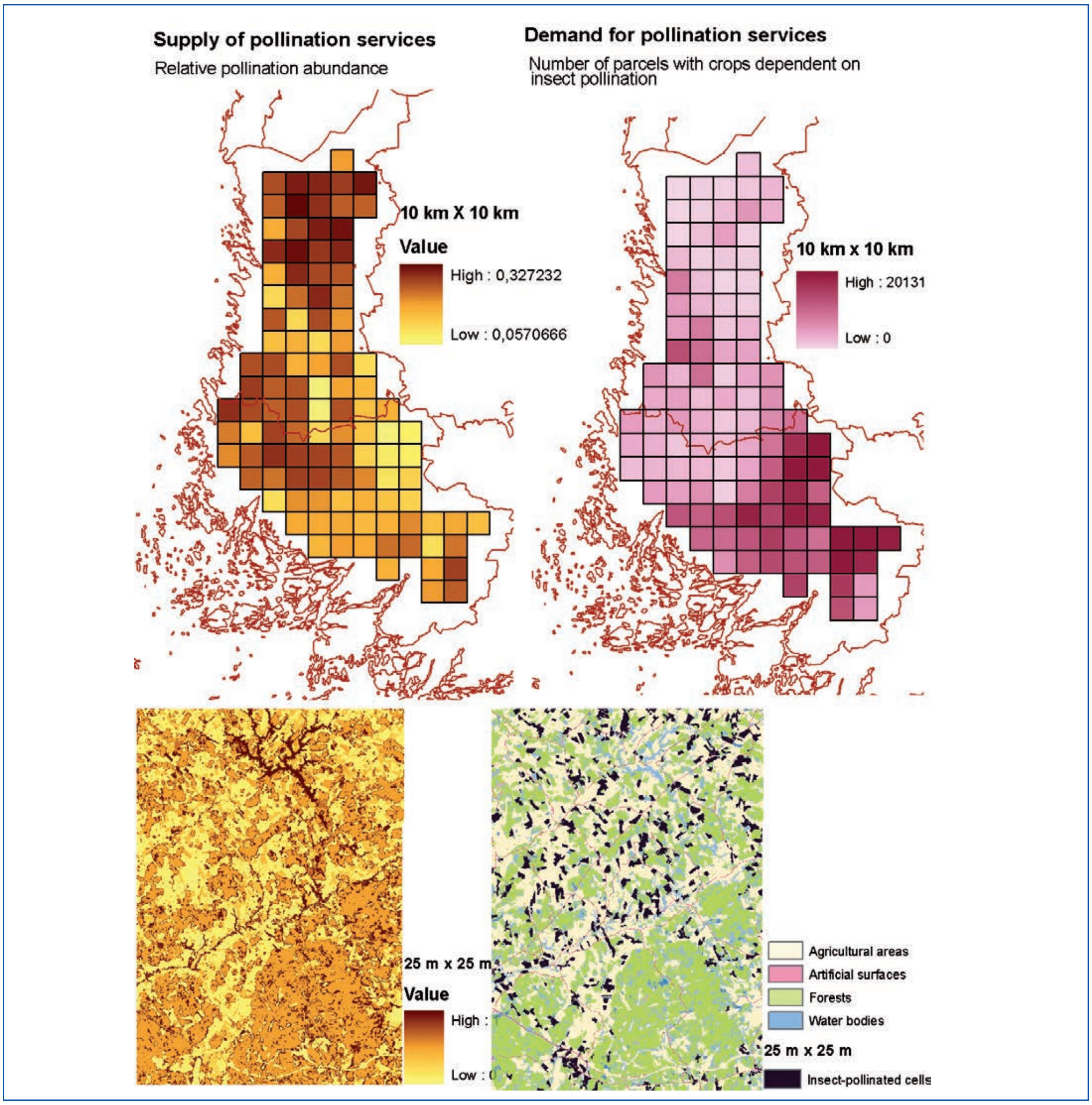


Figure 4.2. Finnish case study on pollination with maps showing the supply and demand

The case study shows that mapping pollination is very sensitive to scale. The Rekijoki river valley has the largest existing aggregation of species-rich semi-natural grasslands in Finland. It represents a nationally unique area with a high conservation priority and is a national pollinator insect hotspot with several threatened species. This is easily visible in the 25 m and 500 m grid maps. However, in the 10 km grid map this area receives a lower than average value in the availability of pollination services, because the areas surrounding the river valley are relatively intensively cultivated arable areas with generally a low pollination service level. This example highlights that, whereas the availability of pollination services for cultivated crops may be optimal in landscapes with relatively even distribution of suitable bumblebee habitat (in the northern areas of the Finnish case study area), this does not mean that these same landscapes would be best for conservation of pollinator insect diversity.

The UK case

The UK case study maps two sets of indicators for pollination services using empirical data of the richness of nectar-carrying plants, of insect-pollinated crops and of crop pollinator richness across the British landscape. A main result of the UK study is that much of the insect-pollinated crops grown in Great Britain are planted in the south and east of Britain, whereas their wild flower resources follow a tendency towards the south and west. More detailed analyses of single insect-pollinated crop species (oil-seed rape and field bean, Figure 4.3) or groups of ecologically similar species (fruit trees and berries) suggest that there is potential for spatial mismatches between crops and their wild pollinators at least in certain regions of the country.

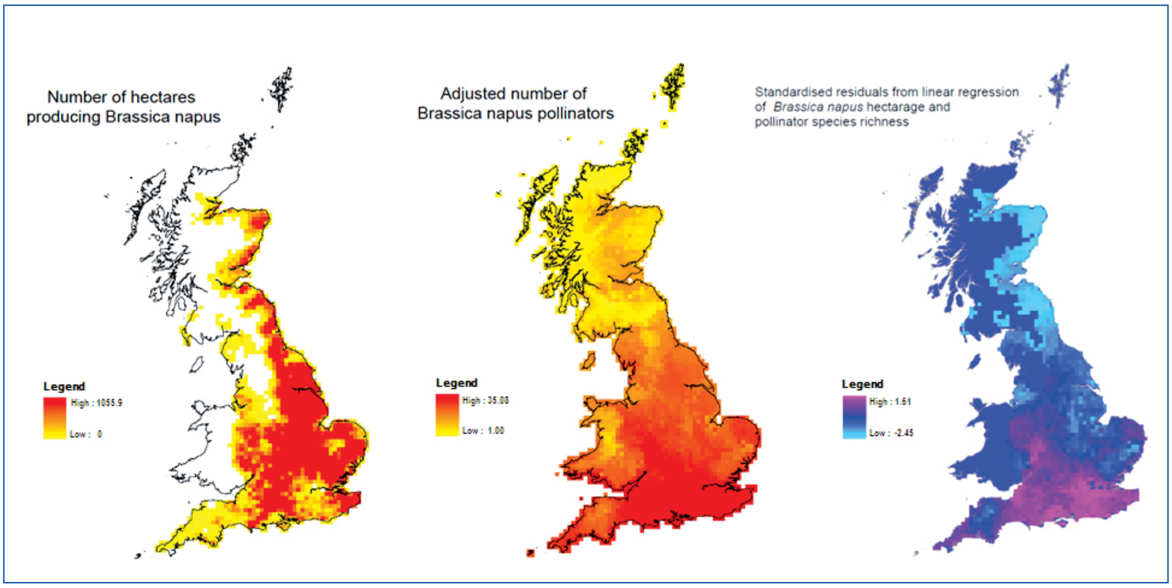


Figure 4.3. Distribution of oil seed rape crops, the species richness of its wild pollinators, and the potential for pollination mismatches. Pink shades indicate high overlap between crops and pollinator richness and light blue shades show low overlap. Dark blue indicates areas where no crops are grown.

A difference between the UK and European level case studies was that the UK study has produced a map on pollinator species richness (based on real species distribution data), whereas the European mapping has estimated relative pollinator abundance. While it seems reasonable that pollinator abundance is more important than species richness for the supply of effective pollination services, diverse pollinator communities may, however, provide a degree of redundancy or functional complementarity in the pollination system. Such diversity may therefore underpin service resilience in the face of environmental changes that extirpate species.

Stakeholder views

From interviews conducted as part of the policy analysis it became evident that the stakeholders at regional and local levels focused their attention more on managed bees instead of wild pollinators. However, it remains to be seen if the commercialization of pollination services creates more interest in wild pollinators. Most of the stakeholders, when asked about the drivers behind pollinator loss, quoted the market economy as a key driver. Perceptions were targeted at the socio-economic arena rather than ecologic drivers or pressures. On the other hand this is concordant with the fact that economic instruments, e.g. the agri-environment support, were seen as suitable tools for steering the situation. Market economy and economic instruments were seen to be the two most important determinants of crop cultivation and the measures and practices used.

The concept of ecosystem services was expressed to be useful by the stakeholders, but on the other hand it has opened up new questions about responsibilities and liabilities. Especially the relations between different policies and also the responsibilities of different stakeholders in the agricultural business need to be clarified and analysed. Many stakeholders hold the opinion that they don't lack any relevant information. Instead, the operationalization of the scientific information and development of good social practices were identified as key concerns. Based on the stakeholder interviews it can be concluded that, in addition to scientific knowledge and formal administrative tools, informal practices and codes of conduct are important aspects of pollinator conservation.

More attention should apparently be paid to investigating the role of informal institutions and practices. All of the interviewed people reacted positively to the maps which were shown during the discussions. The method of valuing the landscape from the perspective of pollinators seemed to raise the stakeholders' interest. Yet they were also critical and suspicious about the application of these kinds of maps (fear of bureaucracy or further control). Trust is a highly important issue when developing practices and measures at the local level. When discussing pollination in the context of land use planning in administration, the opinions did not give rise to optimism. Pollination as an ecosystem service takes place at smaller geographical scales than the current land use planning processes.

5. The impacts of EU policies on ecosystem services

Policy messages

Mapping, assessment and valuation of ecosystem services are necessary but not sufficient steps in achieving the ecosystem services targets of the EU Biodiversity Strategy. Following the TEEB procedure (TEEB 2010b), capturing the value for society requires a thorough understanding of the impacts of current policies on the ecosystems and more specifically on the mechanisms that determine the levels of the various ecosystem services. To know better means to be able to manage better, and possibly more cost-effectively. Therefore, in this last section of the PRESS-2 report, we discuss the state of knowledge and understanding of the effects of EU policies on ecosystem services.

A great number of EU policies influence ecosystems and the services they provide directly or via social and economic drivers of change, though many of them still do so mostly implicitly and unintentionally. International trade, agriculture, land use policies and nature conservation together create a complex and still only partly understood mixture of policies.

Including the ecosystem services concept into all social and economic policies would allow for a systematic review of the consequences of measures for services beyond conventional environmental assessments. It would also help in identifying and including services such as pollination, which are otherwise easily ignored.

Yet, even the most detailed literature review will not yield enough information to cover all synergies and trade-offs of measures, because they are also highly dependent on site-specific factors such as soils, climate, slopes and management history.

An important aspect in designing the implementation of the Biodiversity Strategy is that it is people at the local level that are often involved in actually implementing policy measures and sometimes have the most relevant knowledge.

However, even when local knowledge is included, this is no guarantee that policy measures achieve what it is being developed for. In order to be able to react and adapt to new circumstances consequences of policies must be continuously monitored and flexible in design. Therefore, it is necessary to quantify goals and determine baseline levels describing what the situation was before the measure against which progress is verifiable.

Introduction

The first phase of the PRESS study (Maes et al. 2011) revealed that many Ecosystem Services (ESS) are both targeted and affected by existing policies, even if ESS were not described explicitly as such. Examples are agricultural policies, water policies, forest policies, and of course biodiversity and conservation policies. However, Maes et al. (2011) also showed that the impacts of EU policies on ecosystem services in general need to be examined in some depth, as many of these policies represent complex frameworks, with multiple goals and measures that affect the services in different ways. This section provides a start of such an analysis from a twofold perspective.

The first perspective looks at the impact of a set of EU policies on ecosystem services and more precisely at some of the measures that the policies suggest. More precisly, the effect of green infrastructure on the provision of ESS is discussed. The green infrastructure approach advocated by the EU (European Environmental Agency (EEA) 2011) is not a measure as such, but rather a strategy on the policy level[1]. It is nevertheless included in the analysis on behalf of its relevance for biodiversity conservation and because the approach is closely linked to the other measures discussed in this chapter. These other measures comprise measures of new or future policies, namely the greening options of the future CAP, as well as wetland restoration, a measure considered for the Blueprint to Safeguard Europe's Water Resources[2]. The second perspective of our analysis provides insights into how a specific ecosystem service, pollination, is affected by different EU policies. Both analyses are based on literature reviews, which are not exhaustive.

Results

In Table 5.1 an overview is presented of the effects of policy measures which are part of the EU regulatory policies and frameworks. The scores are explained in the next few pages describing each of the policy columns. The table summarizes the results of a literature survey.

Table 5.1. Effect of policy measures on ecosystem services based on scientific literature.

Class of Eco-system Services	Ecosystem service	Green infrastructure in urban areas	Ecological set-aside/ ecological focus areas		Maintenance of permanent grassland		Crop rotation Diversi-fication	Wetland resto-ration
			Fallow land	Buffer strips	Intensive use	Extensive use		
P	Biomass for energy & biofuels		⇔	⇔	–	–		
P	Crop production		–	–		–	–	
P	Livestock				+	+		
P	Wild food (fish, berries, game, mushrooms)							+
R	Climate regulation	+	+		–	+	+	⇔
R	Regulation of water flows	+		+	–	+		+
R	Water purification	+	⇔	+	–	+	⇔	+
R	Air purification	+		+				
R	Soil fertility		⇔				+	
R	Erosion control and prevention		⇔	+				+
R	Pollination			+		+	+	
R	Pest control			⇔			+	
H	Habitat provision and connection	⇔	+	+		+	+	+
C	Recreation	+				+		+
C	Aesthetic information	+	⇔	+		+	+	+
C	Cultural & inspira-tional services	+		+		+		
	Additional trade-offs	Allergens Invasive alien species Energy for maintenance Low conservation opportunities	Bare soils in fallow land change the direction of the effects and increase erosion and leaching of pollutants			Extensive grasslands used for livestock production, have lowstocking densities		High recreation rate disturbs animal breeding and nesting

+: Policy measure is expected to enhance the provision of ecosystem services
–: Policy measure is expected to decrease the provision of ecosystem services
⇔: Policy measure is expected to result in positive, negative or neutral effect depending on particular management approaches

1 http://ec.europa.eu/environment/nature/ecosystems/index_en.htm.

2 http://ec.europa.eu/environment/water/blueprint/index_en.htm.

Green infrastructure

Green infrastructure can be defined as a strategically planned and delivered network of high quality green spaces and other environmental features[3]. Table 5.2 lists the elements that make up green infrastructure.

Table 5.2. Elements that make up green infrastructure (Mazza et al. 2011).

Green Infrastructure element (privately or publically owned):	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 (e.g. IUCN categories I, II and IV) or wilderness zones. All ecosystem types could be part of such core areas: woodland, rivers & riparian areas, lakes and ponds, wet- and peatlands, coastal and upland/mountain areas, heath- and grassland.
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 (e.g. multi-use forests and High Nature Value farming systems). Such areas help maintain the permeability of the land-/river-/townscape (i.e. enable species to exist in the wider landscape and move between core areas)
Green urban and peri-urban areas	Parks, gardens, urban forests, orchards, green walls, green roofs, sustainable urban drainage systems.
Natural connectivity features	Ecological corridors (containing landscape elements such as hedgerows, wildlife strips, stone walls), stepping stones (i.e. 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 (i.e. bridges that are covered by an appropriate habitat to encourage the movement of animals across them), tunnels and fish passes.

In the context of urban planning and urban ecology, there is a vast body of literature about the potential benefits of urban green space (or urban green infrastructure) designed to provide ecosystem services. Managers and planners in cities are increasingly concerned about climate change and resulting consequences such as flooding or extreme heat events. Biological carbon sequestration in urban tree cover and soils has been suggested as a potential tool for climate change mitigation. There is the direct removal of carbon dioxide from the atmosphere and the cooling effects of vegetation through shading and transpiration, thus may reduce energy use for air conditioning. Another service of urban tree cover is the improvement of air quality and thereby of human health as trees intercept the transport of air pollutants. The services of urban green infrastructure also include the regulation of urban water quality and quantity. The removal of pollutants by urban streams can be increased by adding coarse woody

3 http://ec.europa.eu/environment/nature/ecosystems/index_en.htm.

debris, constructing in-channel gravel beds, and increasing the width of vegetation buffer zones and tree cover. Vegetated landscapes such as green roofs and rain gardens can be used to reduce both the amount of urban stormwater runoff and its pollution load. Apart from these regulating services, there are a number of cultural services urban forests and parks provide e.g. outdoor recreation, nature observation, photography, boating, swimming and fishing. Most of these services come at a cost. Potential disservices listed are the increase of allergens, the promotion of invasive plants, host pathogens or pests.

Next to urban green infrastructure there is of course rural green infrastructure. According to the EEA (2011), agri-environment measures make a major contribution to green infrastructure. Measures discussed for the amendment of the Common Agricultural Policy (CAP) in 2013 could also help to support the green infrastructure approach and therefore contribute to sustainable ecosystem services provision.

Greening the CAP

The greening option in the CAP is characterized by greening of direct payments (Pillar 1), i.e. 30 % of direct support will be made conditional to "greening". This means that farmers must engage in environmentally supportive practices which will be defined in legislation and which will be verifiable. The impact will be to shift the agricultural sector in a more sustainable direction, with farmers receiving payments to deliver public goods (and services) to their fellow citizens (European Commission 2011c). Concrete measures discussed are ecological set-aside, buffer strips, the maintenance of permanent grassland and crop rotation/diversification.

Ecological set-aside/ecological focus areas

Ecological set-aside/ecological focus areas are a fixed percentage of the farm land put to an environmental use rather than agricultural production. The fallowing of land has been a traditional practice, but this set-aside decreased. It was re-introduced in 1988 as a voluntary and in 1992 as an obligatory supply control mechanism within EU agricultural regulations. While the primary aim of the policy was to control the supply of agricultural production, a wider role for set-aside in relation to environmental protection was recognized in the 2003 CAP reform.

Where set-aside land is allowed to naturally regenerate, a patchy habitat containing many broad-leaved plants develops and this has been shown to provide good breeding and feeding habitat for many birds. Crop stubbles and weed seeds benefit wintering birds. The other major form of management involves sowing it with a grass mixture. The resulting dense grassland is attractive to a variety of small mammals. Non-rotational set-aside generally develops a greater abundance of invertebrates than other in-field arable habitats, but access for birds may be constrained by the density of the vegetation. The main benefit set-aside has for water quality is the reduction of inputs of fertilizers or pesticides to farmland. Keeping an adequate soil cover is hence a key factor for retaining the beneficial effects of set-aside in this respect. Set-aside does also play a role in erosion control. There is lowering of the average soil erosion rate of the remaining arable fields when set-aside is introduced. This is due to the fact that farmers tend to take the steepest fields out of production. Some studies also see a positive effect in terms of climate change adaptation. In terms of cultural services, set-aside can be seen as introducing diversity into the landscape and improving its amenity value. It can also introduce colour into the landscape, for example through flowers (e.g. poppies) and butterflies in species-rich field margins or naturally regenerating wildflower grassland.

Buffer strips

Permanent vegetated buffers, including vegetative filter strips, riparian buffers, and grassed waterways, are installed in many areas to filter sediments from retained waters and deter sediment transport to water bodies and ground water. Along with reducing sediment transport, the filters also help trap sediment bound nutrients as well as pollutants such as pesticides. Apart from water purification, vegetative buffers can filter airstreams of particulates by removing dust, gas, and microbial constituents. When planted in strategic designs, shelterbelts can effectively mitigate odor. Buffer strips provide habitats and connect existing habitats to facilitate species migration. Vegetation along rivers provides habitat for a wide range of wildlife including woodpeckers, ducks, shorebirds and deer. However, while strips can serve as barriers to the movement of weeds and pests they also provide habitats for unwanted species and are a potential source of some crop pests. Apart from being habitat, filter strips can buffer hedges and other ecologically valuable habitats alongside fields from pesticide drift and fertilizers. Vegetated buffer strips surrounding cultivated fields decrease soil erosion. Depending on their appearance, buffer strips can also contribute to the recreational appeal of landscapes by breaking up monocultures or increasing the aesthetics of stream courses. As traditional features in some landscapes, field margins may have heritage values and give a sense of place or are used for recreation, e.g. by using them as jumps for horses during fox hunting or to enhance game bird populations. While all vegetation of buffer strips can potentially be used as raw material, agroforestry buffers are systems of land use especially planted for the production of harvestable trees or shrubs.

Maintenance of permanent grassland

Managed permanent grassland or permanent pasture (as opposed to natural, non-managed grasslands, terms usually used interchangeably, is according to the Commission Regulation (EC) No 1120/2009, art. 2(c) “land used to grow grasses or other herbaceous forage that has not been included in crop rotation of the holding for five years or longer.” The value of permanent pasture for the environment has long been recognized and this led to the introduction of a safeguard being put in place under the 2003 CAP Reform to encourage the maintenance of existing permanent pasture to avoid a massive conversion into arable land, given its positive environmental effect.

The services provided beyond animal production are dependent on the type of grassland and on its management. Extensively used grasslands are often associated with rare or traditional livestock breeds, which in turn are valued as providing aesthetic, cultural and historical benefits, as well as genetic resources for future breeding programmes. Further, extensively used grasslands are among the most species-rich habitats in Europe. Because of this they have the potential to enhance pollination services and hence primary production. Today, extensively used grasslands have a great value for recreation and tourism as people are attracted by the birds, diverse plant life and open-air landscapes of grasslands. Further, extensively used grasslands have contributed considerably to the development of ecological knowledge and are testing grounds for key ecological concepts. Conversion of arable land into pasture is very efficient in reducing nitrate leaching. Hay from extensive grasslands might also provide an alternative source of fuel. Grasslands store approximately 34% of the global stock of carbon but unlike trees, where above-ground vegetation is the primary source of carbon storage, most of the grassland carbon stocks are in the soil. However, whether grassland is rather a sink or a source depends again on its management. There are also some considerable trade-offs. Increasing demands for agricultural products and biofuels compete strongly with the maintenances of grasslands. Another trade-off can be found between livestock production and other ESS.

Crop rotation/diversification

Agricultural intensification and associated monocultures are known for their negative impact on a range of ESS. Crop rotation/diversification is thus considered as one measure for a more sustainable agriculture in the future. The European Commission (2011b) defines crop rotation as “*planned and ordered succession of different crops on the same field (usually lasting 3-5 years)*”. Under the greening option, three crops with the main crop not exceeding 70% of arable and open air horticulture area and the third not less than 5% are suggested. No specific crops can be required or excluded due to the rules of the WTO, but voluntary growth of leguminous crops should be encouraged. The fact that crops cannot be specified makes the assessment of impacts of crop rotation and diversification difficult as different crops have different effects on ESS.

Increased plant diversity can create biotic barriers against new pests by promoting natural enemy abundance. Overall, herbivore suppression, enemy enhancement, and crop damage suppression effects were significantly stronger on diversified crops than on crops with none or fewer associated plant species. Yet pest-suppressive diversification schemes can have a negative impact on production, in part due to reducing densities of the main crop by replacing it with intercrops or non-crop plants. Other advantages of crop rotation include the increase of wild pollinators, the accumulation of soil organic carbon and even the sequestration of atmospheric CO_2, maintaining and restoring soil fertility, leading to increased yields relative to monocultures and increased yield stability in nitrogen-limited environments without having to employ costly and water-polluting fertilizers. Another benefit that is derived from crop diversification relative to monocultures is the aesthetic value of the landscape.

Blueprint to Safeguard Europe's Water Resources

Although called green infrastructure this concept also has a blue component, which refers to the aquatic and wetland network (rivers and streams, canals, ponds, wetlands, etc.). One focus of the upcoming Blueprint to Safeguard Europe's Water Resources[4] will be on the acceleration of the implementation of water-related green infrastructure measures. One measure currently under evaluation in the context of the Blueprint is wetland restoration.

Since evidence is growing that rising investments in technical and structural measures have not been accompanied by reduced flood damages, alternative, 'softer' approaches, such as wetland restoration, are discussed and implemented. Wetlands can regulate water outputs from catchments by storing and slowing the flow of floodwaters, providing flood control and thus reducing the public cost of floods. In coastal areas, wetlands such as marshes and other flood plains can reduce coastal erosion and enhance coastal flood protection. The habitat qualities of wetlands attract high numbers of animals and animal species, many of which depend entirely on wetlands. Rivers and associated wetlands provide ecological connections. These do not only include a range of wildlife habitats but also support species dispersal and migration. Shallow depth, large surface area and high shoreline complexity are likely to provide a high biodiversity of birds, benthic invertebrates and macrophytes. As water passes through healthy wetlands, the wetlands function as traps for nutrients, and water is filtered and cleaned. Wetlands further contribute to groundwater recharge and thus play an important role in water supply, providing drinking water as well as water for industrial use and irrigation. There is also a growing understanding of the role of wetlands in sequestering carbon in long-lived pools and thus contributing to climate regulation. Wetlands are important tourism destinations because of their aesthetic value and the high diversity of the animal and plant life they contain. Yet, nature based recreation such as wildlife viewing, hiking, running, cycling, canoeing, horse riding and dog walking can have negative environmental effects, when proper management is missing and visitor numbers are too high and noisy, trails are left, litter is not removed, etc. Wetland ecosystems also provide a range of provisioning services. Fish and fishery products, berries or mushrooms can also be directly harvested from wetlands. While hunting in wetlands is in the developed world rather perceived to be a recreational service, the game can also be counted as provisioning service.

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4 http://ec.europa.eu/environment/water/blueprint/index_en.htm

Policy analysis of the pollination service

The International Risk Governance Council (IRGC[5]) "considers that, although pollination is a critical issue that is well acknowledged within the scientific community, it appears to be neglected and insufficiently appreciated by policymakers, industry (particularly the agricultural sector) and the general public. As a result, the IRGC believes that the threats to pollination services and related risks are not adequately taken into account, directly or indirectly, in policies and regulations that may affect pollinators and their habitats." (IRGC, 2009)

A way to identify the policies which have, may have, or should have significance for pollination, is to look at the work which has been done to identify the drivers behind pollinator loss. In research literature these drivers have been identified as: changing land use patterns, agro-chemicals, diseases, invasive species, climate change, fire, overgrazing and introduction of non-native plants. There are numerous policies which affect these drivers. Table 5.3 lists global as well as European policies and key regulatory frameworks at EU scale that affect pollination services by influencing the drivers behind pollination loss, showing that management of the pollination ecosystem service is indeed a complex, multilevel policy issue.

Table 5.3. Key regulatory frameworks that affect pollination services in Europe

Convention on Biological Diversity International Pollinator Initiative	Guidance for improving and developing policies and practices to enhance pollinator conservation and habitat restoration
The Common Agricultural Policy and rural development policies	Key policy that provides a suite of measures that may enhance (or decrease) wild pollination services
Nature directives (Habitats and Birds)	Protection of habitats that host pollinator populations, species conservation
EU Biodiversity Strategy 2020	Overall biodiversity is important for pollinators. Degradation of habitats is one of the drivers behind pollinator loss
Plant Protection Products Directive	Regulates pesticide use and thus of key importance for pollinators
IAS Strategy	Commission is currently working on a dedicated legislative instrument on Invasive Alien Species. This potentially mitigates pollinator loss
Climate change policy	Climate change has many negative effects on pollinators and pollination
Environmental Impact Assessment (EIA) Directive	EIA is an important tool for land use policies, while land use change is a driver of pollinator loss
Forest policies	Forest edges represent essential habitats for wild pollinators
Environmental Liability Directive	Prevent and restore damage to animals, plants, natural habitats and water resources, and damage affecting the land

The directives and regulations in Table 5.3 are considered the most directly relevant policy frameworks for pollination management. The table is elaborated in the next few pages.

5 The International Risk Governance Council (IRGC) is an independent organisation based in Switzerland whose purpose is to identify and propose recommendations for the governance of emerging global risks. To ensure the objectivity of its governance recommendations, the IRGC draws upon international scientific knowledge and expertise from both the public and private sectors in order to develop fact-based risk governance recommendations for policymakers, untainted by vested interests or political considerations.

Convention on Biological Diversity and International Pollinator Initiative

The Convention on Biological Diversity (CBD) has legitimised the global concern for pollinators through prioritising them in the Conservation and Sustainable use of Agricultural Biological Diversity programme in 1996. From the programme resulted an international pollinator workshop which in turn led to "The São Paulo Declaration on Pollinators". This declaration proposed an International Pollinator Initiative (IPI)[6]. The Food and Agriculture Organization (FAO) was invited to facilitate the initiative. A Plan of Action (POA) for the IPI was developed. It outlines guidance for improving and/or developing policies and practices to enhance pollinator conservation and habitat restoration.

European Pollinator Initiative (EPI)

The European Pollinator Initiative (EPI) was formed in 2000 and aims to protect and enhance the biodiversity and economic value of pollinators throughout Europe[7]. The EPI action plan, as well as other Initiatives' Action Plans, contains four elements: assessment, adaptive management, capacity building and mainstreaming. The EPI's main strategy is to integrate and co-ordinate local, national and international activities into a cohesive network to overcome the currently fragmented activities of scientists, end-users and stakeholders.

The Common Agricultural Policy (CAP)

While agriculture provides suitable habitats for many pollinators it can also have negative effects on them. Pollinators require habitats for both foraging for nectar and pollen as well as nesting. Farmland biodiversity has drastically declined in the past few decades due to agricultural intensification and a shift to large-scale monocultures has led to the loss and fragmentation of extensively used grasslands. In addition to this loss of habitats and therefore loss of foraging and nesting sites pollinators are negatively affected by fertilizers or other agro-chemicals use. The diversity of plant and plant production, which is of utmost importance for agricultural production, also depends on the abundance and diversity of pollinators. Agricultural land management has created a rich variety of landscapes and habitats over the centuries, including a mosaic of woodlands, wetlands, and extensive tracts of open country sides.

Even though pollination is not mentioned as one of the priority areas in the CAP, it may have positive effects on pollination through providing and sustaining pollinator-friendly environments and conditions. Pollinators or pollination are not mentioned explicitly and the effects of the measures on pollination turn out to be mixed. Agri-environment schemes are not designed at EU-level but at Member State or even regional levels and can differ widely among Member States. Evaluation of the impact thus becomes very challenging. The preservation of the remaining extensively used grasslands or re-creation of flower-rich grasslands is essential and can contribute greatly to sustain the abundance and diversity of insect pollinators. Knowledge gaps currently impede development of effective management plans that support pollination services and recommend research that combines multiyear, multiscale monitoring of bee abundance and pollination functions in response to habitat modification to restore pollination services in landscapes.

Habitats Directive

The European Habitats Directive (Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora) forms the cornerstone of Europe's nature conservation policy. Especially in

6 http://www.internationalpollinatorsinitiative.org/

7 http://www.europeanpollinatorinitiative.org/

Annex I of the Habitats Directive, several habitat types suitable for pollinators are listed, including some grasslands and wet meadows[8].

Rural development policies

Policies closely coupled to those mentioned so far are rural development policies, as they influence land use and thereby influence the pollination. The essential regulation for rural development on European level is the Council Regulation 1698/2005/EC to support rural development by the European Agricultural Fund for Rural Development (EAFRD).

Birds Directive

The Wild Birds Directive (79/409/EEC, see also 2009/47/EC) was adopted in 1979 and aims to protect and conserve wild bird species naturally occurring in the EU. It may also have a positive effect on pollinators as some bird species, such as hummingbirds, sunbirds, honeycreepers and some parrot species are important pollinators, too. According to the FAO (2008), on a global scale "26 species of hummingbirds, 7 species of sunbirds and 70 species of passerine birds – all of which are known to pollinate plants" are endangered. Many pollinators are also important food sources for higher animals and their loss may threaten predatory bird species (IRGC 2009).

Plant Protection Products Directive

The Plant Protection Products Directive (91/414/EEC) of 15 July 1991, concerning the release of plant protection products, regulates the sale of pesticides and herbicides within the EU. The directive aims to ensure that marketed products do not pose a threat to human, animal and environmental health. The Regulation 396/2005 on pesticide residues in food and feed is closely related. Both Directive 91/414 and Regulation 396/2005 aim at a high level of protection of human health and the environment. As pesticides are known to pose a risk to pollinators these EU policies are likely to benefit pollination, too.

Environmental Impact Assessment (EIA) Directive and rural development policies

The Environmental Impact Assessment (EIA) Directive (Directive 85/337/EEC) was introduced in 1985. The aim of this directive is to provide a high level of protection of the environment and to contribute to the integration of environmental considerations into the preparation of public or private projects before authorising their implementation. The EIA is an important tool for land use policies. As pointed out above, changes in land use have been identified as one of the drivers behind pollinator loss due to the accompanying loss of nesting and foraging sites. While land use policies and management are usually implemented more at the Member State than EU level, the EIA is one way to ensure sustainable land use development within the EU.

Forest policies

Another prominent land use within the EU is forestry. It can be assumed that European forests contribute to pollination services, although evidence is still restricted to tropical forests. While forestry policy mainly lies with each Member State there is a common EU forestry strategy, which is currently under review. While in a report from the workshop on the review of the EU forestry strategy (EC, 2011f) pollination

8 Council of the European Communities (1992). Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora. OJ L 206, 22/07/1992 P. 0007-0050.

is not mentioned explicitly, a general valuation and payment for non-wood products and services and ecosystem services is suggested.

Environmental Liability Directive

The Environmental Liability Directive (2004/35/EC), based on the "polluter pays principle", was adopted on 30 April 2004 and came into force on 30 April 2007. It establishes a common framework for liability, preventing and remedying damage to animals, plants, natural habitats and water resources, and damage affecting the land. It seeks to ensure that, in the future, environmental damage in the EU is prevented or remedied and that those who cause it are held responsible. This directive may be applicable, directly or indirectly, to loss of pollinators.

Other policies

The above mentioned directives and regulations are the most evident policy frameworks for pollination. However, there are other policy areas, which should also be considered even if the connection has not been empirically verified or is otherwise poorly known. For example, effects of climate change on pollination are highly debated, however, there is lack of empirical evidence about the connection. EU Regulations related to climate change might therefore also be relevant for pollination (EC 2011g). Since agricultural products are part of world economy, also EU trade policy has indirect links to pollinators through creating pressures (e.g. population growth and demand for food supplies), which in turn influence the direct drivers of pollinator loss, e.g. intensifying agriculture.

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PART 2. TECHNICAL REPORT

This part of the report represents the scientific material upon which the synthesis report is based. It reports in detail the different methodologies that have been used and provides all the background material for readers who prefer a more in-depth analysis of the PRESS results.

Chapter 7 includes a policy assessment. It examines how different policy measures affect the provision of ecosystem services. Chapters 8, 9 and 10 present the different case studies: water purification, recreation and pollination.

7. A qualitative analysis of the effect of EU policies on ecosystem services

7.1 Introduction

Many policies address ecosystem services implicitly, and policy makers are increasingly starting to include the concept of ecosystem services (ESS) in their guidelines and strategies directly. One example of this is the EU's Biodiversity Strategy to 2020, announced in May 2011, in which ESS are not only mentioned but are also linked to specific targets (European Commission 2011a), based on the ability of ecosystems to produce services, with biodiversity as a key functional element. The concept is increasingly being advocated in other policy fields too, such as sustainable land and water use, and climate change mitigation (TEEB 2010).

The first phase of the PRESS study (Maes et al. 2011) revealed that many ESS are both targeted at and impacted by existing policies, even if ESS were not mentioned explicitly as such (with the exception of a few conservation-related documents). Areas which seem to affect ESS are related to agricultural policies, water policies, forest policies, as well as biodiversity and conservation policies. However, the first PRESS study also revealed that the impact of policies on ESS has to be studied in depth, as many of these policies represent complex frameworks, with multiple goals and measures that affect ESS differently. This chapter provides a start for such an analysis from a twofold perspective.

The first perspective looks at the impact of policies on ESS and more precisely at some of the measures that the policies suggest. This becomes a very challenging task, when considering that for example the Common Agricultural Policy (CAP) or the Water Framework Directive (WFD) have a wide range of measures and even rely on measures of other policies such as the Nitrates Directive for their implementation. For analysis of this, the effect of green infrastructure on the provision of ESS is discussed. According to the European Commission: "*Green Infrastructure is a concept addressing the connectivity of ecosystems, their protection and the provision of ecosystem services, while also addressing mitigation and adaptation to climate change. It contributes to minimising natural disaster risks, by using ecosystem-based approaches for coastal protection through marshes/flood plain restoration rather than constructing dikes. Green Infrastructure helps to ensure the sustainable provision of ecosystem goods and services while increasing the resilience of ecosystems. The concept is central to the overall objective of ecosystem restoration, which is now part of the 2020 biodiversity target.*

Green infrastructure also promotes integrated spatial planning by identifying multi-functional zones and by incorporating habitat restoration measures and other connectivity elements into various land-use plans and policies, such as linking peri-urban and urban areas or in marine spatial planning policy. Its ultimate aim is to contribute to the development of a greener and more sustainable economy by investing in ecosystem-based approaches delivering multiple benefits in addition to technical solutions, and mitigating adverse effects of transport and energy infrastructure." [1]

1 http://ec.europa.eu/environment/water/blueprint/index_en.htm

The green infrastructure approach advocated by the EU[2] is not a measure as such, but rather a strategy on the policy level. It is nevertheless included in the analysis due to its relevance for biodiversity conservation and because the approach is closely linked to the other measures discussed in this chapter. These other measures comprise those included in new or future policies, namely the greening options of the future CAP, as well as wetland restoration, a measure considered for the Blueprint to Safeguard Europe's Water Resources[3] . The green infrastructure approach and the other measures are qualitatively assessed for their impact on various ESS's. The second perspective of our analysis provides insights into how a specific service, pollination, is affect by different policies.

Both analyses are based on literature reviews. However, owing to the broad range of topics, the literature review is not exhaustive but rather provides insights into the various fields. It was assumed that some of the topics covered, for example the reform of the CAP, are not yet well addressed by peer-reviewed journals. Though Web of Science (WoS) is the most recognised proprietary database for peer-reviewed journal content (e.g. Mikki 2009) it refers to peer-reviewed information. Google Scholar also refers to reports and other grey literature, such as the technical report from the European Environmental Agency (2011) on green infrastructure or the report from Hart and Baldock (2011) from the Institute for European Environmental Policy that looks at the greening option of the CAP. Therefore, Google Scholar was chosen over WoS. The search for literature for section 7.1 used the keywords 'ecosystem service' and the official name of the measure (e.g. ecosystem services and ecological set-aside or ecological focus areas). Some of these terms are rather new and in many cases these searches did not yield much information. However, although the term 'ecosystem services' is not always used, many individual services are well studied, such as erosion control or carbon sequestration. The same procedure was used for the agricultural measures. For example, the term ecological set-aside is rather new, but literature on the benefits and problems of set-aside, fallow or buffer strips are similarly well researched. While many possible combinations were searched, as pointed out above, the literature review was not exhaustive but rather provides insights. The search for literature for section 7.2 was a combination of policy documents and peer-reviewed articles on pollination. The aim was to identify those policies which directly or indirectly affect pollination. In this context a keyword search for the words 'pollination' or 'pollinators' within different policy documents would have not made much sense, as the topic and corresponding terms are not often mentioned yet. Instead the starting point for the literature review was to identify the different drivers behind pollinator loss based on scientific research. After this it was possible to identify the policies that have an effect on those drivers. Some policies were explicitly mentioned in the literature, some others needed a deeper and more implicit analysis. The analysis also relied on similar analyses between policies and pollination as starting points for further analyses (e.g. IRGC, 2009 and Byrne and Fitzpatrick, 2009).

The experiences from the two different perspectives are synthesised, allowing for some conclusions to be made about trade-offs between different policies as well as recommendations for a policy design that supports synergies and avoids trade-offs.

2 http://ec.europa.eu/environment/nature/ecosystems/index_en.htm.
3 http://ec.europa.eu/environment/nature/ecosystems/index_en.htm.

7.2 Specific policy measures affecting ecosystem services

7.2.1 Green infrastructure

According to the EU Biodiversity Strategy, based on scientific evidence many ecosystems and their services in the EU have been degraded, largely as a result of land fragmentation. Target 2 of the Strategy focuses on maintaining and enhancing ecosystem services and restoring degraded ecosystems by incorporating green infrastructure (European Commission 2011a). Table 7.1 presents elements that, according to Mazza et al. 2011), make up green infrastructure.

Table 7.1. Elements that make up green infrastructure (Mazza et al. 2011).

Green Infrastructure element (privately or publically owned)	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) or wilderness zones. All ecosystem types could be part of such core areas: woodland, rivers & riparian areas, lakes and ponds, wet- and peatlands, coastal and upland/mountain areas, heath- and grassland.
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 land-/river-/townscape (ie enable species to exist in the wider landscape and move between core areas)
Green urban and peri-urban areas	Parks, gardens, urban forests, orchards, green walls, green roofs, sustainable urban drainage systems.
Natural connectivity features	Ecological corridors (containing landscape elements such as 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 pass.

However, a number of problems have been identified intarget 2 of the Biodiversity Strategy, starting with the fact that the definition of green infrastructure, as provided in the introduction of this chapter, as well as connections between green infrastructure, biodiversity, and ecosystem service provisioning remain vague. However, the European Commission is working on the publication of a Green Paper on Green infrastructure, tackling this vaguenesses and the absence of a coherent implementation approach.

The following paragraph discusses the issues raised above and gives some examples on how green infrastructure supports the provision of ESS in urban areas. In subsequent parts of this chapter, potential measures of the new CAP (ecological set-aside and maintenance of permanent grassland) and the Blueprint to Safeguard Europe's Water Resources (wetland restoration) are discussed. Even though these measures are part of different policies, they also contribute to the restoration or conservation of green infrastructure.

While there are a number of studies funded by the EU on green infrastructure and its implementation[4], knowledge about the role of green infrastructure in the delivery of ecosystem services is still incomplete (Lawton et al. 2010). Therefore, a complete assessment of every element of green infrastructure would go beyond the scope of this report, as it would require not only extensive social but also natural science research. This also applies for the broad biodiversity–ecosystem services nexus which is not yet completely understood. However, in the context of urban planning and urban ecology, there is a vast body of literature about the potential benefits of urban green spaces or urban green infrastructure to provide ecosystem services (e.g. Sukopp 2008; Pataki et al. 2011). Examples are given for the following ESS:

- climate regulation (carbon (C) sequestration, direct removal of carbon dioxide, cooling through shading)
- air purification
- regulation of water flows
- water purification
- recreation
- aesthetic information
- cultural values and inspirational services

Zahran et al. (2008) found that managers and planners in cities are increasingly concerned about climate change and its consequences such as flooding or extreme heat events. Biological carbon (C) sequestration in urban tree cover and in soils has been suggested as a potential tool for climate change mitigation (McHale et al. 2007; Niemelä et al. 2010). Pataki et al. (2011) point out two further climate-regulating services. On the one hand there is the direct removal of carbon dioxide (CO2) from the atmosphere. On the other hand effects of vegetation on local cooling through shading and transpiration can be found, which decrease solar heat gain and thus, for example, reduce energy usage for air conditioning or even influence rainfall (Pataki et al. 2011). Another reason why municipalities are interested in increasing their urban tree cover is to improve air quality and human health as trees intercept the transport of air pollutants (Bowker et al. 2007; Pincetl 2010).

The services provided by urban green infrastructure and the ecosystems therein also include the regulation of urban water quality and quantity. In his study about urban streams in North America, Booth (2005) suggests that the removal of pollutants by urban streams can be increased by adding coarse woody debris, constructing in-channel gravel beds, and increasing the width of vegetation buffer zones and tree cover. Clausen (2007) and Shuster et al. (2008) suggest vegetated landscapes such as bioswales, green roofs, and rain gardens to reduce both the amount of urban stormwater runoff and its pollution load.

Apart from the regulating services, urban forests and parks provide a number of cultural services. Dwyer et al. (1991) identified some such services, including recreation, aesthetics, education, sense of place, religious value or cultural heritage. Recreational ecosystem services in particular have many facets as they provide possibilities for, for example, outdoor recreation, nature observation, photography, boating, swimming and fishing (Niemelä et al. 2010). Holbrook (2009) provides a comprehensive overview of the literature on the benefits of green infrastructure for urban-dwellers' physical, mental and social health.

4 http://ec.europa.eu/environment/nature/ecosystems/index_en.htm.

While the list of ecosystem services provided by green infrastructure in the urban context is even longer than the examples given above[5], some disservices or trade-offs have also to be mentioned. While the establishment and maintenance of urban green areas creates a lot of jobs, its management requires a lot of resources. Pataki et al. (2006) list for urban trees: the energy for planting, pruning, watering, fertilising, repairing sidewalks and road surfaces, and removing debris. Other potential disservices such as the increase of allergens, the promotion of invasive plants, host pathogens or pests are pointed out by Lyytimäki et al. (2008). A trade-off between the provision of recreational services and conservation arises when visitor numbers in nature conservation areas or national parks located in or close to urban regions are so high that the conservation goals of these areas are compromised (e.g. Sterl et al. 2008).

While the discussion so far deals with the urban context, a number of measures suggested to improve green infrastructure are or will be part of other policies targeted towards the rural context. One prominent example is the Common Agricultural Policy. According to the EEA (2011) agri-environment measures already make a major contribution to green infrastructure. Measures discussed for the amendment of the CAP in 2013 could also help to support the green infrastructure approach and therefore contribute to sustainable ecosystem services provision. Two of these measures, ecological set-aside and maintenance of permanent grassland, are discussed in the following section.

7.2.2 Greening the CAP

Discussions about the future of the EU Common Agricultural Policy were initiated by the Directorate General for Agriculture and Rural Development (DG AGRI) of the European Commission in April 2010 in the context of the preparation of the EU Multiannual Financial Framework (MFF) 2014-2020 (European Commission 2011b). The greening option is characterized by greening of direct payments (Pillar 1), i.e. 30 % of direct support will be made conditional on "greening". This means that all farmers must engage in environmentally supportive practices which will be defined in legislation and which will be verifiable. The impact will be to shift the agricultural sector significantly in a more sustainable direction, with farmers receiving payments to deliver public goods to their fellow citizens (European Commission 2011c) .

Concrete measures discussed under the greening option are ecological set-aside, also called ecological focus areas, the maintenance of permanent grassland areas and crop rotation/diversification.

7.2.2.1. Ecological set-aside/ecological focus areas

Ecological set-aside/ecological focus areas are a fixed percentage of the farmland put to an environmental use rather than agricultural production. According to Hart and Baldock (2011) the areas could include fallow land (land with no productive purpose), unploughed land, buffer strips, flower strips, beetle banks, skylark plots, grass margins, the maintenance of landscape features (including hedges, walls, terraces, ponds, groups of trees), and even permanent crops managed with no or minimal inputs.
In the following the measures (a) fallow land and (b) buffer strips are discussed separately concerning their impact on the provision of ESS.

a) Fallow land

The fallowing of land in arable rotations has been a traditional practice across Europe for much of its agrarian history. Rotating crops and leaving land uncropped has a range of agronomic benefits including weed control, disease prevention and improved soil fertility for future cropping (IEEP, 2008). Due to agricultural intensification, however, traditional set-aside has decreased. Set-aside was re-introduced in 1988 as a voluntary and in 1992 as an obligatory supply control mechanism within EU agricultural regulations. While the primary aim of the policy was to control the supply of agricultural production, a

5 http://ec.europa.eu/environment/nature/ecosystems/index_en.htm.

wider role for set-aside in relation to environmental protection was recognised in the 2003 CAP reform. The ESS affected by set-aside, tackled in this literature review, are:

- habitat provision and connection
- water purification
- soil fertility
- erosion control/prevention
- climate regulation (via carbon capture and storage in plants and soils)
- production of raw materials (biomass for energy and biofuels)
- aesthetic information

The effects of set-aside on ESS depend on a variety of factors (IEEP 2008; Vannini et al. 2008):

1) whether set-aside is rotational i.e. it forms part of a crop rotation and moves around a holding over time or whether it is non-rotational and remains in one place. For non-rotational set-aside the duration of the set-aside (short term, long term or permanent) is important.
2) whether set-aside remains bare or has a vegetation cover. Differences in environmental impact also arise from different vegetation covers, which can be for example natural regeneration, stubble or sown vegetation. The type of vegetation sown also makes a difference (e.g. legumes vs. oil seeds).
3) the way in which set-aside is managed e.g. if herbicides are used to control weeds or if vegetation is cut.
4) site-specific conditions (like area and steepness of slopes) and more generally the environmental and climatic conditions of the areas in which set-aside lands are located, including the kind of vegetation surround the fallow land.
5) the history of use and management of the area.

Clear benefits arise from naturally regenerated set-aside for breeding and feeding farmland birds. Where set-aside land is allowed to naturally regenerate, a patchy habitat containing many broad-leaved plants develops and this has been shown to provide good breeding and feeding habitat for many birds. Crop stubbles and weed seeds benefit wintering birds. The other major form of management for set-aside involves sowing it with a grass mixture. The resulting dense grassland is not ideal for the foraging of small birds, but is attractive to a variety of small mammals. Non-rotational set-aside generally develops a greater abundance of invertebrates than other in-field arable habitats, but access for birds may be constrained by the density of the vegetation (van Buskirk and Willi 2004; Silcock and Lovegrove 2007; Hodge et al. 2006; Vannini et al. 2008). For a more detailed analysis of the consequences of fallow set-aside for biodiversity see Hodge et al. (2006) and a meta-analysis of 127 published studies from van Buskirk and Willi (2004) quoted therein.

The main benefit set-aside brings to water quality is in the reduction of inputs, such as fertilisers or pesticides, to farmland and consequently reduced pollution from pesticides and fertilisers (Silcock and Lovegrove 2007; Kersebaum et al. 2003). Apart from this very simple fact, the effect of set-aside on water quality via leaching is again dependent on the factors mentioned above. Not surprisingly, Froment et al. (1999) found that uncovered, bare fallow and natural regeneration appear to increase leaching risk of nitrate as there is no root zone that can keep soil mineral nitrate. Keeping an adequate soil cover is hence a key factor for retaining the beneficial effects of set-aside in this respect (Tonitto et al. 2006). Sown crops can reduce leachable nitrate. This is especially true for so-called catch crops. Laurent and Ruelland (2011) analysed the capacity of Lopsided oat *(Avena strigosa)* to reduce nitrate loads. Lopsided oat is recognised in conservation agriculture for its rapid growth, its efficiency in limiting weeds and the fact it can be destroyed by rolling after freezing, i.e. it does not require herbicides. The authors found the efficiency of the crop to be high as it can reduce the nitrate load from 20% to 70%. However, the capacity to reduce nitrate loads depends on the type of crop or mix of crops adopted for the soil cover (Vannini et al. 2008). The effects of set-aside on the ecosystem service water purification have been analysed in chapter 3.

As pointed out above, set-aside was traditionally used to improve soil fertility. The positive impacts were associated with introducing certain plants as green cover to improve soil structure and improve soil organic matter (Oréade-Brèche 2002) (see also crop rotation/diversification above). Crop yields have been found to be higher following set-aside than after another crop (Silcock and Lovegrove 2007).

Set-aside, however, does not only play a role in improving soil fertility but also in erosion control. Van Rompaey et al. (2001) show that there is lowering of the average soil erosion rate of the remaining arable fields when set-aside is introduced. This is due to the fact that farmers tend to take the steepest fields out of production. Apart from the choice of fields taken out of production, soil protection depends largely on management and more precisely the presence and type of green cover (Vannini et al. 2008). The greatest erosion benefits are provided by non-rotational grass cover (Oréade-Brèche 2002). Bare soil is considered to have the highest negative effect on soil erosion (e.g. Bonan 2002).

Some studies also attest to the fact that set-aside has a positive effect in terms of climate change adaptation. Non-rotational set-aside, for example, is considered capable of helping species to adapt to climate change by providing connectivity of habitats within fragmented landscapes, i.e. green infrastructure, aiding species dispersal between isolated remnants of habitats (Silcock and Lovegrove 2007; IEEP 2008).

In terms of climate change mitigation set-aside plays a role in soil carbon sequestration i.e. the removal of atmospheric CO_2 by plants and the storage of fixed carbon as soil organic matter, which is increased by the conversion from conventional agriculture to land uses with high carbon inputs and low levels of disturbance, such as permanent set-aside (IEEP 2008).

Set-aside is currently also used for the production of non-food crops such as biofuels, biomass for energy production, pharmaceuticals and industrial lubricants (IEEP 2008). Silcock and Lovegrove (2007) found that nearly 6 million ha of set-aside in Europe is used for growing non-food crops and the majority of EU countries are increasing their use of set-aside for non-food crops. Thereby, the vast majority of industrial crops grown on set-aside are energy crops, in particular oilseed rape used for biodiesel and, to a lesser extent, short rotation coppice (SRC) and miscanthus (Silcock and Lovegrove 2007). However, Don et al. (2011) argue that, in the light of the high future demand for energy crops in Europe, second-generation crops such as SRC or miscanthus should be increased as they emit 40% to >99% less N_2O than conventional annual crops. This is a result of lower fertiliser requirements as well as a higher N-use efficiency, due to effective N-recycling (Don et al. 2011).

While at least second-generation crops are low input crops both in terms of fertilisers/pesticides and fossil-fuel-powered field operations (Silcock and Lovegrove 2007), they can have greater water requirements than the crops they are replacing (Berndes 2002). In practice, this means that drier regions are likely to be much less suitable for biomass production than wetter regions (Silcock and Lovegrove 2007). Another concern associated with biomass crops is their possibly adverse landscape impact. This relates to their height and unfamiliar appearance, but also landscape diversity may be reduced by producing extensive monocultures of energy crops (Robertson et al. 2008).

While Silcock and Lovegrove (2007) state that short rotation coppice are at least more beneficial for wildlife than the arable crops which are replaced, other authors show that in general the cultivation of energy crops is causing the loss of species (see for example Groom et al. 2007, Kovács-Hostyánszki et al. 2011).

In terms of cultural services, set-aside can be seen as introducing diversity into arable landscape and improving its amenity value. It can also introduce colour into landscape, for example through flowers (e.g. poppies) and butterflies in species-rich field margins or naturally regenerating wildflower grassland (Silcock and Lovegrove 2007). Yet, some citizens may feel that uncropped areas make the landscape look untidy and unattractive or disturb the more uniform appearance of the surrounding land. Overall, across Europe, the impact of set-aside on the landscape, concerning its aesthetic value, was assessed to be neutral (Oréade-Brèche 2002).

Comparing the relative merits of rotational and non-rotational set-aside as well as differences in cover crops is not straightforward and much depends on the environmental objectives being pursued (Baldock and Beaufoy, 1992).

b) Buffer strips

Vegetated buffers have many forms and sizes, their breadth ranging from 0.5 m to 50 m or more, for example floodplains. Vegetation also varies from natural, semi-natural to economic plants and includes grass strips, wildflower strips, strips sown to bird cover crops, unsown cultivated strips with naturally regenerated flora, sterile strips maintained by cultivation or herbicides, buffer strips, beetle banks (Marshall and Moonen 2002) and even trees (Kumar 2009; Udawatta et al. 2008). Their functions also vary widely and change over time. For example, field margins exist in the landscape because they have, or had in the past, real agricultural functions, such as hedges and walls, which were maintained to keep farm stock in or out. In arable land, field margins delineate the field edge and land ownership (Marshall and Moonen 2002). The ESS affected by buffer strips that addressed in this literature review are:

- regulation of water flows
- water purification
- air purification
- habitat services/ connecting services
- pest control
- pollination
- production of raw materials (biomass for energy and biofuels)
- erosion control/prevention
- aesthetic information
- recreation

Today, permanent vegetated buffers, including vegetative filter strips, riparian buffers, and grassed waterways, are installed in many areas to filter sediments from retained waters and deter sediment transport to water bodies and groundwater. Along with reducing sediment transport, the filters also help trap sediment-bound nutrients as well as pollutants such as pesticides (Marshall and Moonen 2002; Jose 2009; Tilman et al. 2002; Loomis et al. 2000; Laurent and Ruelland 2011). In their synthesis of 80 representative experiments, Liu et al. (2008) found that a 10 m buffer and a 9% slope optimised the sediment-trapping capability of vegetated buffers. The trapped pollutants are absorbed by the plants and broken down by plants and bacteria to less harmful substances. In an example from western France, Patty et al. (1997) showed that grassed buffer strips reduced nitrate flow by 47% to 100% at the agricultural parcel scale. Roadside buffer strips also filter run-off from city streets containing various pollutants or eroded soil (Loomis et al. 2000).

Apart from water purification, Jose (2009) found that vegetative buffers can filter airstreams of particulates by removing dust, gas, and microbial constituents. Tyndall and Colletti (2007) even suggest that when planted in strategic designs, shelterbelts could effectively mitigate odours.

Apart from their filtering function, buffer strips provide habitats and connect existing habitats to facilitate species migration (Rollett et al. 2008; Loomis et al. 2000; Marshall and Moonen 2002). Loomis et al. (2000) found that vegetation along rivers provides habitat for a wide range of wildlife including woodpeckers, ducks, shorebirds and deer. Trees and shrubs in floodplains offer shelter and areas for nesting and roosting of many bird species. In addition, the vegetation shades the stream, keeping the water cool for fish and reducing the algae growth that is detrimental to fish (Loomis et al., 2000). Marshall and Moonen (2002) found botanical diversity, particularly wild flowers and invertebrates, in margin strips. Buffer strips alongside cultivated fields also provide habitats for pollinators as well as pest predators and can also be managed to reduce inputs of weeds and other agricultural pests (Tilman et al. 2002; Marshall and Moonen 2002). However, while strips can serve as barriers to the movement of weeds and pests they also provide habitats for unwanted species and can be the sources of some crop pests (Marshall and Moonen 2002).

Apart from being habitat, filter strips can buffer hedges and other ecologically valuable habitats alongside fields from pesticide drift and fertilisers (Silcock and Lovegrove 2007; Marshall and Moonen 2002).

Another function of buffer strips is described by Kumar (2009) and Udawatta et al. (2008) with the example of agroforestry buffers. Agroforestry buffers are systems where land is used not only for the production of harvestable trees or shrubs grown among or around crops or on pastureland, but also to improve water and soil quality. Gopalakrishnan et al. (2009) also point out the use of riparian and roadway buffer strips to produce non-food products in the form of biomass for energy or biofuel production. Jose (2009) suggests that agroforestry practices also provide improved wildlife habitat by increasing structural and compositional plant diversity on the landscape. However, in all the above examples, the consequences of harvesting buffer strips for habitat services were not assessed and trade-offs cannot be excluded.

Vegetated buffer strips surrounding cultivated fields decrease soil erosion (Tilman et al. 2002; Rollett et al. 2008). Morschel et al. (2004) gave the example of south-west France, where large scale sediment deposition on roadways caused by intense spring and summer storms led to significant cleanup costs. Modelling the effects of grass strips on soil erosion rates suggests that buffer strips of 12 m or 24 m width reduce sediments deposition. Savings in the first year of planting are in the order of about 2% of current estimated cleanup costs for 12 m wide strips, and this amount increases to almost 35% in subsequent years for 24 m strips (Morschel et al. 2004).

Similar to wetlands, buffer strips are currently under evaluation in the context of the Blueprint to Safeguard Europe's Water Resources[6] amongst others for their benefits of natural water retention potential, i.e. the services buffer strips provide in terms of regulating water flows.

Depending on their appearance, buffer strips can also contribute to the recreational appeal of landscapes by breaking up monocultures or increasing the aesthetics of stream courses (Loomis et al. 2000). As traditional features in some landscapes, field margins may have heritage values and give a sense of place or are used for recreation, e.g. by using them as jumps for horses during fox hunting to enhance game bird populations (Marshall and Moonen 2002).

6 http://ec.europa.eu/environment/water/blueprint/index_en.htm

7.2.2.2. Maintenance of permanent grassland

The variety in types of grasslands across Europe is considerable, ranging from almost desertic types in south-east Spain through steppic and mesic types to humid grasslands/meadows, which dominate in the northern and north-western Europe (Silva et al. 2008). However, there is a commonly defined characteristic. Managed permanent grassland or permanent pasture (as opposed to natural, non-managed grasslands, a term usually used interchangeably, is according to the Commission Regulation (EC) No 1120/2009, art. 2(c) "land used to grow grasses or other herbaceous forage that has not been included in crop rotation of the holding for five years or longer." The value of permanent pasture for the environment has long been recognized and this led to the introduction of a safeguard being put in place under the 2003 CAP Reform to encourage the maintenance of existing permanent pasture to avoid a massive conversion into arable land, given its positive environmental effect (Hart and Baldock 2011). The rational for including the measure "maintenance of permanent grasslands" in Pillar 1 in the greening option is, that when the measure is tied to direct payments it should be more effective in terms of conservation than if the measure is voluntary. The following ESS are supported by the different types of grasslands:

- livestock production
- aesthetic information
- cultural values and inspirational services
- recreation
- habitat provision and connection
- pollination
- regulation of water flows
- water purification
- production of raw materials (biomass for energy and biofuels)
- Climate regulation

The wide extent of grassland in the UK (Bullock et al. 2011) and elsewhere in Europe (Silva et al. 2008) is the result of the expansion of this habitat by humans over the centuries to provide grazing and fodder for animal production meat, dairy products, wool, as well as horse keeping, e.g. for agricultural labor or transport. However, the services provided beyond animal production are not only dependent on the type of grassland but also on its management, which differs from extensively used grasslands to intensively used improved grasslands with re-sowing, fertilizing and high stock densities.

Extensively used grasslands are often associated with rare or traditional livestock breeds, which in turn are valued as providing aesthetic, cultural and historical benefits, as well as genetic resources for future breeding programmes (Bullock et al. 2011). Further, extensively used grasslands are among the most species rich habitats in Europe. WallisDeVries et al. (2002) for example found that calcareous (chalky) grasslands are Europe's most species-rich plant communities (up to 80 plant species/ m^2). The botanical value of sown cover on the other hand depends on the seed mixture and subsequent management, as well as the nature of the site (Silcock and Lovegrove 2007).

Because extensively used grasslands support more species and a greater abundance of animals (Cole et al. 2002) they have the potential to enhance pollination services (Bullock et al 2011) and hence increase primary production (Tilman et al. 1996, Hector et al. 1999, Balvanera et al 2006, Cardinale et al. 2012). Ockinger and Smith (2007) and Jauker et al. (2009) could even show that the abundance and species-richness of bees, butterflies or hoverflies in arable fields is related to the distance of the fields from extensively used grasslands (Bullock et al. 2011).

Extensively used grasslands are part of the cultural landscape and are remnants of thousands of years of farming practices all over Europe (e.g. Bullock et al. 2011; Silva et al. 2008; Biala et al. 2008). Further, especially extensively used grasslands are known to have positive effects on the chances of survival for archaeological features and the information they contain (Bullock et al. 2011). Today, extensively used grasslands have a great value for recreation and tourism as people are attracted by the birds, diverse plant life and open-air landscapes of grasslands (Silva et al. 2008). Bullock et al. (2011) also found that extensively used grasslands have probably contributed more than any other ecosystem to the development of the UK's ecological knowledge and are testing ground for key ecological concepts.

Information about the impact of permanent pasture on water quantity and quality is generally in relation to alternative land uses. Laurent and Ruelland (2011) compared several agricultural land uses and found that nitrate loads show the highest risk of leaching with maize, and the lowest with permanent pasture and temporary pasture. This confirms findings by Rode et al. (2009), who showed that conversion of arable land into pasture is very efficient in reducing nitrate leaching. Yet, at the example of south-west England, Jarvie et al. (2010) showed that concentrations of polluting nutrients derived from agriculture, such as nitrogen and phosphorous are higher in intensive livestock pastures than in low-intensity grassland.

In terms of regulation of water flows the management of grasslands makes an important difference, too. Intensive grazing and the resulting compaction of the soil causes decreased infiltration and increased runoff, which both increases the risk of flooding and reduces the recharging of aquifers (Weatherhead and Howden 2009).

Hay from extensively used grasslands might also provide an alternative source of fuel (Bullock et al. 2011). Tilman et al. (2006) for example showed that high diversity prairie grassland in the USA could produce reasonable biomass for fuel with low fertiliser inputs.

Grasslands store approximately 34% of the global stock of carbon but unlike trees, where above-ground vegetation is the primary source of carbon storage, most of the grassland carbon stocks are in the soil (Silva et al. 2008). However, whether grassland is rather a sink or a source depends again on its management. Areas converted from arable land and maintained under well managed permanent grassland, as pastures or rangelands, constitute potential C sinks (Conant et al. 2001). Soussana et al. (2010) describe a range of management practices to reduce C losses and increase C sequestration: (i) avoiding soil tillage and the conversion of grasslands to arable use, (ii) moderately intensifying nutrient-poor permanent grasslands, (iii) using light grazing instead of heavy grazing, (iv) increasing the duration of grass leys; (v) converting grass leys to grass-legume mixtures or to permanent grasslands.

While there are manifold benefits derived from permanent grasslands there are also some considerable trade-offs. Increasing demands for agricultural products and biofuels compete strongly with the maintenances of grasslands (Silva et al. 2008). Another trade-off can be found between livestock production and other ESS. Tallowin et al. (2005) showed in their study of a range of English lowland grasslands that the most intensive grasslands carried over three times the stocking rate of unfertilised extensively used grasslands. The management of grasslands for a higher production including inputs of inorganic fertilizers and the sowing of competitive grass varieties, which allows higher stocking densities or more frequent cutting of fields for silage. This management practice, however, causes decline in plant species richness and the replacement of plant species of conservation value with those typical of eutrophic, disturbed conditions. This replacement is further exacerbated by the use of herbicides (Bulllock et al. 2011; Mortimer 2011).

7.2.2.3. Crop rotation/diversification

Agricultural intensification and associated monocultures are known for their negative impact on a range of ESS (e.g. Power 2011). In order to address some of the negative consequences, crop rotation/

diversification is considered as one measure for a more sustainable agriculture in the future. The European Commission (2011b) defines crop rotation as "*planned and ordered succession of different crops on the same field (usually lasting 3-5 years)*". Under the greening option, three crops with the main crop not exceeding 70% of arable and open air horticulture area and the third not less than 5% is suggested. No specific crops can be required or excluded due to the rules of the WTO, but voluntary growth of leguminous crops should be encouraged. This fact, that crops cannot be specified, makes the assessment of impacts of crop rotation and diversification difficult as different crops have different effects on ESS. The ESS affected by crop rotation and diversification, tackled in this literature review, are:

- pest control
- pollination
- soil fertility
- climate regulation (sequestration of atmospheric CO2)
- aesthetic information
- water purification

Tilman et al. (2002) attest crop rotation a positive effect on maintaining and restoring soil fertility, leading to increased yields relative to monocultures (Smith et al. 2008) The inclusion of legumes and/or fibrous rooted crops in crop rotations (Altieri 1999) and species mixtures and with legume and non-legume combinations are techniques to increase yield stability in nitrogen-limited environments (Schlapfer and Schmid 1999), without having to employ costly and water polluting fertilizers (Hajjar et al. 2008).

Lin (2011) states that increased plant diversity can create biotic barriers against new pests by promoting natural enemy abundance. This finding is confirmed by the meta-analysis on 552 experiments in 45 articles published over the last ten years, accomplished by Letourneau et al. (2011). The authors found that increased crop diversity including intercropping schemes, inclusion of flowering plants, and use of plants that repel herbivores or attract them away from the crop reduce herbivores and/or increase the natural enemies of herbivores. Overall, herbivore suppression, enemy enhancement, and crop damage suppression effects were significantly stronger on diversified crops than on crops with none or fewer associated plant species (Letourneau et al. 2011). Yet, Letourneau et al. (2011) also found that pest-suppressive diversification schemes had a negative impact on production, in part due to reducing densities of the main crop by replacing it with intercrops or non-crop plants. Recent studies have suggested that farm-level diversification can especially contribute to natural pest control in cases were wider landscapes are structurally simple (Tscharntke et al. 2005). In complex landscapes, however, adding farm-level complexity does not necessarily enhance the benefits of pest control services (Power 2011).

Power (2011) points out other advantages of crop rotation; for example the benefits of crop rotation with mass-flowering crops are assumed to benefit wild pollinators.

West and Post (2002) found that optimizing agricultural management, including practices like crop rotation, can contribute positively to the accumulation of soil organic carbon and even to the sequestration of atmospheric CO_2.

Another benefit that is derived from crop diversification relative to monocultures is the aesthetic value of the landscape. Mattsson et al. (2000) for example found in investigations in Sweden that people prefer a varying landscape. Similar results were found on a regional level in Saxony, Germany and Satakunta, Finland where respondents of a survey pointed out their enjoyment of the beauty of structurally diverse cultural landscapes, which can be destroyed by large areas of monocultures (Maes et al. 2011).

The effects of crop rotation schemes on the ecosystem service water purification will be analysed in a quantitative analysis later in this report (see chapter 8).

7.2.3. Blueprint to Safeguard Europe's Water Resources

While green infrastructure includes a green component, which refers to natural and extensively used terrestrial environments, it also has a blue component, which refers to the aquatic and wetland network (rivers and streams, canals, ponds, wetlands, etc.). One focus of the upcoming Blueprint to Safeguard Europe's Water Resources[7] will be on the acceleration of the implementation of water-related green infrastructure measures. One measure currently under evaluation in the context of the Blueprint is wetland restoration. The following text qualitatively describes the following ESS wetlands provide:

- habitat provision and connection
- regulation of water flows
- water purification
- erosion control/prevention
- climate regulation (via carbon capture and storage in plants and soils)
- recreation
- aesthetic information
- wild food (fish, berries, mushrooms, game)

The presence of water, high plant productivity, and other habitat qualities of wetlands attracts high numbers of animals and animal species, many of which depend entirely on wetlands (Zedler and Kercher 2005). In their study about England's Wildlife Sites and Ecological Network, Lawton et al. (2010) found that rivers and associated wetlands provide ecological connections across England. These do not only include a range of wildlife habitats but also support species dispersal and migration. However, the term "wetland" encompasses a wide variety of habitats from coastal to freshwater ecosystems, and the services provided are dependent on specific habitat characteristics (Zedler and Kercher 2005).

Since evidence is growing that rising investments in technical and structural measures have not been accompanied by reduced flood damages alternative, 'softer' approaches, such as wetland restoration, are discussed and implemented (Wharton and Gilvear 2006)[8]. Wetlands can regulate water outputs from catchments by storing and slowing the flow of floodwaters (Zedler and Kercher 2005), providing flood control and thus reducing the public cost of floods (e.g. de Groot et al. 2002). In coastal areas, wetlands such as marshes and other flood plains can reduce coastal erosion. Further, Lawton et al. (2010) cite Empson et al. (1997) and Möller et al. (1999) who found that a significant part of low lying soft shorelines such as salt marsh and other coastal habitats play an economically critical role in coastal flood protection.

As water passes through healthy wetlands, the wetlands function as traps for nutrients, and water is filtered and cleaned (Lawton et al. 2010). The amounts of organic wastes from human activities that can be treated by wetlands and other aquatic ecosystems are relatively large (de Groot et al. 2002) (for more details see chapter 8).

However, Hansson et al. (2005) show that differing wetland features also have differing effects. Shallow depth, large surface area and high shoreline complexity are likely to provide a high biodiversity of birds, benthic invertebrates and macrophytes and to have high nitrogen retention, whereas a small, deep wetland is likely to be more efficient in phosphorus retention, but less valuable in terms of biodiversity. The ESS water purification provided by wetlands is analyzed quantitatively in chapter 8 of this report. Wetlands further contribute to groundwater recharge and thus play an important role in water supply, providing drinking water as well as water for industrial use and irrigation (MEA 2005).

7 http://ec.europa.eu/environment/water/blueprint/index_en.htm.

8 See also: http://ec.europa.eu/environment/water/flood_risk/better_options.htm..

There is also a growing understanding of the role of wetlands in sequestering carbon (C) in long-lived pools and thus contributing to climate regulation (Zedler and Kercher 2005). However, while wetlands are known to store vast quantities of C, especially in their soils, they can also be a significant source of CO_2 when their pristine status is disturbed (e.g. Mitra et al. 2005). To what degree wetlands function as net sinks or sources of greenhouse gases appears to depend on interactions involving the physical conditions in the soil, microbial processes, and vegetation characteristics (Smith et al. 2003).

In their meta-analysis about the economic values of natural and constructed wetlands Ghermandi et al. (2010) found that recreation in wetlands is a highly valued service. Wetlands are important tourism destinations because of their aesthetic value and the high diversity of the animal and plant life they contain (MEA 2005). Yet, nature based recreation such as wildlife viewing, hiking, running, cycling, canoeing, horse riding and dog walking can have negative environmental effects. In their review of the recreation ecology literature Steven et al. (2011) identified 69 papers from academic journals between 1978 and 2010 that examined the effect of recreational activities on birds. Sixty-one of the papers (88%) found negative impacts, including changes in bird physiology (all 11 papers dealing with this issue), immediate behavior (37 out of 41 papers), as well as changes in abundance (28 out of 33 papers) and reproductive success (28 out of 33 papers). This is a very typical trade-off, with a scale problem not easy to solve: the provision of recreational opportunities by an ecosystem will generally only benefit people in the immediate vicinity, whereas the existence of a high level of biodiversity may be valued by people at a much larger spatial scale (Brander et al. 2010).

Wetland ecosystems also provide a range of provisioning services. Coastal wetlands for example provide breeding and nursery areas to species which, as adults, are harvested elsewhere (de Groot et al. 2002). However, fish and fishery products, berries or mushrooms can also be directly harvested from wetlands (MEA 2005). While hunting in wetlands is in the developed world rather perceived to be a recreational service, the game can also be counted as provisioning service.

7.2.4 Discussion

The literature available, when using the keywords "green infrastructure" and "ecological set-aside" in combination with "ecosystem services" was not abundant. The breakdown of keywords into measures such as "fallow" or "buffer strips" and services, such as "erosion control" or "carbon sequestration", in turn, yielded an overwhelming number of peer-reviewed papers, books and other reports of which the most up-to-date ones where chosen for analysis.

In general the analysis showed that a number of ESS, which are supported by the measures are well described by literature. In the literature reviewed, the services found most to be supported by the policy measures were: water purification, aesthetic information, climate regulation and habitat provision and connection services as well as the regulation of water flows and recreation services. Erosion prevention, pollination and the production of raw material are supported by three of the measures explicitly according to the consulted literature. Air purification, cultural values and inspirational services, soil fertility and pest control were described for two measures.

In terms of trade-off and synergies Baldock and Beaufoy (1992) point out that much depends on objectives being pursued with a measure. For example, the measure to maintain permanent pasture can support different ESS, which are almost mutually exclusive. Depending on which definition of "permanent" is used the ESS supported are changing. A truly permanent (rarely, if ever, cultivated or re-seeded, never ploughed and more likely to consist of semi-natural vegetation) has great benefits to constrain soil carbon losses and is likely to have some impact on water quality and soil functionality and most importantly biodiversity (Hart and Baldock 2011). This kind of pasture, however, does allow only extensive livestock production. A more flexible definition of pasture, for example with frequent re-seeding of specific plants, would allow high stocking densities and even the production of raw materials. Especially high stocking densities can, however, endanger benefits for water quality and biodiversity. Trade-offs can also be found for other measures. ESS supported by crop rotation and fallows depend by and large on management and the plants chosen for cultivation. While some plants are good for soil fertility others are more beneficial for ground breeders, again other plants can be used as raw materials. Depending on the choice of plant and its management, synergies with other ESS will increase or decrease. Buffer strips too will not have the same benefits for valued species when harvested frequently for the production of raw materials and biomass for energy production.

These different possibilities raise the challenge of deciding, whose preferences count most, which also becomes apparent at the example of recreation. Many recreational opportunities benefit people in close vicinity. Recreation might, however, be disturbing for biodiversity which may be valued by people at a much larger spatial scale. So which preference should be given priority, especially when taking into account that the people in close vicinity might also be the people who are responsible for implementing policy measures (Prager et al. 2011). Often, the very same actors also have considerable knowledge of the bio-physical, economic and social context in which a measure is implemented.

7.3 Policy analysis and pollination

The International Risk Governance Council (IRGC[9]) "considers that, although pollination is a critical issue that is well acknowledged within the scientific community, it appears to be neglected and insufficiently appreciated by policymakers, industry (particularly the agricultural sector) and the general public. As a result, the IRGC believes that the threats to pollination services and related risks are not adequately taken into account, directly or indirectly, in policies and regulations that may affect pollinators and their habitats." (IRGC, 2009)

A way to identify the policies which have, may have, or should have significance for pollination, is to look at the work which has been done to identify the drivers behind pollinator loss. In research literature these drivers have been identified (e.g. Potts et al. 2010):

- changing land use patterns
- agro-chemicals
- diseases
- invasive species
- climate change
- fire and overgrazing
- introduction of invasive alien species

There are numerous policies which affect these drivers. It is safe to say that pollination is thus indeed a complex, multilevel policy issue. In the following the most important policies and initiatives from the global and European level that are either directly or indirectly related to pollinators are shortly described.

9 The International Risk Governance Council (IRGC) is an independent organisation based in Switzerland whose purpose is to identify and propose recommendations for the governance of emerging global risks. To ensure the objectivity of its governance recommendations, the IRGC draws upon international scientific knowledge and expertise from both the public and private sectors in order to develop fact-based risk governance recommendations for policymakers, untainted by vested interests or political considerations.

7.3.1 Global policies and initiatives

7.3.1.1. Convention on Biological Diversity and International Pollinator Initiative

The Convention on Biological Diversity (CBD) has legitimised the global concern for pollinators through prioritising them in the Conservation and Sustainable use of Agricultural Biological Diversity programme in 1996. From the program resulted an international pollinator workshop which in turn led to “The São Paulo Declaration on Pollinators”. This declaration proposed an International Pollinator Initiative (IPI)[10]. The Food and Agriculture Organization (FAO) was invited to facilitate the initiative. A Plan of Action (POA) for the IPI was developed. It outlines guidance for improving and/or developing policies and practices to enhance pollinator conservation and habitat restoration. The plan was accompanied by a book edited by Eardley et al. (2006), reflecting the plan’s main elements along with case studies, references, recommendations and best practices, to provide guidance for policy makers and conservationists (Byrne and Fitzpatrick, 2009).

The Global Pollination Project on “Conservation and Management of Pollinators for Sustainable Agriculture, through an Ecosystem Approach” is closely related to the IPI, aiming at harnessing the benefits of pollination services provided by wild biodiversity for human livelihoods and sustainable agriculture, through an ecosystem approach in selected countries. The project is coordinated by the FAO, with implementation support from the United Nations Environment Programme (UNEP)[11].

IPI-POA has further developed into a series of regional initiatives[12].

7.3.2 European policies and initiatives

7.3.2.1. European Pollinator Initiative (EPI)

The European Pollinator Initiative (EPI) was formed in 2000 and aims to protect and enhance the biodiversity and economic value of pollinators throughout Europe[13]. The EPI action plan, as well as other Initiatives’ Action Plans, entails 4 elements: assessment, adaptive management, capacity building and mainstreaming. The EPI’s main strategy is to integrate and co-ordinate local, national and international activities into a cohesive network to overcome the currently fragmented activities of scientists, end-users and stakeholders. EPI has an Interim Steering Committee with partners from Reading University (UK), Göttingen University (Germany), Aegean University (Greece), and Institut National de la Recherche Agronomique (INRA, France). This committee facilitates the development of the network. Also a number of regional contacts have been established to coordinate local interests and link them to regional activities. The EPI is supported by the EU FP7 projects ALARM and STEP.

7.3.2.2. EU projects ALARM and STEP

The ALARM[14] (Assessing LArge-scale Risks to biodiversity with tested Methods) project, running from 2004 to 2009 focused on the assessment and forecast of changes in biodiversity and in structure, function, and dynamics of ecosystems. In particular, risks arising from pollinator loss, climate change, environmental chemicals and biological invasions in the context of current and future European land-use patterns were assessed. The STEP[15] (Status and Trends of European Pollinators) project, which

10 http://www.internationalpollinatorsinitiative.org/jsp/globalpollproject.jsp
11 http://www.internationalpollinatorsinitiative.org/jsp/globalpollproject.jsp
12 http://www.cbd.int/agro/pollinator.shtml
13 http://www.europeanpollinatorinitiative.org/
14 http://www.alarmproject.net/alarm/
15 http://www.step-project.net/

started in 2010 will run until January 2015 and will document the nature and extent of the pollinator declines, examine functional traits associated with particular risk, develop a Red List of important European pollinator groups, in particular bees and lay the groundwork for future pollinator monitoring programmes. STEP will also assess the relative importance of potential drivers of such change, including climate change, habitat loss and fragmentation, agrichemicals, pathogens, alien species, light pollution, and their interactions. Furthermore, the project will measure the ecological and economic impacts on declining pollinator services and floral resources including effects on wild plant populations, crop production and human nutrition. It will review existing and potential mitigation options, providing novel tests of their effectiveness across Europe.

7.3.2.3. The Common Agriculture Policy (CAP)

While agriculture provides suitable habitats for many pollinators it can also have negative effects on them (ECPA, 2011). Pollinators require habitats for both foraging for nectar and pollen as well as nesting. However, farmland biodiversity has drastically declined in the past few decades due to agricultural intensification and a shift to large-scale monocultures has led to the loss and fragmentation of extensively used grasslands (Öckinger & Smith, 2007, IRGC 2009) and other non-crop habitats, such as field boundaries and woodland patches (Hietala-Koivu et al., 2004). In addition to this loss of habitats and therefore loss of foraging and nesting sites pollinators are negatively affected by fertilizer or other agro-chemical use (IRGC, 2009; Klein et al., 2007). The diversity of plant and plant production, which is of utmost importance for agricultural production in turn, also depends on the abundance and diversity of pollinators (Biesmeijer et al. 2006).

The multifaceted connections between farming practices and natural resources have been acknowledged by the European Commission (EC 2011d). Alongside the negative effects listed above positive connections can be found, too. Agricultural land management has created a rich variety of landscapes and habitats over the centuries, including a mosaic of woodlands, wetlands, and extensive tracts of open country sides. The rich variety of habitats facilitated the diversification of species including pollinators. However, as pointed out in the section 7.2, pollination is not the only ESS derived from these landscapes. The ecological integrity and the scenic value of landscapes make rural areas attractive for the establishment of enterprises, for places to live, and for the tourist and recreation businesses.

Taking these and other reasons into account the EU Common Agricultural Policy (CAP) has the goal to ensure that its regulations are compatible with environmental requirements and that CAP measures promote the development of agricultural practices preserving the environment and safeguarding the countryside. Three priority areas have been identified in the CAP to protect and enhance the EU's rural heritage (EC 2011d):

- Biodiversity and the preservation and development of 'natural' farming and forestry systems, and traditional agricultural landscapes;
- Water management and use;
- Climate change

Even though pollination is not mentioned as one of the priority areas in CAP, all of the three above-mentioned activity areas may have positive effects on pollination through providing and sustaining pollinator friendly environments and conditions.

In CAP the farmers are identified as key stakeholders in maintaining an environmentally friendly countryside (EC 2011d). There are at least two direct incentives targeted at farmers:

- payments are targeted at measures promoting environmentally sustainable farming practices (e.g. agri-environment measures);

- farmers with non-respect for the environmental laws are sanctioned through a reduction in support payments from the CAP.

The first above mentioned incentives are voluntary and aim to create a positive atmosphere for providing environmental services in farming (EC 2011e). Agri-environment measures are suggested as a key element for the integration of environmental concerns into the Common Agricultural Policy. Payments are provided to farmers when implementing the measures to compensate for additional costs arising from the implementation (e.g. due to reduced production). Agri-environment payments may only be made for actions farmers undertake above the reference level of mandatory requirements as currently defined by codes of “good farming practice” (GFP). Agri-environment payments are co-financed by the EU and the Member States (EC 2005).

Some of the agri-environmental measures of the CAP are (EC 2005):

- Environmentally favourable extensification of farming;
- Conversion of arable land to grassland and rotation measures;
- Management of low-intensity pasture systems;
- Set-aside
- Undersowing and cover crops
- Strips (e.g. farmed buffer strips)
- Integrated farm management and organic agriculture;
- Input reduction;
- Ensuring genetic diversity;
- Preservation of landscape and historical features such as hedgerows, ditches and woods;
- Conservation of high-value habitats; (and)
- Maintenance of existing sustainable and extensive systems.

The objectives of the measures are manifold and benefit a number of ESS. When going through literature related to agri-environmental measures (e.g. Cooper et al., 2009; Hart et al., 2011; EC, 2005) it is evident that conservation and sustainability of fauna and flora as well as biodiversity in general are mentioned as objectives of agri-environmental measures. Further, the quality of soil and water gain a lot of attention. Pollinators or pollination are not mentioned explicitly and the effects of the measures on pollination turn out to be mixed.

Agri-environment schemes are not designed at EU-level but at Member State or even regional levels and can differ widely among Member States. Evaluation of the impact thus becomes very challenging (ECPA, 2011). In Finland, all the farmers who have signed the contract for agri-environmental measures have to apply an array of basic measures. In addition they can also choose from a selection of voluntary special measures, e.g. management of traditional rural biotopes, management of other biodiversity habitats, organic farming and construction of wetlands. The research results of the Finnish MYTVAS project show that agri-environmental schemes in Finland have been much more significant for water purification than pollination. Further, in terms of biodiversity and pollinators the basic measures (e.g. field margins and buffer zones) had a low significance. The voluntary special measures were found to be more effective, especially the maintenance of traditional rural biotopes. The most urgent policy development in Finland is to ensure that the role of biodiversity conservation is integrated more strongly into the common agricultural practices. One way to ensure this is turning the effective, but not so often applied, special measures into a selection of mandatory measures (Kuussaari et al., 2008).

Rollett et al. (2008) suggest coordinated efforts and reward contributions to habitat heterogeneity and encourage appropriate foraging and nesting sites for pollinators. Measures that will promote this could include (Rollett et al. 2008):

- • Flower-rich field margins, set-aside and hedgerows to provide alternative foraging and nesting sites for pollinators;
- Low input and extensive systems;
- Reduced fragmentation of habitat through co-ordinated action at the landscape level;
- Reward for heterogeneity through co-ordinated action at the landscape level;
- Specific planting schemes to encourage specific pollinator species; and,
- Appropriate timing of management practices to avoid disturbance to pollinator habitat.

Öckinger and Smith (2007) found that especially the preservation of the remaining extensively used grasslands or re-creation of flower-rich grasslands is essential and can contribute greatly to sustain the abundance and diversity of insect pollinators. Kremen et al (2007) argue, however, that knowledge gaps currently impede development of effective management plans that support pollination services and recommend research that combines multiyear, multiscale monitoring of bee abundance and pollination function in response to habitat modification to restore pollination services in landscapes.

7.3.2.4. Habitats Directive

The European Habitats Directive (Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora) forms the cornerstone of Europe's nature conservation policy. It is built around two pillars: the Natura 2000 network of protected sites and the strict system of species protection[16]. The directive aims to protect approximately 1000 species and some 220 habitats and the Natura 2000 network has designated areas for species protection, and ideally, the establishment of monitoring programs to measure and ensure species protection (ECPA 2011). Especially in Annex I of the Habitats Directive, several habitat types suitable for pollinators are listed, including some grasslands and wet meadows[17]. The Habitats Directive also lists some butterfly species. However, their role in pollination is lower than for bees. Yet, if we consider biodiversity, the meaning of these 'supplementary species' should not be underestimated.

7.3.2.5. Rural development policies

Policies closely coupled to those mentioned so far are rural development policies, as they influence land use and thereby influence the pollination. The essential regulation for rural development on European level is the Council Regulation 1698/2005/EC to support rural development by the European Agricultural Fund for Rural Development (EAFRD). Examples of measures / projects eligible for funding include[18]:

- Payments to farmers to compensate for the cost incurred and forgone in managing Natura 2000 sites on their land;
- Support to private forest owners or forestry associations to cover the cost and income forgone resulting from restrictions aimed at safeguarding Natura 2000 sites;
- Agri-environment and forest environment payments to farmers / landowners;
- Encouraging of tourism activities through the provision of information centres, signposting and access to natural areas;
- Measures to raise environmental awareness.

16 http://ec.europa.eu/environment/nature/legislation/habitatsdirective/index_en.htm
17 Council of the European Communities (1992). Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora. OJ L 206, 22/07/1992 P. 0007-0050.
18 http://europa.eu/legislation_summaries/agriculture/general_framework/l60032_en.htm

7.3.2.6. IAS Invasive Alien Species Strategy

Invasive alien species (IAS) are recognised as one of the five pressures directly driving biodiversity loss (Shine et al. 2010). The Environment Council, the European Parliament, the Committee of the Regions and the European Economic and Social Committee have all stressed the need for an EU strategy on IAS and an effective early warning system and for effective response mechanisms at EU level (COM (2008) 789). In EU 2020 Biodiversity Strategy the combat against invasive alien species is one of the targets (EU 2011).

Invasive alien species are linked to pollination in several ways (European Commission 2009). First, alien pollinator species may disrupt pollination services due to competition with local bee species. Second, invasive alien plants may outcompete native plants und thus alter the foraging possibilities of bees. On the other hand, new pollinator species might also be welcomed by farmers, since new plants may require new kind of pollinators. Thus the question of invasive alien species needs to be studied in a framework which takes into account the challenges of climate change and adaptation. Third, there is the question of parasites on managed bees (European Crop Protection Association 2011). The parasitic mite Varroa destructor is an invasive alien species and was introduced to Europe by infested Asian honey bees that were imported during a research program. The mite damages bees by sucking hemolymph (a circulatory fluid) and by transmitting viral diseases. It is largely agreed in the pollinator research community that most current beekeeping problems are caused, directly or indirectly, by this parasite. The *Varroa* mite is the factor with the most pronounced economic impact on the beekeeping industry.

7.3.2.7. Climate change policy

The effects of climate change on pollination are poorly studied yet important issue. So far it has been shown that the most important effect of climate change is an increase in temperatures. Because insects and plants may react differently to changed temperatures it causes two kinds of mismatches in the plants-pollinator interaction: temporal and spatial mismatch. Mismatches may affect plants by reduced insect visitation and pollen deposition, while pollinators experience reduced food availability. Coope (1995) gives three possible scenarios for species' responses to large-scale climatic changes:

1. Adaptation to the new environment
2. Emigration to another suitable area
3. Extinction

The first response is unlikely, since the expected climate change will occur too rapidly for populations to adapt by genetic change (evolution). As temperatures increase and exceed species' thermal tolerance levels, the species' distributions are expected to shift towards the poles and higher altitudes (Deutsch et al. 2008; Hegland et al. 2009). On the other hand, wild pollinators might not be able to follow the movement of crops. Bees which are specialised are more likely to have difficulties whereas generalist species have more options to survive (Hoegh-Guldberg et al. 2008). This is a risk to biodiversity. It has also been shown that climate change together with habitat degradation and/or fragmentation cause severe problems to pollinators (Warren et al. 2001). Loss of pollinators is thus a problem where multiple drivers' mutual effects should be studied carefully. The European Climate Adaptation Platform (CLIMATE-ADAPT[19]) aims to support Europe in adapting to climate change. It is an initiative of the European Commission and helps users to access and share information on:

- Expected climate change in Europe
- Current and future vulnerability of regions and sectors
- National and transnational adaptation strategies
- Adaptation case studies and potential adaptation options
- Tools that support adaptation planning

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19 http://climate-adapt.eea.europa.eu/

7.3.2.8. Birds Directive

The Birds Directive (79/409/EEC, see also 2009/47/EC) was adopted in 1979 and aims to protect and conserve wild bird species naturally occurring in the EU. European Member States must conserve, maintain and restore the bird habitats by:

- Creating protection zones;
- Maintaining habitats;
- Restoring destroyed biotopes; (and)
- Creating biotopes

Birds do not have a significant role in pollination in Europe but still all these activities may also have a positive effect on pollinators as they increase biodiversity and possibly maintain pollinatorfriendly habitats. Globally some bird species, such as hummingbirds, sunbirds, honeycreepers and some parrot species are important pollinators, too. According to FAO (2008) on a global scale "26 species of hummingbirds, 7 species of sunbirds and 70 species of passerine birds – all of which are known to pollinate plants" are endangered. Many pollinators are also important food sources for higher animals and their loss may threaten predatory bird species (IRGC 2009).

7.3.2.9. Plant Protection Products Directive

The Plant Protection Products Directive (91/414/EEC) of 15 July 1991, concerning the release of plant protection products, regulates the sale of pesticides and herbicides within the EU. The directive aims to ensure that marketed products do not pose a threat to human, animal and environmental health. The Regulation 396/2005 on pesticide residues in food and feed is closely related. Both Directive 91/414 and Regulation 396/2005 aim at a high level of protection of human health and the environment. As pesticides are known to pose a risk to pollinators (ECPA 2011; Eardley et al. 2006; Kevan 1977; Johansen and Mayer 1990) these EU policies are likely to benefit the ESS pollination, too.

7.3.2.10. Environmental Impact Assessment (EIA) Directive and rural development policies

The Environmental Impact Assessment (EIA) Directive (Directive 85/337/EEC) was introduced in 1985. The aim of this directive is to provide a high level of protection of the environment and to contribute to the integration of environmental considerations into the preparation of public or private projects before authorising their implementation. Construction work and other interventions in the natural surroundings are considered as projects that fall within the scope of the Directive. More specifically, the EIA Directive identifies the need to assess the effects of a project on:

- Human beings, fauna and flora;
- Soil, water, air, climate and the landscape;
- The interaction between the factors mentioned in the first and second indents; and
- Material assets and the cultural heritage.

EIA is an important tool for land use policies. As pointed out above changes in land use have been identified as one of the drivers behind pollinator loss (Potts et al. 2010, FAO 2008) due to the accompanying loss of nesting and foraging sites. While land use policies and management are usually implemented more at the Member State than EU level, the EIA is one way to ensure sustainable land use development within EU.

7.3.2.11. Forest policies

Another prominent land use within the EU is forestry. A case study by Priess et al. (2007) on different land use scenarios in Sulawesi, Indonesia, showed that depending on the magnitude and location of ongoing forest conversion, pollination services are expected to decline continuously and thus directly reduce coffee yields by up to 18%, and net revenues per hectare up to 14% within the next two decades (compared to average yields of the year 2001). Currently, forests in the study area annually provide pollination services worth € 46 per hectare. However, simulations also revealed a potential win-win constellation, in which ecological and economic values can be preserved, if patches of forests (or other natural vegetation) are maintained in the agricultural landscape. Although the results from the case study in the tropics cannot be readily transferred to Europe as climate and other factors vary considerably it can be assumed that European forests also contribute to pollination services (MA 2005). While forestry policy mainly lies with each Member States there is a common EU forestry strategy, which is currently under review. While in a report from the workshop on the review of the EU forestry strategy (EC, 2011f) pollination is not mentioned explicitly, a general valuation and payment for non-wood products and services and ecosystem services is suggested.

7.3.2.12. Environmental Liability Directive

The Environmental Liability Directive (2004/35/EC), based on the "polluter pays principle", was adopted on 30 April 2004 and came into force on 30 April 2007. It establishes a common framework for liability, preventing and remedying damage to animals, plants, natural habitats and water resources, and damage affecting the land. It seeks to ensure that, in the future, environmental damage in the EU is prevented or remedied and that those who cause it are held responsible. This directive may be applicable, directly or indirectly, to loss of pollinators.

The above mentioned directives and regulations are the most evident policy frameworks for pollination. However, there are other policy areas, which should also be considered even if the connection has not been empirically verified or is otherwise poorly known. For example, effects of climate change on pollination are highly debated, however, there is lack of empirical evidence about the connection (Bartomeusa et al. 2011; Stein et al. 2009). EU Regulations related to climate change might therefore also be relevant for pollination (EC 2011g). Furthermore, environment is considered as one determinant for public health in the European Health Strategy. However, the European environment and health strategy of 11 June 2003 [COM(2003) 338] does not mention the pollinators or pollination explicitly. Yet, the connections between food security, agriculture and pollination are evident (FAO 2008). Since agricultural products are part of world economy, also EU trade policy has indirect links to pollinators through creating pressures (e.g. population growth and demand for food supplies), which in turn influence the direct drivers of pollinator loss, e.g. intensifying agriculture.

7.4 Synthesis and recommendations for policy design

A more exhaustive review or further research would likely reveal that the ESS found in the literature review in section 7.1 of this chapter could be found for the other measures considered in this report and the measures in turn also benefit services not described here. This is supported by section 7.2, which clearly shows that when looking at the pollination service a great number of policies can be found to be influential though not explicitly. Especially when looking at policies that influence the drivers of pollinator change and here especially land use change. However, international trade, agriculture, land use policies and nature conservation together create a complex mixture of policies which affect each other and ultimately also pollination and pollinators, which is poorly understood as yet.

A more rigorous, systematic review would also be necessary to provide detailed answers to the questions about synergies and trade-offs between services affected by measures, such as ecological set-aside or maintenance of permanent grassland. More importantly such a review could provide concrete starting points for well targeted research. More concrete research would for example be of utmost importance to understand intermediary services such as pollination, where benefits are not directly measurable, but literature suggests that these services might be of great importance. Further, both literature review and further research would be necessary also to improve the understanding of the connections between biodiversity and the provision of ecosystem services (Bradlay et al. 2012, Naeem et al. 2012).

Including the ecosystem services concept into policies would allow a systematic review of the consequences of measures for services beyond conventional environmental assessments. It would also help in identifying and including services such as pollination, which are otherwise easily ignored.

Yet, even the most detailed literature review will not yield enough information to cover synergies and trade-offs of measures when taking into account the fact that they are also highly dependent on site-specific factors such as soils, climate, slopes but also management history. In terms of biodiversity conservation the species valued are also highly place-specific as their habitat requirements vary considerably.

The fact that synergies and trade-offs vary and much information is needed poses a well-known problem for policy makers, namely the problem of making decisions on the basis of incomplete information or more simply making decisions under uncertainty. This problem is amplified by the fact, that even if all services could be quantified and all synergies and trade-offs assessed, the preference of one service over the other would still cause the challenge of whose preferences count. As people from the local level are those who are actually implementing policy measures and often have considerable knowledge it is necessary to design policies which include their views into decision-making.

The authors agree with the EEA (2011) that the integration of such an approach into existing policies, more specifically here into the CAP, is possible and could be beneficial for biodiversity conservation. Especially the ecological set-aside and the permanent parts therein, like buffer strips could enhance species migration in the wider landscape and therefore provide the opportunities for species to adapt to climate change. However, knowledge of local conservationists or farmers about occurrence of a valued species, their abundance and behaviour could help to make a decision about how to design ecological set-aside in order to achieve the highest impact, not only for conservation. Species, however, do not realign their migration patterns along farm boundaries. Therefore, the next higher levels of decision making are of great importance too. Landscape planners have to develop meaningful concepts for Green Infrastructure in cooperation with local actors. Another option is proposed by the European Commission (EC 2011h) in the context of the CAP reform, namely the encouragement, via compensation, of collective contracts or collaboration between farmers. These contracts are meant for environmental projects and ongoing environmental practices such as the collective installation of landscape elements to cover larger adjacent areas.

However, even when local knowledge is included, this is no guaranty, that measures or the Green Infrastructure approach achieve what they were designed for. Successful implementation depends on an unknown number of complexly coupled factors, ranging from impacts of climate change to global markets and social and cultural perceptions. . In order to be able to react and adapt to new circumstances consequences of policies must be continuously monitored and flexible in design. Therefore, it is necessary to quantify goals and determine baseline levels describing what the situation was before the measure against which progress is verifiable.

8. Mapping and assessment of water purification services at multiple spatial scales

8.1 Introduction

Water purification is an important ecosystem service. Ecosystems, in particular lakes, rivers and floodplains, have the capacity to retain, process and remove pollutants, sediments and excess nutrients. This avoids pollution of downstream waters and more importantly, it contributes to the provision of clean water for multiples uses.

In this study nitrogen (N) serves as a common water quality metric. Excessive nitrogen loading is a leading cause of water pollution (Cardinale 2011; Grizzetti et al. 2011; Sutton et al. 2011), mainly as a result of artificial fertiliser application and through the combustion of fossil fuels. The excess nitrogen runs in rivers, streams, lakes and further downstream in estuaries and coastal zones causing eutrophication (Billen et al. 2011; Grizzetti et al. 2011). In the European Union, specific policies are put in place to control the input of nitrogen to river basins: the Nitrates Directive is designed to protect the EU's waters against nitrates from agricultural sources and the Water Framework Directive aims at good water quality and good ecological status by 2015.

Recently, over 200 researchers combined their knowledge in the first European Nitrogen Assessment (ENA) providing a comprehensive overview of current nitrogen issues, the cascade effects and the interactions and feedbacks (Sutton et al. 2011). Nitrogen is brought into watersheds from atmospheric deposition, crop fixation and the use of fertilizers, as well as by the import of food and feed. A large scale nitrogen budget shows that only 22% of the net anthropogenic nitrogen input to European river basins is exported to the European seas indicating that substantial retention of nitrogen occurs within river basins (Billen et al. 2011). Most of this nitrogen is retained in soils and groundwater but river systems are also important sinks for nitrogen (Mulholland et al 2008). The main pathways of nitrogen delivery to the river network are direct inputs via point sources and the leaching of nitrogen that is not retained in soils and aquifers (Durand et al. 2011). River systems remove dissolved nitrogen from the surface water by plant uptake, sedimentation and denitrification, hereafter collectively called nitrogen retention. Grizzetti et al. (2007) estimated that between 7 and 27% of nitrogen entering the river network of several European river basins is retained and higher values are reported for Baltic basins (Lepistö et al. 2006).

Nitrogen loading is a key pressure to ecosystems. While enhanced N fixation has undeniable societal benefits, N is also a powerful environmental pollutant. The intensification of N release to the environment has resulted in important and growing effects on human and ecological health (Table 8.1; Johnson et al. 2010), affecting essential ecosystem services such as the provision of clean air and water, recreation, fisheries, forest products, aesthetics and biodiversity (Compton et al. 2011). Table 8.1 identifies the tradeoffs that arise between different ecosystem services and biodiversity resulting from nitrogen loading and the challenge for policy and river basin management is to find an optimal balance. Figure 8.1 shows the resulting impact of N loading on various ecosystem services.

Table 8.1. Ecosystem services and human benefits affected by increasing nitrogen (Compton et al. 2011)

Ecosystem Service	Impact on benefit	Mechanism of impact
Production of food and materials	+	Increased production and nutritional quality of food crops
	+	Increased production of building materials and fibre for clothing or paper
	-	Stimulation of ozone formation, which in turn can reduce agricultural and wood production
	-	Soil acidification, nutrient imbalances and altered species composition and diversity in forests and other natural ecosystems, which ultimately impact stability and resistance to disease, invasive species and fire
Fuel production	+	Increased use of fossil fuels to improve human health and wellbeing across the globe
	+/-	Increased N inputs required for some biofuel crops can affect other services
Clean air	-	NOx-driven increases in ozone and particulates exacerbate respiratory and cardiac conditions
	-	Increased allergenic pollen production
Drinking water	-	Increased nitrate concentrations lead to blue-baby syndrome, certain cancers
	-	Increased acidification and mobility of heavy metals and aluminum
Swimming	-	Stimulation of harmful algal blooms that release neurotoxins (interaction with phosphorus)
	-	Increased vector-borne diseases such as West Nile virus, malaria and cholera
Fishing	+	Increased fish production and catch for some very N-limited coastal waters
	-	Increased hypoxia and harmful algal blooms in coastal zones, closing fish and shellfish harvests
	-	Reduced number and species of recreational fisheries from acidification and eutrophication
Hiking	-	Altered biodiversity, health and stability of natural ecosystems
Climate regulation	+/-	Variable and system-dependent impacts on net CO_2 exchange
	-	Stimulation of N_2O production, a powerful greenhouse gas
UV regulation	-	Increased N_2O release, which has strong ozone-depleting potential
Visibility	-	Increased NO_x in air stimulates formation of particulates, smog and regional haze
Cultural and spiritual values	-	Altered biodiversity, food webs, habitat and species composition of natural ecosystems
	-	Damage to buildings and structures from acids
	+/-	Long range trans-boundary N transport and associated effects (both negative and positive)

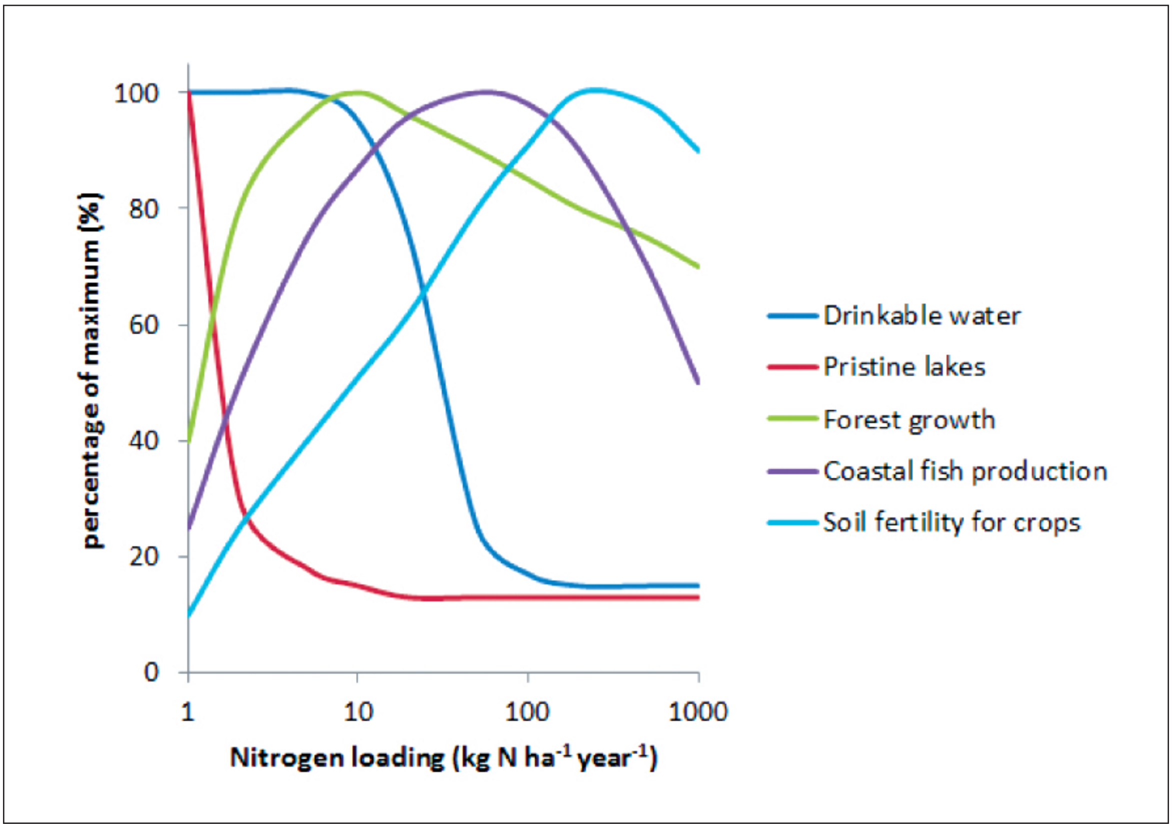


Figure 8.1. Ecosystem service production functions as function of nitrogen loading (Compton et al. 2011)

In this study, we present the building blocks for assessing how benefits from water purification services can be accounted for. In the first phase of the PRESS study (Maes et al. 2011), a biophysical modeling approach was developed which will serve as a solid basis for the valuation of this service and for scenario assessment studies. We estimated the contribution of rivers, streams and lakes to purifying water through the removal of nutrient pollutants from runoff water. The methodology was based on models that calculate a nitrogen budget within the boundaries of watersheds, catchments or river basins. This ecosystem service was mapped at three spatial scales: the Yorkshire Ouse catchment (UK), the German Elbe river basin and the European continent including all river basins that drain into European seas. Rivers, streams and lakes were shown to have an important function in nitrogen removal. The European river and stream network was estimated to remove 1.5 million ton of nitrogen from surface waters. Where this service results in a relatively small improvement of the water quality, on average, benefits increase in downstream direction and in-stream retention results in a 50% reduction of the nitrogen concentration.

This study extends the above mentioned approach with a monetary valuation and an analysis of scenarios. These scenarios involve land use and land management decisions which influence the amount of nitrogen which runs off to surface waters or which percolates to the ground water. We focus in particular on agricultural land use as well as on restoration of aquatic habitats. The assessment is carried out at different spatial scales ranging from small catchments in Finland to larger basins in Denmark and the UK (Table 8.2, Figure 8.2). These studies are complemented by a European-wide assessment.

Table 8.2. Description of the study sites.

Finland. Two well monitored catchments were selected as case study areas in Finland. Lepsämänjoki catchment (214 km^2) is a sub-basin of the Vantaanjoki river basin in southern Finland. River Lepsämänjoki is meandering slowly through cropland while a tributary collects waters from forested upland covered by lakes. The length of the main branch of the river Lepsämänjoki is 33.5 km. The main river is also prone to floods, especially during snow melting in spring. Soil types in the catchment are clay and rocky soils. Crops, mainly spring cereals, cover 23% of the area, the rest being forest. Yläneenjoki catchment (233 km^2) is located in upper reaches of the Eurajoki basin in southwestern Finland. The river Yläneenjoki is 33 km long and it discharges to the lake Pyhäjärvi. There are several small rapids in the river Yläneenjoki. Water retention is therefore increased by dams in the river and several small wetlands in the surrounding areas. Main soil types are clay and till, but there are also some silt and organic soil types. Crops (mainly spring cereals) cover 25% of the catchment area. In 2005 animal density was 0.53 ha^{-1}. In both catchments nutrient loading to the river origins mainly from agriculture, though there are also households which are not connected to the municipal waste water treatment system. The river Lepsämänjoki is estimated to achieve good ecological condition by 2021 and the river Yläneenjoki by 2027.
UK. The Yorkshire Ouse catchment encompasses a diverse range of environmental characteristics ranging from grazed uplands with high rainfall in the upper catchment areas to the west, to lowland arable and urban areas with lower rainfall in the east. Overall 31% of the catchment area is arable and 44% agricultural grassland. Upstream of the more urbanised lower reaches (near York and Harrogate) the Ouse catchment is largely rural and includes the Swale, Ure and Nidd tributaries, showing a climatic range (mean annual rainfall 913 mm, but varying from <650 to >2200 mm), a wide diversity of agricultural and other land uses, and varied urban coverage. According to CEH QUESTOR modelling studies, during 1996-2004, good chemical status was achieved throughout the Ouse for dissolved oxygen, biological oxygen demand and ammonium, although for soluble reactive phosphorus, only parts of the Swale and Ure were compliant. For nitrate, all reaches are classified as moderately low or better, which complies with the EC Nitrates Directive legislation. In terms of biology, current classification based on macro-invertebrates reveals all reaches to be fairly good quality or better, many being in the highest class. Using existing standards, the Yorkshire Ouse is a largely clean river network.
Denmark. The Odense Fjord catchment is located on the Danish island of Funen (242 000 citizens). . The size of the catchment is 1046 km^2 which includes the major urban area of Odense but is otherwise mostly rural. The aquatic environment in the catchment includes a significant number of aquifers and surface water bodies of rivers and lakes in addition to the fjord itself. The amount of open water courses in the catchment is approximately 1100 km and about 2600 lakes and ponds. The Odense Fjord in itself has an area of approximately 65 km^2. Large parts of the fjord are shallow. The water bodies are subject to varying degrees of environmental pressure, in particular nutrient losses from agriculture. Environmental improvement targets to reach good environmental status in the fjord have mainly been formulated in terms of reduction of nitrogen loads into the Fjord. Improvement in the ecological status of the lakes however has mainly been defined in terms of reductions in phosphorus. There are 2270 farms operating in the area comprising both pure horticulture and animal husbandry ranging from very small farms of less than 1 hectare to large commercial farms. The average farm size in the catchment is 50 hectares.
Europe. The European case considers all river basins that discharge into European seas. These river basins are subdivided into almost 31 thousand catchments with an average size of 180 km^2.

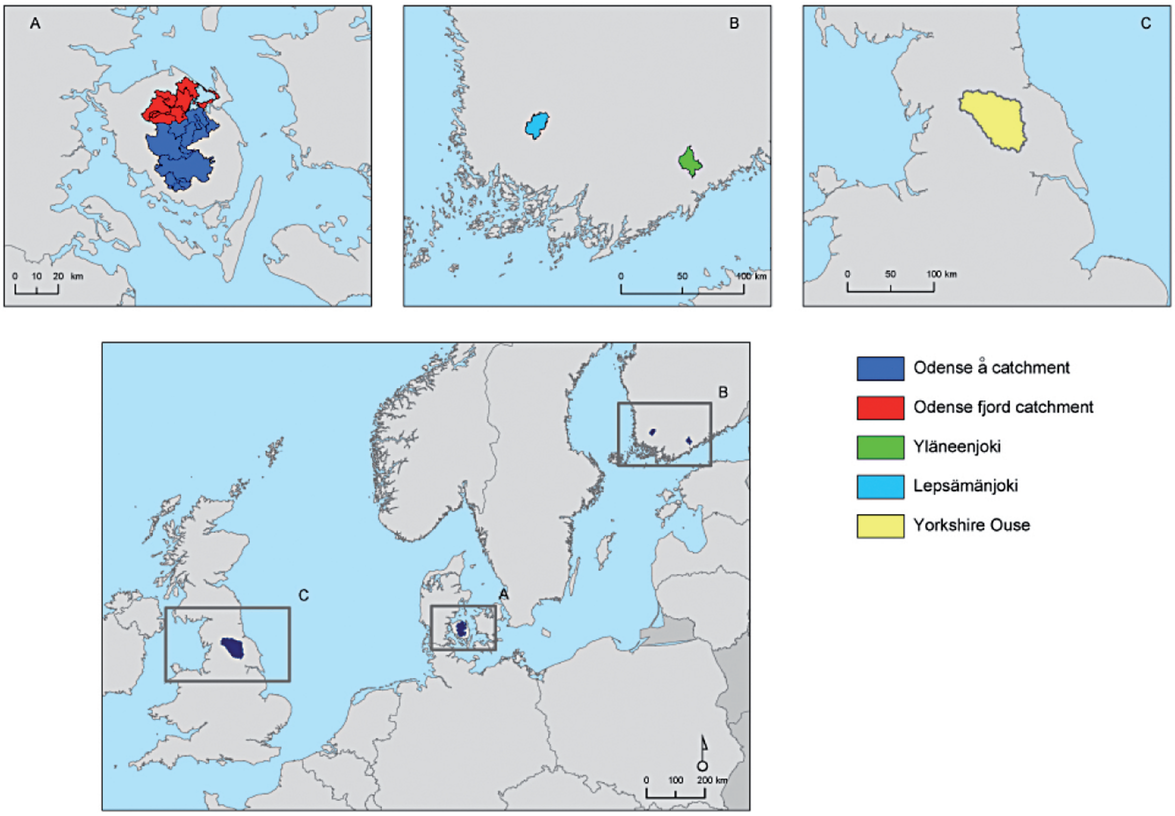


Figure 8.2. Case study sites.

We used the ecosystem services cascade model to frame our spatial assessments (Figure 8.3). This model was adopted by the TEEB study (TEEB, De Groot et al. 2010). It links ecosystems and biodiversity to human wellbeing through the flow of ecosystem services. Ecosystems provide the structure and the processes which in turn define the capacity of delivering a service. This capacity can be exploited for human wellbeing as a benefit which we can value (either via monetary estimates or other indicators expressing value).

The cascade model was applied on water purification services using nitrogen retention and nitrogen removal by aquatic ecosystems. Freshwater ecosystems retain and remove excess nitrogen through denitrification (bacteria in oxygen poor sediments that convert nitrogen compounds into atmospheric nitrogen gasses), uptake of nitrogen by water plants, phytoplankton and hence the food web, and sedimentation and burial of N. These processes are collectively called nitrogen retention and define the capacity of ecosystems to remove nitrogen. The actual removal takes place if N is entering the system and besides natural background N most has an anthropogenic source. Nitrogen removal leads to several benefits which can be valued by assessing costs saved for downstream water treatment, increased health or increased social values.

The different assessments of this chapter followed this cascade structure following essentially a three-step process:

1. A scenario based modeling of land use change relative to a baseline or Business as Usual (BAU)
2. The application of biophysical models to estimate water purification as indicated by nitrogen retention
3. The valuation of the benefits of this ecosystem services using monetary valuation methods

The remainder of this chapter is structured along these three methodological steps before the results of the different case studies are presented and discussed.

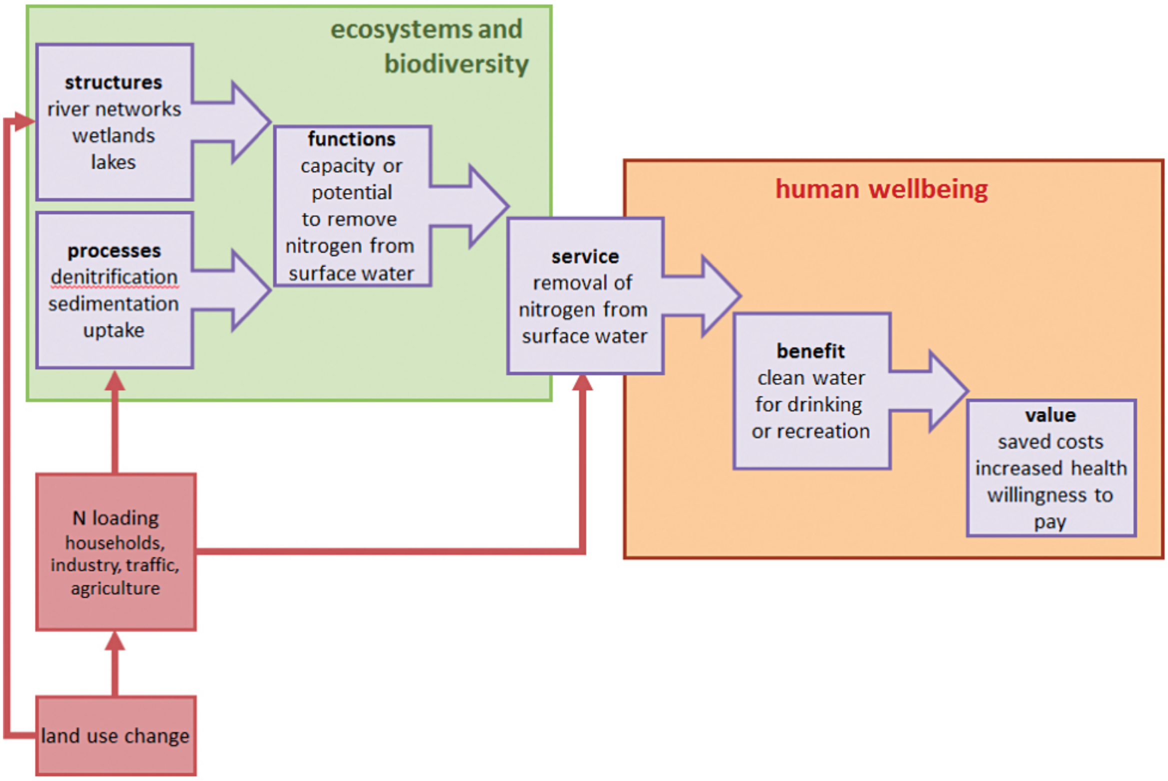


Figure 8.3a. The ecosystem services cascade model (Hains-Young and Potchin 2010; De Groot et al. 2010), applied on water purification services using nitrogen as a common water-quality metric.

8.2. Scenarios

Environmental scenarios are increasingly used to address discontinuity and uncertainties of future developments and to design robust policies that can withstand the test of time (Lavalle et al. 2011). Explorative scenarios, for example explore the possible effect of specified measures or drivers (e.g. policies, technological changes) on future developments and conditions.

In the policy analysis earlier in this report (chapter 2) it became clear, that policy measures usually affect not only one but a whole range of ecosystem services, positively but sometimes also negatively. In the case at hand we provide quantitative information for policy makers concerning the impact of various policy measures on the ecosystem service water purification. However, it should be mentioned here that the measures analysed are not primarily meant to support water purification, but our assumption is that the measures have effects. A previous study (Maes et al. 2011) has shown that maps from different scales yield different results concerning the consequences of policies on water purification. Variations may come from different data, but may, however, also vary with habitats and geographic areas (Garrod 2009). Therefore we will use a hierarchical approach with maps produced on different levels. One set of maps covers the European level with a lower resolution which is complemented by maps from sub-national levels in the UK, Finland and Denmark.

Here, we test in essence three scenarios that each have the potential to affect the total amount of nitrogen that river networks can retain. From Figure 8.4, it follows that nitrogen retention services are affected by nitrogen inputs on the one hand and the capacity of ecosystems to retain nitrogen on the other hand (see section 8.3). Hence, policies aimed at changing nitrogen input or measures that affect nitrogen retention capacity can be addressed relative to a scenario of policy inaction or Business as Usual (Figure 8.3b).

The first scenario (**GREENCAP**) includes measures that relate to land-use change which is expected following the implementation of the new Common Agricultural Policy as well as from additional regional measures. In October 2010, the European Commission presented a proposal to reform the Common

Agricultural Policy (CAP) after 2013. The second scenario (**FERTRED**) refers to measures to reduce the application of fertiliser. The third scenario (**WETRESTORE**) tests how structural measures such as wetland and river restoration which affect river flow have associated effects on nitrogen retention. The time horizon of these scenarios is 2020. The policy measures that were tested with this approach are summarized in Table 8.3 and correspond to the measures analysed in the policy chapter (chapter 2), containing the greening option of the future CAP, wetland restoration as possible future measure implemented under the Blueprint to Safeguard Europe's Water Resources. One measure, which is not dealt with in the policy analysis chapter, but considered an important measure for clean drinking water is the reduction of fertiliser application, for example via a full implementation of the Nitrates Directive or via the introduction of a fertiliser tax.

Not all measures could be included in all sub-studies due to differences in modelling approaches but also due to research design. Some measures described in the scenarios were not considered as they were not relevant for the respective catchment (Figure 8.3b). E.g. in the Finnish case river restoration through the construction of wetlands was not considered as both rivers in the catchments are already meandering. Table 8.3 provides an overview of which case study covers which measures. Details, e.g. such as which percentage of the land is set-aside, or which corps are used for diversification, vary from case study to case study too and are presented in the results section. In order to refer in a coherent way to the scenarios we combined where appropriate the name of the study area (EU, FI, UK, DK) with the name of the scenario (GREENCAP, FERTRED WETRESTORE). Each combination of study area and scenario includes a particular set of policy measures according to Table 8.3.

Table 8.4 contains more information on the models that were used to assess land use change that arises from implementing the different scenarios. Land use changes affect nitrogen retention in several ways. For instance, different crops require different fertiliser rates which, in turn, result in different nitrogen inputs to river systems. Another clear example is wetland restoration (at the cost of agricultural areas) which increases the capacity to retain nitrogen resulting in a better water quality.

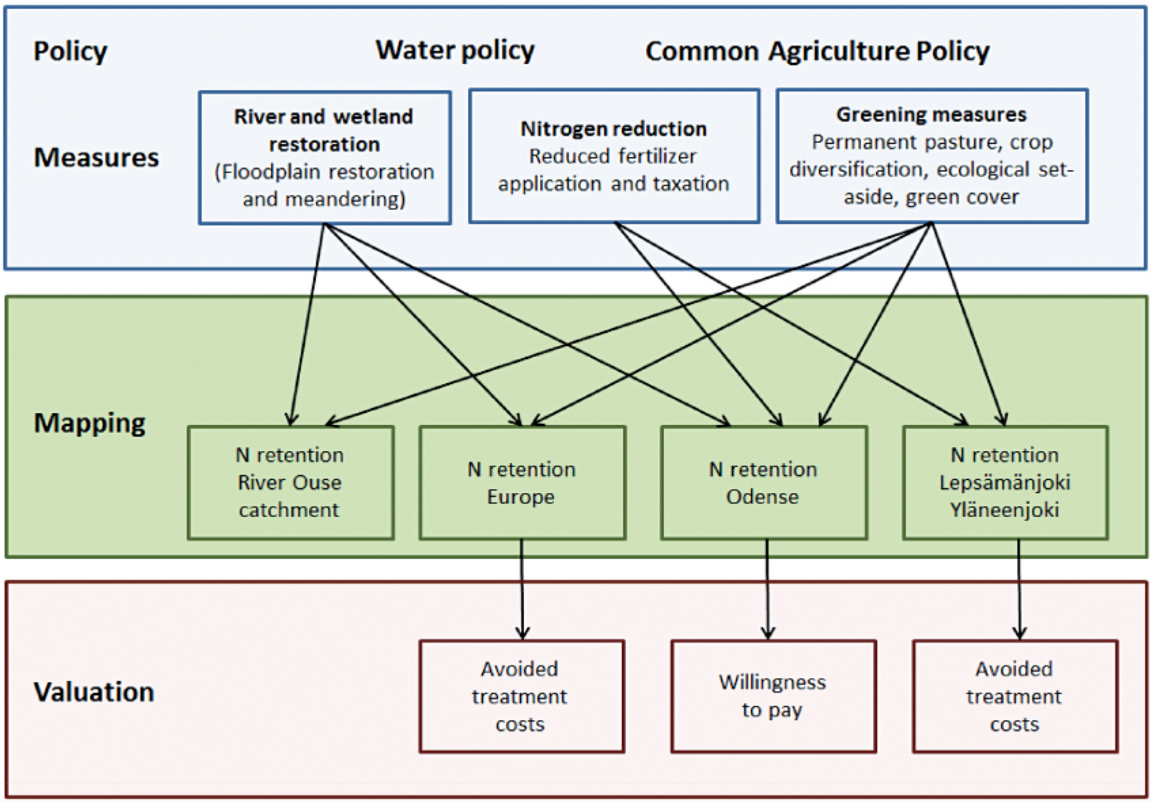


Figure 8.3b. Scenario-based approach for the assessment of water purification services at different spatial scales in Europe. Water and agricultural policies deliver scenarios for measures that aim to reduce nitrogen inputs or to restore aquatic habitats. These measures were tested against a Business as Usual scenario in order to calculate the difference in nitrogen retention by river basins. The different retention was valuated in monetary terms.

Table 8.3a. Policy measures and application on the study sites.

Scenario name	Measures	EU	UK	FI	DK
GREENCAP Greening measures under the new CAP proposal	Permanent grassland	x	x		
	Crop rotation/ diversification	x		x	
	Ecological set-aside (ecological focus areas)	x	x	x	x
	Green cover			x	
FERTRED	Reduced fertilizer application			x	x
WETRESTORE	River and wetland restoration	x	x		x

Table 8.3b. Description of the policy measures and the expected outcomes from the perspective of the year 2020 based on research results.

Measure 1: Permanent grassland

Permanent grassland is grassland that has not been in rotation for at least 5 years. Grasslands prolong the residence time of water and nitrogen in soils and allow micro-organisms such as bacteria to process excess nutrients and therefore contribute to reduced water pollution. While the maintenance of the area of permanent grassland did not lead to an increased retention of nitrogen, a conversion of permanent grassland into arable land would have caused increased nitrogen loads in water bodies as the residence time would have been shortened.

Measure 2: Crop rotation/ diversification

Crop rotation is the planned and ordered succession of different crops on the same field (usually lasting 3-5 years). 3 crops of different types are at least required with the main crop not exceeding a certain % of the arable area. While certain crops, such as leguminous crops were known to be beneficial for water quality, no specific crops could be required or excluded as part of the crop rotation in the CAP policy until 2020 to ensure WTO compatibility. Furthermore, land use changes due to crop diversifications were not significant enough and so the impacts of crop rotation and diversification on the ecosystem service water purification remain rather low.

Measure 3: Ecological set-aside (ecological focus areas)

Although set-aside was first introduced into the CAP – on a voluntary basis – in 1988 as a production control mechanism in response to over production of cereals, the CAP reform saw its wide range of ecological benefits and re-introduced the measure as ecological set-aside. This means a certain percentage of the farm land is left fallow (not in production) for environmental purposes. In the case of permanent crops, ecological set-aside may take the form of buffer or grass strips. Although impacts of ecological set-aside vary depending on whether set-aside is rotational, on how land is maintained and on its location (e.g. buffer strips along water courses, or joined up with other farms to form a connected network) benefits for the ecosystem service water purification are not significant on a larger scale, since the percentage of set-aside is too small be have an effect on water quality.

Measure 4: Green cover
Green cover is the temporary plant cover of land that would otherwise remain bare at certain times in the year, especially during rainy winter month, when run-off is high. The cover can either be stubbles remaining from previous harvest or is seeded as soon as possible after harvesting the preceding crop. Although the measure was not included in the greening option of the CAP, some countries included it in national agricultural policies. This measure contributed significantly to water purification due to an increased water and nitrogen residence time in the soil, allowing bacteria to process and reduce nitrogen loads of water running into adjacent water bodies. Further, the green cover contributed to an increase in nitrogen storage in the soil.

Measure 5: Reduced fertiliser application
Several measures to reduce fertiliser were applied varying from Member State to Member State. Within the national action programmes for the implementation of the EU Nitrates Directive the Member States expanded their incentive systems to reduce fertiliser application. Other Member States introduced fertiliser taxes, which regulated the demand and thus application of fertiliser. While this measure did not directly contribute to the ESS water purification, this measure contributed significantly to the reduction of nitrogen water pollution.

Measure 6: Wetland and river restoration
Aquatic ecosystems such as wetlands, rivers and lakes contribute to the ESS water purification by containing micro-organisms such as plankton and macrophytes that take up nitrogen from the water and therefore reduce pollution. The slower rivers run, the more time do these micro-organisms have for their uptake. Though river restoration such as addition of floodplains and meanders is quite costly, its implementation under the Blueprint to Safeguard Europe's Water Resources was continuously advanced, first to slow down flowing waters but also to increase the volume of water bodies allowing more micro-organisms to work and decrease nitrogen pollution. While the first assumption did not prove to be true and no significant reduction of pollution in existing rivers could be found, the increase of water volume due to new water bodies such as floodplains proved in some cases to be quite effective to reduce water pollution.

Table 8.4. Short description of the models that were used to provide scenarios for land use change and nitrogen inputs and application of the models on the different study sites

Scenario name	Europe	UK	FI	DK
GREENCAP	*CAPRI*	*ChREAM*	*INCA*	*FMM*
FERTRED			*INCA*	*FMM*
WETRESTORE	*LISFLOOD*	*NALTRACES*		*WetMod*

CAPRI (Common Agricultural Policy Regionalised Impact Analysis Modelling System) is an agro-economic model developed for policy impact assessment of the CAP and trade policies from global to regional scale with a focus on the EU. CAPRI is capable to simulate changes in crop production and to calculate N-budgets (Leip et al. 2011) which were considered in the **EU-GREENCAP** scenario.

LISFLOOD is a GIS-based hydrological rainfall-runoff-routing model that is capable of simulating the hydrological processes that occur in a catchment. The areas which act as possible floodplains under the **EU-WETRESTORE** scenario are calculated by Feyen et al. (2011). First, river discharges were translated into river water depths based on approximated river channel geometries. The river water depths were resampled from the 5 km river network to 100 m resolution based on the river network obtained from the pan-European River and Catchment Database CCM2 (Vogt et al. 2007). Finally, river water levels were extrapolated onto the high-resolution (100 m) digital elevation model of the CCM2 database to delineate flooded areas and inundation depths.
The **ChREAM** project developed an integrated modeling approach to assess the costs and benefits to the rural community of changing farming and community practices to produce a healthy and sustainable river environment of good amenity value. A key focus of the analysis is to examine how (within a context of reforms of the Common Agricultural Policy and complicating issues such as climate variability and non-agricultural sources of pollution) the EU Water Framework Directive is likely to affect agricultural activities concerning fertilisers, pesticides and faecal matter and so impact upon incomes within already fragile farming communities. A spatially and temporally sensitive econometric behavioural model of rural land use was developed. Here land use data collected on a 2km square grid across all of Great Britain for a period of more than 40 years was combined with information on market prices, costs, quantity and financial policy measures, the physical environment, meteorological and other data. A multi-input, multi-output model was developed and successfully tested against both other specifications and in an out-of-sample actual versus predicted validation exercise. The model was found to be a highly robust predictor of land use and land use change under a wide variety of conditions. Its outputs include estimates of farm income and land use under present or feasible future conditions. The econometric model was used to examine the changes in agricultural land use arising from a variety of different policy options and decision tools, including taxes on fertilisers, quantity restrictions on activities and the most efficient reallocation of land. In all cases the analysis provided both measures of the financial impact upon farmers and the effect on water quality
FFM (Farm Management Model) was used to maximise the profit of the individual farms in the Odense catchment area (**DK-GREENCAP** and **DK-FERTRED** scenarios). The endogenous parameters in the model, and thus the parameters that the farms can adjust in order to maximise their profits are the land use defined as the area allocated to each crop and the level of fertilisation on the fields. The solution of this maximisation problem is constrained by restrictions on the allowable area of each crop and limits on N application set by the non-tradable quota system defined in Danish Environmental Law. Further documentation of the model equations, restrictions and data can be found in Fonnesbech-Wulff et al. (2011). The model optimisation is implemented in GAMS.
WetMod is a simple flooding model that was used to identify possible areas for wetland restoration. It was assumed that all drains and ditches are removed from the wetland area, forcing surface water from the topographical direct watershed through the wetland (Hoffmann et al., 2005). The model was used to implement the **DK-WETRESTORE** scenario

Note: Three scenarios (**FI-GREENCAP**, **FI-FERTRED** and **UK-WETRESTORE**) were assessed by imposing measures directly in the biophysical models. This can be done by changing model parameters according to the particular scenario measures. These models are described in the following section

8.3. Biophysical mapping of nitrogen retention and removal

Seitzinger et al. (2006), in a review paper on nitrogen removal with a focus on denitrification, proposed a useful model to assess the capacity of systems to remove nitrogen (Figure 8.4). At the ecosystem scale, geology and hydrology interact to control the residence time of water and thus the processing time of N within an aquatic system. This, in turn, affects the proportion of N inputs that are removed. At the same time, N loading limits the amount of N available for removal. With increasing residence time of water in a system, a higher proportion of the available N can be removed. But also the higher the nitrogen loading, the more nitrogen is removed through denitrification and this is observed across whole range of lakes, rivers, wetlands, estuaries. These principles were applied in the different models used in this case study, be it at different resolution and with different detail of the processes that are included to model nitrogen compounds and transformations that occur in the soil, water or the atmosphere. Table 8.5 presents brief descriptions of the models that have been used in this assessment.

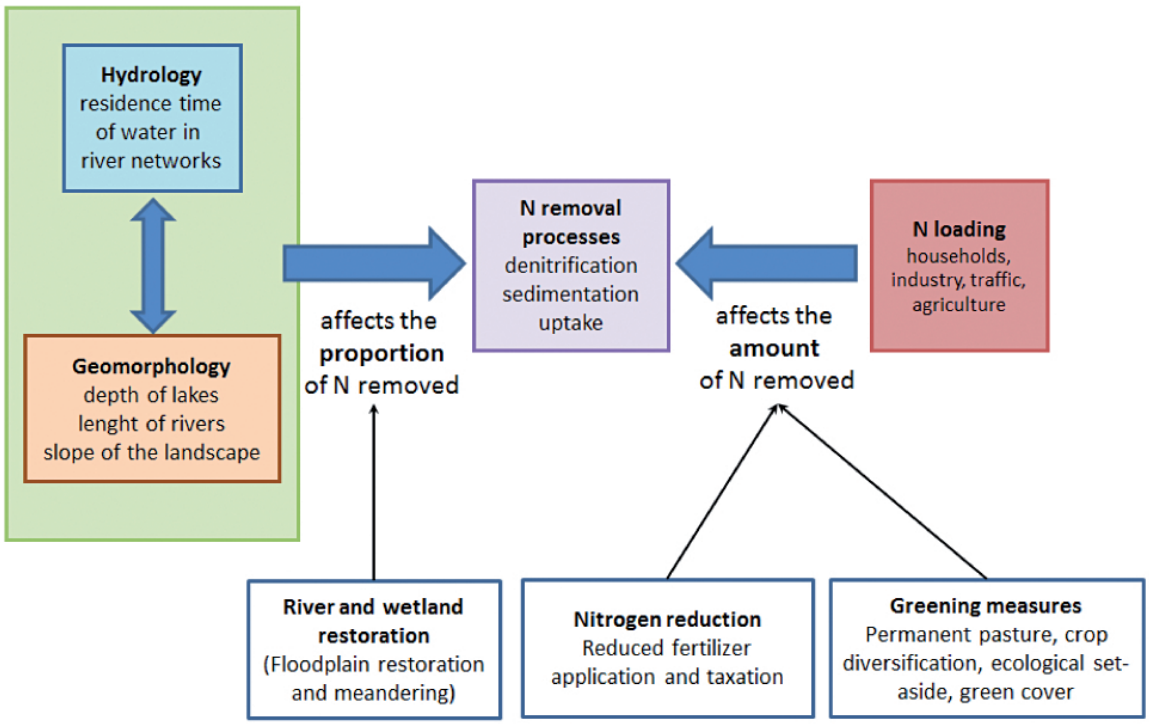


Figure 8.4. Schematic of the interaction of hydrology, geomorphology, and N loading on denitrification (redrawn from Seitzinger et al. 2006). The different policy measures that were tested in this study are included at the bottom. River and wetland restoration increase the proportion of nitrogen that is removed and thus enhance water purification services. Nitrogen reduction and greening measures affect the amount of nitrogen that is entering into the river network and change the total amount of nitrogen that is retained and removed.

Table 8.5a. Models used for mapping nitrogen retention in rivers and catchments.

Europe. GREEN is a statistical model developed to estimate total nitrogen and total phosphorus fluxes to surface water in large river basins (Grizzetti et al., 2008). Fluxes are calculated at the scale of sub-catchments connected to each other according to the river network structure. In the application at European scale, a catchment database covering all Europe was developed based on the Arc Hydro model with an average sub-catchment size of 180 km^2 (Bouraoui et al., 2009). For each sub-catchment the model considered the input of diffuse sources and point sources of total nitrogen and estimates the nitrogen fraction retained during the transport from land to surface water (basin retention) and the nitrogen fraction retained in the river segment (river retention). Diffuse sources included mineral fertilizers, manure applications, atmospheric deposition, crop fixation, and scattered dwellings, while point sources consisted of industrial and waste water treatment discharges. In the model the nitrogen retention was computed on an annual basis and included both permanent and temporal removal. Diffuse sources were reduced both by the processes occurring in the land (crop uptake, soil denitrification, and soil storage), and those occurring in the aquatic system (aquatic plant and microorganism uptake, sedimentation and denitrification), while point sources are considered to reach directly the surface waters and therefore are affected only by the river retention. For more details on model parameterisation and calibration see Grizzetti et al. (2008) and Bouraoui et al. (2009).

UK. For the Ouse catchment case study the NALTRACES model (Hutchins, submitted) was applied. NALTRACES is a dynamic catchment-scale model simulating annual nitrate-N loads comprising four components: (1) Determination of soil nitrate-N available for leaching (NAL) from diffuse sources to waterbodies. These calculations are driven by data on rainfall, potential evapotranspiration, atmospheric deposition, crop type and fertilization level, livestock numbers and soil properties. (2) A hydrological nitrate-N transfer function. Soil hydrological properties and effective rainfall are used to calculate a fraction of soil NAL, which equates to the diffuse nitrate-N load to the river network. (3) Estimation of point source nitrate-N loads from sewage works. This uses population census data. (4) River channel nitrate-N retention due to denitrification and biological uptake. Based on a world-wide database of observations this is calculated empirically on a reach-by-reach basis (Seitzinger et al. 2002), whereby potential retention is described as a function of the hydraulic load of the river reach (Wollheim et al. 2006). Hydraulic load is calculated using estimates of reach length and water column depth and velocity, all derived from other model applications, in this case QUESTOR (Hutchins et al., 2010) and HEC-RAS. The land use and population data were defined at an approximate spatial resolution of 20 km2. Data on soils, atmospheric deposition and rainfall were available at finer resolution (5 km^2 or less). In the Yorkshire Ouse application the average river reach length was 1.72 km. Daily river flow data were used to derive annual average nitrate-N concentrations. Applications of the HEC-RAS model (Performing organization: Hydrologic Engineering Centre (HEC); River System Analysis RAS) were used to explore the hydraulic impact along a river stretch of removing or introducing a weir. HEC-RAS was used to represent the geomorphology of the stretch on the river Nidd (a tributary of the Ouse) and perform river hydraulics calculations. The output of the model, velocity and hydraulic depth, were then transferred into NALTRACES and used for modelling of the impact of the weir on downstream nitrogen retention. Two model runs were performed: one with weir and one without. The HEC-RAS software permits one-dimensional steady and unsteady river flow hydraulics calculations, sediment transport computations and water quality analyses. The key element is that all those 4 components use a common geometric data representation, and common geometric and hydraulic computation routines. Daily data on river discharge, and river geometry (slopes, elevations and cross section dimensions) were provided by the UK Environment Agency (for details see Booker and Dunbar 2008). The design of the weir at the downstream end of the river stretch (Skip Bridge weir) was provided by the NRFA (UK). In order to model hydraulics of the river Nidd, it was necessary to characterize the roughness of the river bed and banks. Data available from the river habitat survey on the bank and channel vegetation, and data on the channel bed material were used for estimation of the Manning's roughness coefficients. The values of Manning coefficients were adjusted for: (i) river bed (meandering, variation in channel cross sections, irregularity), (ii) banks (effect of obstruction, irregularity, amount of vegetation). In the case study we used steady flow for calculating water surface profiles for steady gradually varied flow. Gradually varied flow is characterized by minor changes in water depth and velocity from cross-section to cross-section. The steady flow component in HEC-RAS is capable of modelling subcritical, supercritical and mixed flow regime. The basic computational procedure is based on the solution of the one-dimensional energy equation which states that the total energy at any given location along the stream is the sum of potential energy and kinetic energy. The change in energy between two cross-sections is called head loss. Energy losses are evaluated by friction (Manning's equation) and contraction/expansion. Validation of the ability of HEC-RAS to represent water surface profiles is described in the literature (e.g. May et al., 2000).

Finland. Changes in N retention were simulated by the Integrated Nutrients in Catchments (INCA; Wade et al., 2002a; Whitehead et al., 1998) model, which integrates hydrology and nitrogen (N) processes in the river and soil compartments. The model is semi-distributed in that the land surface is not described in detail, but rather by land-use classes in sub-basins. These classes are based on current land use (2010) in the catchment. Hydrological input is calculated by the conceptual WSFS model (Bergström 1976; Vehviläinen 1994), which is in operational use for flood forecasting in Finland. In the INCA-N model sources of N include atmospheric deposition, leaching from the terrestrial environment and direct discharges. The key N processes in soil are nitrification, denitrification, mineralization, immobilisation, N fixation and plant uptake. In the river the key N processes are nitrification and denitrification. These nitrogen processes are calibrated against measured values in Finland (Martikainen et al. 1994; Syväsalo et al. 2006; Regina and Alakukku 2010) so that simulated leaching from fields is at the same level with leaching from field experiments (Salo and Turtola 2006; Puustinen et al. 2010). Nutrient loading from forested areas is in general very low (Lepistö 1996, Mattson et al. 2002).

Denmark. NLES-CAT is an empirical-conceptual methodology for calculation of annual values of nitrogen losses at the river basin scale (Schoumans et al., 2009). The river basin is subdivided into sub-basins for which nitrogen fluxes are calculated individually and subsequently routed through the connected river network. The core model of the concept, the NLES model for agricultural land (Kristensen et al., 2008), calculates root-zone losses of nitrogen for individual fields in each sub-basin. NLES was developed based on 1500 observations of annual leaching of nitrogen from the root zone from both experimental fields and fields in normal agricultural production in Denmark. The effects included in the model are: level of total nitrogen added in the crop rotation; fertilisation in spring; autumn fertilisation; nitrogen left by grazing animals; nitrogen fixation by crops; soil type; crop type and climate. Additional diffuse sources include scattered dwellings, while point sources include waste water treatment discharges and industrial discharges. Nitrogen retention in soils, groundwater and surface waters is calculated on an annual basis per sub-basin. In the present application retention values are derived from a national mapping project (Windolf and Tornbjerg, 2009). Nitrogen retention in the catchment shows a marked difference across the catchment (Figure 8.5) dependent on the soil properties and the distance through the catchment to the fjord. Phosphorus losses for each sub-basin are calculated by a regression model developed by Andersen et al. (2005). This model describes phosphorus losses as a function of sub-basin characteristics: hydrologic pathways, fraction of arable land in the sub-basin, soil type, slope of the stream bed, and fraction of riparian meadows and wetlands. Phosphorus loaded into the riverine system is routed through the connected river network taking into account retention in streams and lakes. Phosphorus loadings from scattered dwellings and from point sources are included as for nitrogen.

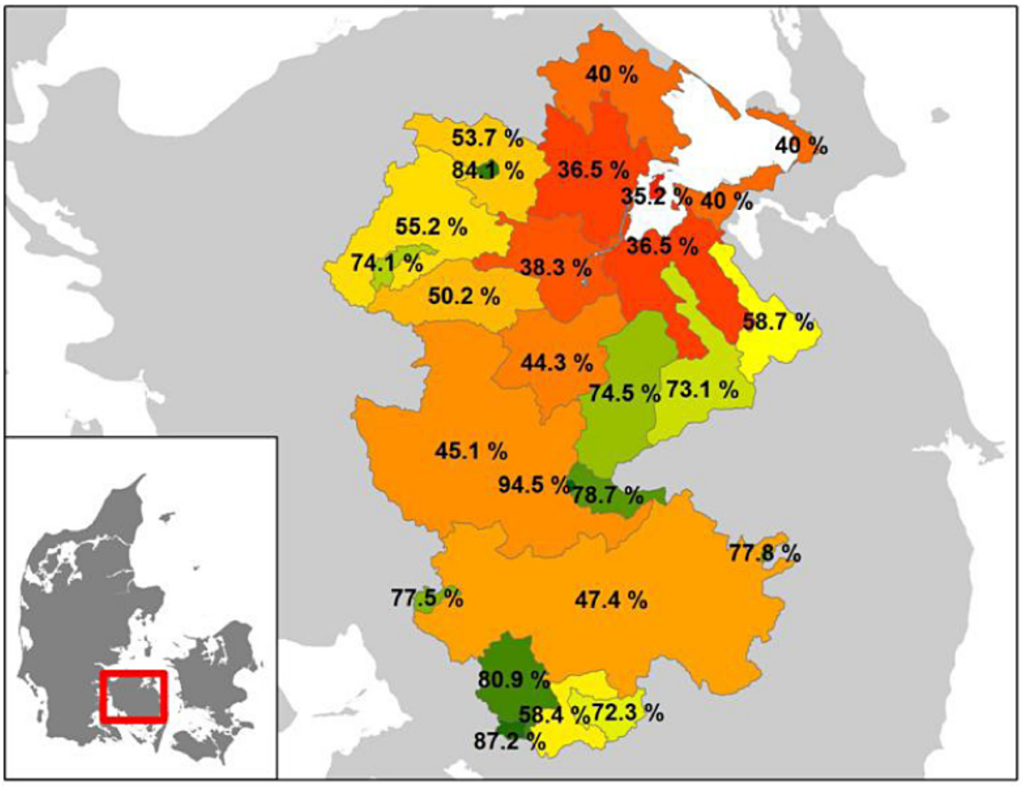


Figure 8.5. Nitrogen retention (% of loading) from the root zone in each sub catchment of the Odense catchment (Danish case study) derived from the model NLES-CAT (Table 8.5).

8.4. Monetary valuation of nitrogen retention and nitrogen removal

High levels of nitrogen can result in increased costs for drinking water production and can result in missed revenue derived from recreation in and around waters (Elsin et al. 2010). A frequently used method of estimating the value of changes in land use or the results of river and wetland restoration consists of estimating the averted costs of water treatment (La Notte et al. 2012). These averted costs are a portion of the benefits that result from an improvement of the water quality as expressed by a reduction of nitrogen concentration. Cost savings are a social benefit and a straightforward way to link water quality changes to particular economic outcomes (Elsin et al. 2010). Avoided treatment costs were applied in the European and Finnish case studies. A second method that is applied in Danish case study is the consumer's willingness to pay for clean water. This represents a methodology that aims to directly measure the benefit derived from water purification services or improved water quality.

8.4.1. An assessment of avoided treatment costs at European scale

We estimated the value of nitrogen retention by using replacement costs based on an assessment of constructed wetlands (CW). CW are engineered systems that have been designed to use the natural processes in treating wastewater and they are considered as the best technical alternative to retain and remove nitrogen at low concentrations (Figure 8.6, Vymazal and Kröpfelová 2007). The choice for using costs of CW for valuing in-stream nitrogen retention is related to the large contribution of mainly two particular nitrogen sources. Diffuse nitrogen emissions from the agricultural sector and point emissions from effluents of water wastewater treatment plants are dominant contributors to the combined sum of nitrogen emissions to river networks (Grizzetti et al., 2011). Nitrogen from these two sources arrives in rivers at low concentration which justifies the choice for using CW based costs in our analysis. CW are indeed applied worldwide to purify wastewater deriving mainly from agriculture and the residual effluents from wastewater treatment plants treating wastewater from industry and households (Kadlec and Wallace, 2009).

The assessment of replacements costs followed a three step approach (Figure 8.7): (1) GREEN calculated the total quantity of nitrogen retained in river catchments; (2) the size of constructed wetlands is scaled in order to remove an equal amount of nitrogen; (3) construction, maintenance and operation costs of wetlands of this size are calculated. The cost calculation in step 3 includes an economy of scale effect. The coefficient ω of the power relation between wetland size A and construction costs P is smaller than one. It follows that larger wetlands can be constructed at a lower cost per unit area. The relation between wetland size and cost is based on case studies for the US (Kadlec and Wallace, 2009). This standard cost model was further extended with a differentiated cost model. The total construction cost was based on 30% of the standard costs and 70% of the differentiated costs. These latter costs entailed country specific cost data for the construction, maintenance and operation of constructed wetlands in Europe using Eurostat statistics on labour cost per country and data on the price of gravel, the main component of sub surface flow wetlands. The following formulas were used to estimate the construction cost in euro m^{-2}:

(1) P_{SSF} = 70 + cost for 1 hour of labour + cost for gravel

(2) P_{FWS} = 20 + cost for 1 hour of labour

Constructing free water flow wetlands is essentially dependent on labour costs only. Labour costs in 2011 varied from a low of 2 euro per hour for Bulgaria to a high of 37.10 euro per hour for Switzerland. The average was 17.10 euro. Prices in 2011 for gravel average about 20 euro per m^2. Finally, the costs for operating and maintaining an artificial wetland were estimated using constant values (3850 € m^{-2} for free water flow systems and 7700 € m^{-2} for sub surface flow systems) and added to the total cost estimate (Masi 2011).

Where necessary we converted foreign currency to € using the average annual exchange of the reference year. We accounted for inflation using the historical consumer price index for the euro-zone using a 2% inflation rate. All the monetary values were reported in terms of constant price referred to the year 2000. Life expectancy of the systems was estimated at 20 years and values were annualized using a depreciation rate of 3%.

A subsurface flow system (SSF) with treatment of water in the root zone

A free water system (FWS) with treatment of water by the pond ecosystem

Figure 8.6. Photos of two types of constructed wetlands (pictures by IRIDRA). There are several types of constructed wetlands: surface flow wetlands, subsurface flow wetlands, and hybrid systems that incorporate surface and subsurface flow wetlands. A surface flow wetland, hereafter referred to as free water system (FWS), consists of a shallow basin, soil or other medium to support the roots of vegetation, and a water control structure that maintains a shallow depth of water. They are mainly used to treat agricultural runoff (Figure). A subsurface flow wetland (SSF) consists of a sealed basin with a porous substrate of rock or gravel and the water level is designed to remain below the top of the substrate (Figure). They are mainly used as secondary treatment for domestic and industrial wastewaters.

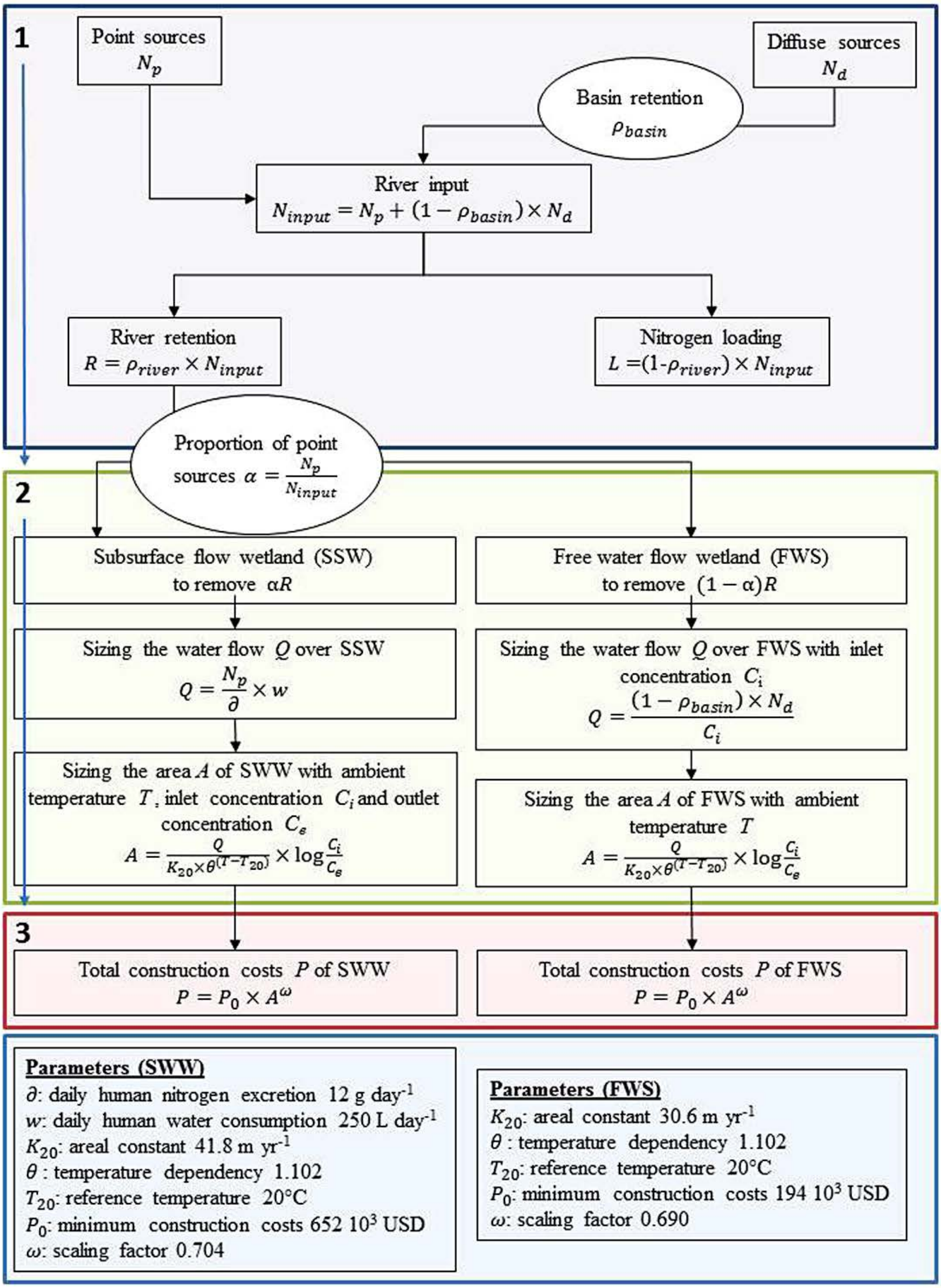


Figure 8.7. Flow diagram representing the three step approach to assess replacement costs of nitrogen retention in river networks. SSW refers to subsurface flow systems; FWS refers to free water flow systems. Parameters of the model are given at the bottom. Calculations based on Masi (2011) and Kadec and Wallace.

8.4.2. Willingness to pay for clean water (Danish case study)

The Danish case study used data from a choice experiment survey to estimate a willingness to pay (WTP) function using a random utility model. The estimated WTP function describes the economic value of the different possible combinations of water quality improvements, e.g. an increase in the water quality status of the fjord to a moderate quality and an improvement in the quality of the lakes to a good quality status, as well as socio-economic characteristics of people. Testing alternative model specifications suggest that income and distance to the water bodies are important determinants of economic value. The individual components of the WTP function give marginal values for changes in individual variables in the valuation (Table 8.5b). For the DK-BAU scenario both the lake and the fjord water quality status is "poor". As an example, the benefits from changing the water quality status of the fjord from poor to moderate is estimated as 68.59 € person^{-1} year^{-1} (Table 8.5b, row 7). For individuals in the high income group this estimate is increased by 30.24 € year^{-1} (Table 8.5b, last row). The results indicate that individuals living further away from the fjord have a lower WTP for water quality improvements, however this results is statistically not significant (Table 8.5, row 9).

Table 8.5b. Mean willingness to pay (WTP) for changes in water quality status in € per person per year based on a survey in Denmark. Standard deviation given in brackets.

Variable	WTP (€ person^{-1} year^{-1})
Lake improve to very good status	119.72 *** (23.9)
Lake improve to good status	128.77 *** (23.9)
Lake improve to moderate status	96.51 *** (23.8)
Fjord improve to very good status	118.07 *** (19.2)
Fjord improve to good status	108.01 *** (18.9)
Fjord improve to moderate status	68.59 *** (18.7)
Distance to improved lake increases by 1 minute in car	-1.04*** (0.4)
Distance to improved fjord by 1 minute in car	-0.31 (0.2)
Lake improved - High income individuals	-6.92 (21.4)
Fjord improved – High income individuals	30.24* (19.2)

Note: ***, **, * ==>Significance at 1%, 5%, 10% level.

8.4.3. Cost based benefit assessment method of the Finnish case study

This case study used a fixed price per kg nitrogen retained by artificial wetlands as common criterion for monetary valuation. In several Finnish case studies, this price (25 € kg^{-1} N) was based on studies on wetlands of different size (Majoinen 2005; Väisänen 2008). These studies took into account observed retention and construction and maintenance costs for 10-15 years of operational cycle of the wetland. In Sweden Byström (2000) estimated that retention cost would be 113- 495 SEK kg^{-1} N if retention percentage of the wetland was about 50-75 %. With the current rate (1 € = 8.8 SEK) this value is close to what was estimated for Finland.

8.5 Results

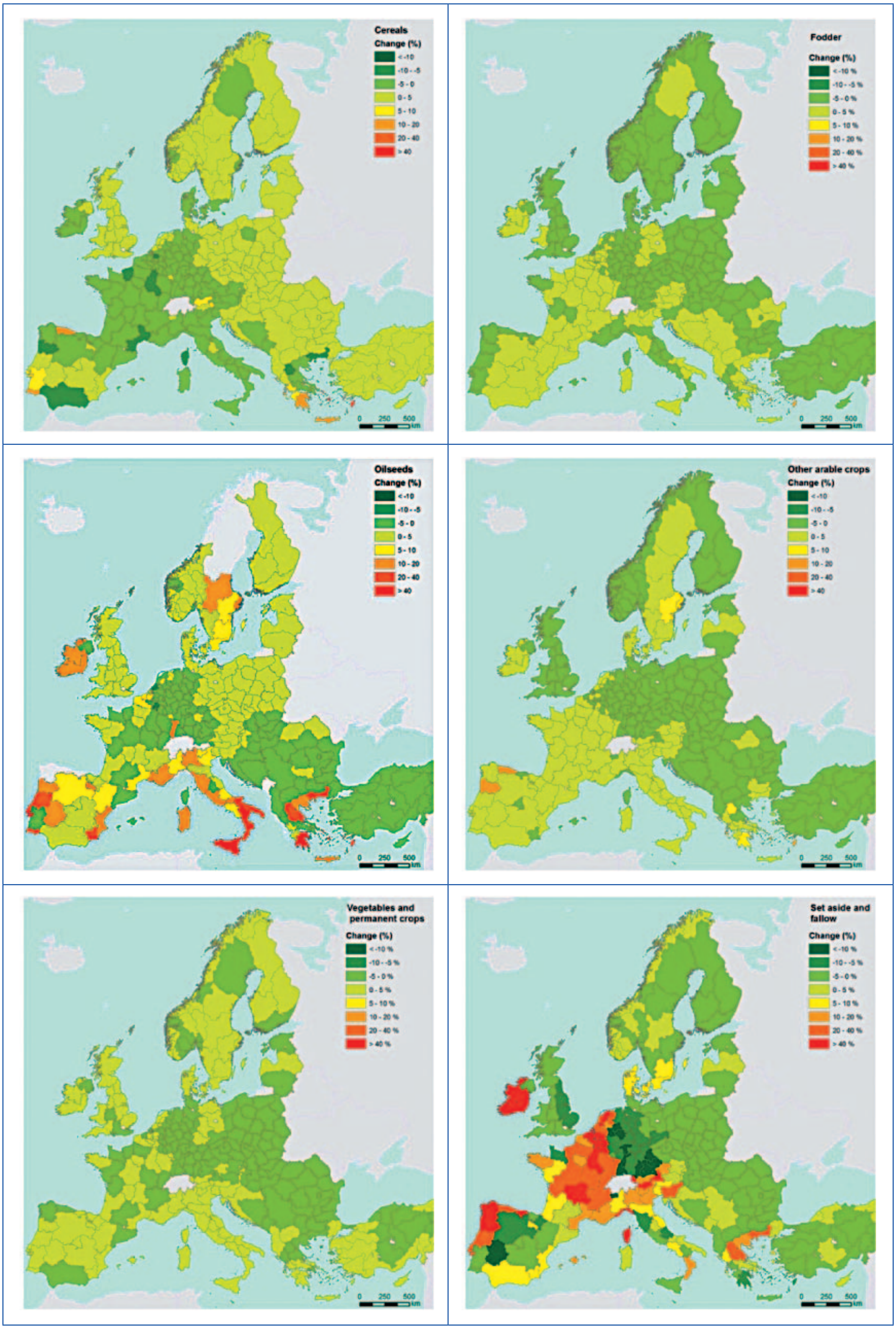
8.5.1. Impact of greening direct payments on nitrogen retention at European scale (EU-GREENCAP)

The Commission proposal for a new agriculture policy involves a greening of the direct payments to farmers. To strengthen the environmental sustainability of agriculture and enhance the efforts of farmers, the Commission is proposing to spend 30% of direct payments specifically for the improved use of natural resources. These measures - crop diversification, maintenance of permanent pasture, ecological set-aside - are expected to result in a positive ecological effect. The measures have been encoded in the CAPRI model. Nitrogen budgets based on CAPRI were then passed as inputs to the GREEN model, which, in turn, calculates the flow, transport and retention of nitrogen through the river basin and network. Once the retention is calculated, avoided treatment costs can be compared for the EU-GREENCAP scenario (Table 8.3) relative to the status quo or Business as Usual (EU-BAU).

Implementing three greening measures to modulate direct payments is expected to result in land use changes. The changes of land use of the EU-GREENCAP scenario relative to the EU-BAU are depicted in Figure 8.8 and are available for NUTS 2 regions. Greening the direct payments is predicted to result in a shift from the south-west to the north-east in cereal production with decreases in cereal crops in France, Germany, Denmark, Luxemburg, Italy, Ireland and parts of Germany, the Netherlands, Austria, Spain and Greece (Figure 8.8). The loss of cereal production is compensated by other countries. The patterns of ecological set-aside, fodder production and other arable crops follow an opposite trend with increasing land use in south-west Europe. Under the EU-GREENCAP scenario fallow land is expected to increase strongly in the Netherlands, Belgium, France, Ireland, the Alpine region, the northern parts of Greece and the north-west of the Iberian Peninsula.

Different crops require different fertiliser rates hence, changes in agricultural land use influence nitrogen inputs to the soil. The resulting change in nitrogen input is depicted in Figure 8.9. This map combines all nitrogen input sources and presents the relative change in total nitrogen input simulated for 2020 at the level of NUTS2 regions when the EU-GREENCAP scenario is compared to the BAU scenario. All in all, the EU-GREENCAP scenario involves relatively small changes in nitrogen emissions in the order of a few percent points.

Combining the CAPRI scenario projections for 2020 with the GREEN model resulted in an estimate of the total nitrogen retained by river networks for both the EU-GREENCAP and the EU-BAU scenarios. These data were subsequently used to estimate avoided treatment costs that arise from the greening measures that were introduced into the new CAP proposal. These savings are presented in Figure 8.9 at the scale of NUTS regions. The net benefit of the EU-GREENCAP scenario relative to the BAU amounts to only 7 million € of saved costs for the EU-27.



Land use change

Figure 8.8. Land-use changes EU-GREENCAP relative to BAU scenario (2020, CAPRI based results)

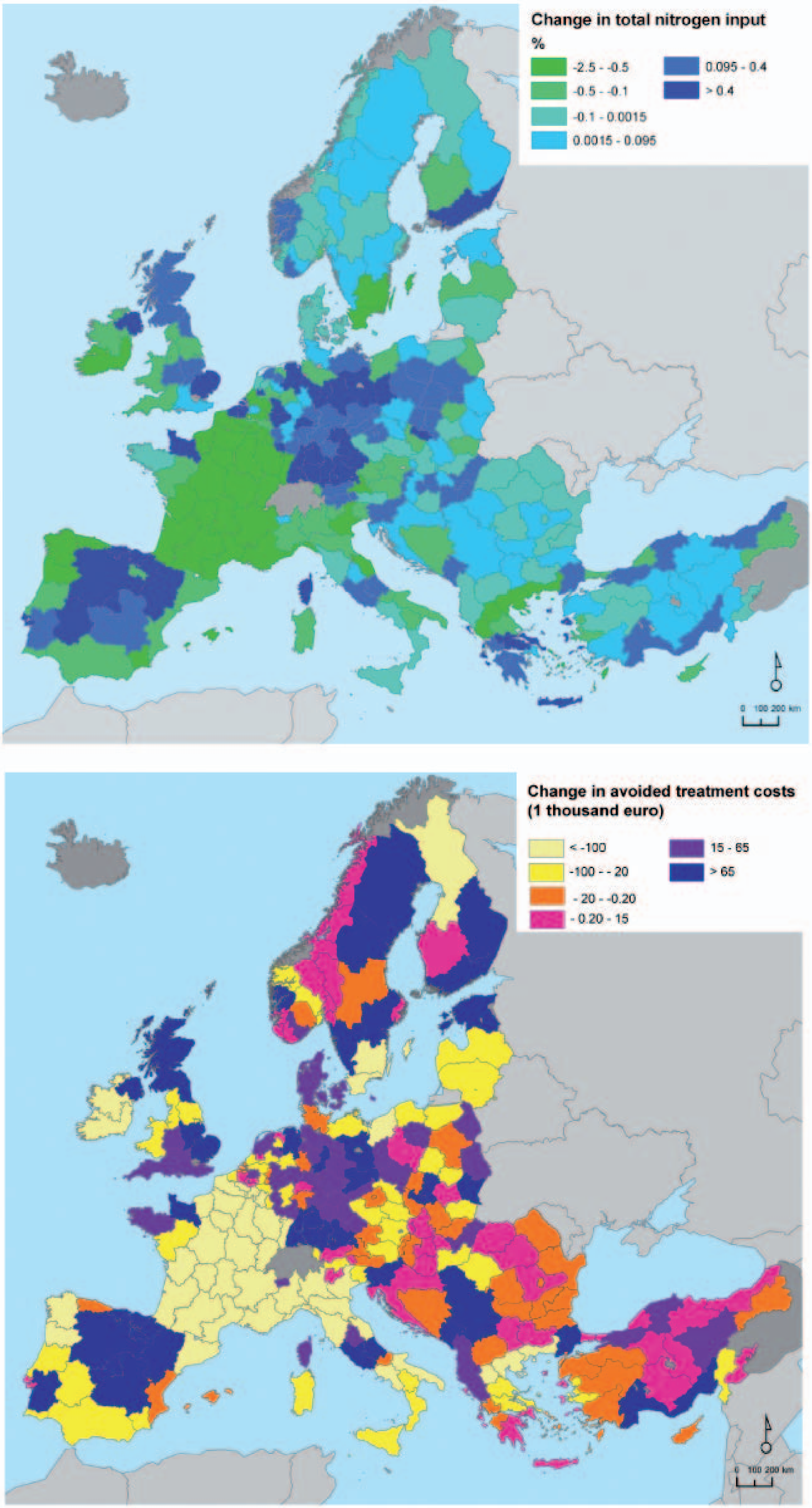


Figure 8.9. Change in nitrogen inputs and assessment of avoided treatment costs comparing the EU-GREENCAP scenario relative to the EU-BAU.

8.5.2. Impact of restoration of rivers and wetlands on nitrogen retention (EU-WETRESTORE)

Floodplains have potentially a high impact on water retention in river basins and therefore may act as sinks for dissolved nitrogen in rivers. Once these areas are flooded, the conditions are created for additional nitrogen retention through sedimentation in the floodplain area and denitrification in the flooded soils.

The EU-WETRESTORE scenario assumes the addition of 112 000 km^2 of 10 year floodplains to the European river network. The model GREEN was adapted to consider nitrogen retention by floodplains. Using depth and surface area, the nitrogen retention capacity in floodplains (as a % of the nitrogen loading) was calculated using a universal formula (Seitzinger et al. 2006). We assumed that floodplains were operational for 1 month per year and we used a nitrogen loading corresponding to 1/12 of the annual nitrogen loading to calculate additional nitrogen retention by wetlands. These data were compared to a GREEN model run without nitrogen retention by floodplains. We used nitrogen input data for the reference year 2005 (EU-BASE).

Integrating floodplains as temporary reservoirs in times of peak flow increases the capacity of rivers to retain, process and remove nitrogen from water. The change in retention capacity relative to the baseline is shown in Figure 8.10. Obviously, retention capacity increases in downstream catchments where natural floodplains used to occur. Catchments where floodplains are assumed in a restored state according to the EU-WETRESTORE scenario can increase nitrogen retention capacity with 1.6% on average.

The additional capacity to retain nitrogen coming from large scale floodplain integration to rivers will result in decreased nitrogen loading of river catchments. This decrease is more pronounced in downstream direction which is clear from Figure 8.11. Total nitrogen loading the European seas is expected to decrease with 7%.

The EU-WETRESTORE scenario is particularly useful to demonstrate how wetland restoration contributes to the enhancement of ecosystem services and hence, to human well-being. Also for this scenario the monetary value of nitrogen retention as service to increase water quality was assessed using the replacement cost methodology. Restoring the functioning of floodplains would save the EU countries 1.4 billion euro of treatment costs for water purification (Table 8.6). In particular Scandinavian countries would achieve high cost savings. Clearly, there are additional benefits of floodplain restoration. In first instance, floodplains protect downstream areas against flooding. Feyen et al. (2010) estimated that the current annual damage of floods in Europe is 6.4 billion euro and this cost is expected to rise further to between 14 and 21.5 billion euro by the end of the century.

Restoring floodplains comes, however, with costs. Floodplains are mainly situated on land that is now used for agriculture. Intersection of the areas that were delineated as floodplains with the CLC land use data shows that almost 57% of the floodplains in the EU-WETRESTORE scenario coincide with areas for crop production while another 17% is used as pasture. Creating floodplains in these areas without the opportunity to continue agricultural activities corresponds to a loss of about 80 000 km^2 of agricultural land.

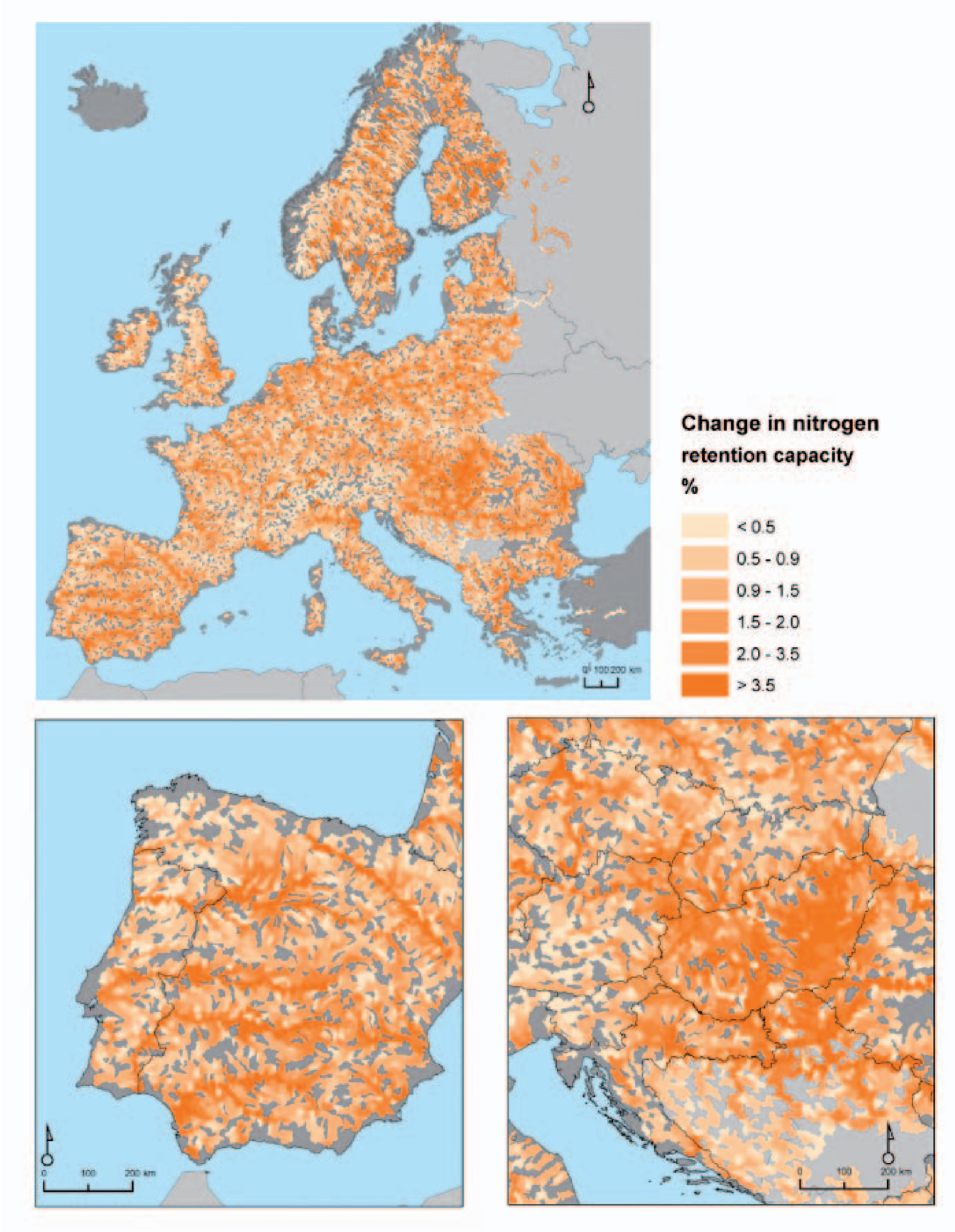


Figure 8.10. Change in the nitrogen retention capacity as a result of floodplain integration across Europe (EU-WETRESTORE scenario)

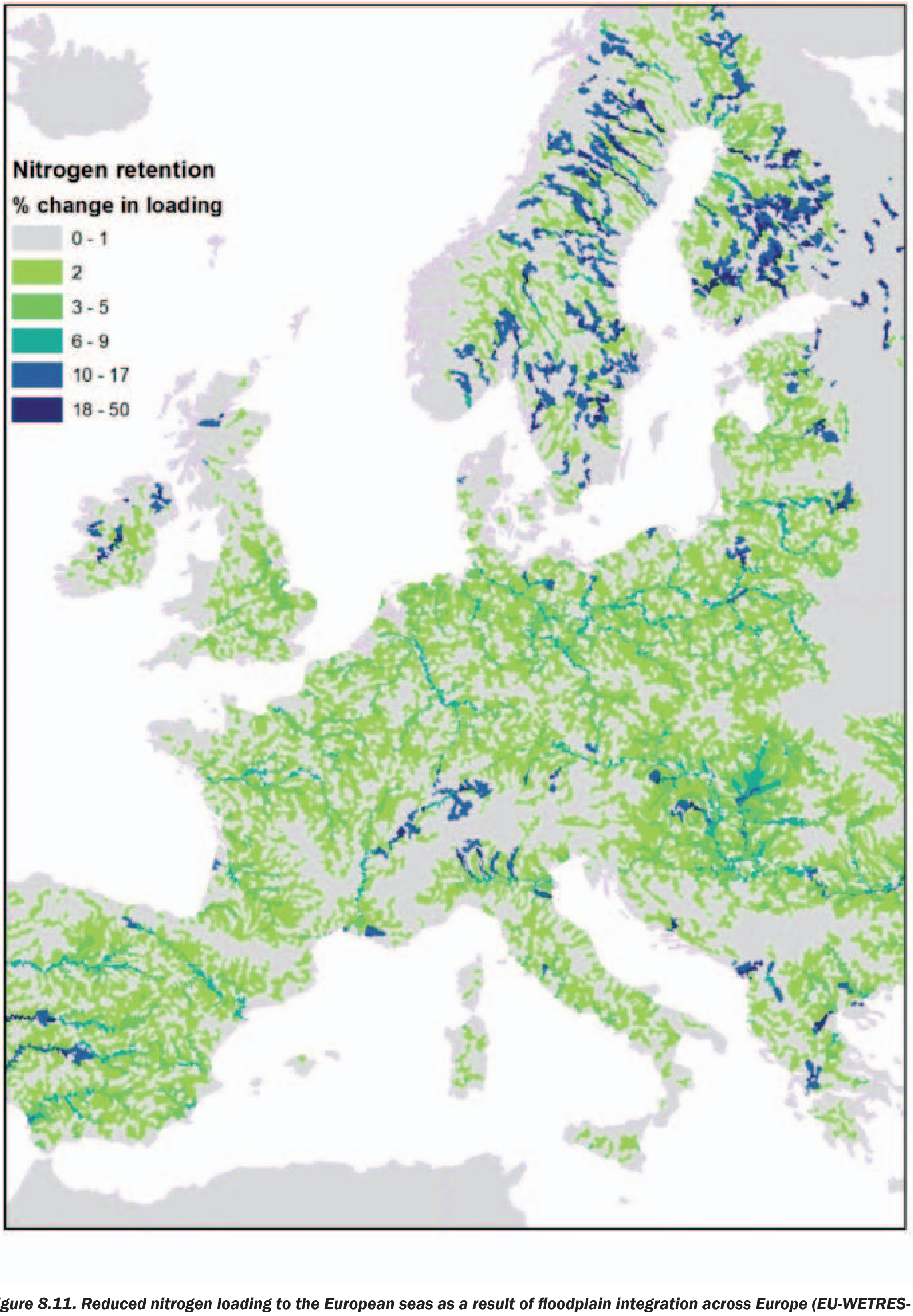


Figure 8.11. Reduced nitrogen loading to the European seas as a result of floodplain integration across Europe (EU-WETRESTORE scenario)

Table 8.6. Monetary valuation of nitrogen retention in 10^6 € of floodplain implementation (EU-WETRESTORE)

Countries	Total value of nitrogen retention without floodplains	Total value of nitrogen retention with floodplains	Difference
Austria	54	75	21
Belgium	38	48	10
Bosnia-Herzegovina	41	49	8
Bulgaria	56	70	14
Croatia	25	39	14
Cyprus	1	1	0
Czech Republic	61	78	17
Denmark	32	36	4
Estonia	82	101	19
Finland	1375	1630	255
France	991	1174	183
Germany	420	578	158
Greece	79	92	13
Hungary	21	73	52
Ireland	67	82	16
Italy	458	520	62
Latvia	138	166	28
Lithuania	116	134	18
Luxembourg	7	8	1
Malta			
Macedonia	20	23	3
Netherlands	29	45	16
Norway	1303	1453	151
Poland	280	355	75
Portugal	74	90	16
Romania	54	94	40
Serbia and Montenegro	52	69	17
Slovakia	13	24	10
Slovenia	19	23	4
Spain	348	419	70
Sweden	2461	2709	249
Switzerland	306	334	28
United Kingdom	317	386	69
EU27	7589	9012	1422

8.5.3. Impact of greening direct payments on nitrogen retention at catchment scale (FI-GREENCAP and FI-FERTRED)

The Finnish agri-environmental program is a main tool for implementing different water policies including the EU Water Framework Directive (WFD) and the EU Nitrates Directive to control nutrient load from agricultural areas. An agri-environmental subsidy program (EEC, 1992) that has water protection as one of its main objectives has been in place in Finland since 1995. This program was used to define current situation in agricultural water protection (FI-BAU). Although the agri-environmental program is on voluntary basis, over 90% of farmers have joined to it. The program consists of basic, additional and special measures. Obligatory basic measures contain maximum allowed fertilization levels for different crops, e.g. 100 - 120 kg N ha^{-1} for spring cereals. Furthermore, a minimum of 5% of crop area should be left as set-aside. Farmers should also choose some of the additional measures, e.g. reduced fertilization and winter-time vegetation cover on cropland. Special measures refer to the construction of wetlands or 15m wide buffer zones.

The FI-GREENCAP scenario is based on the greening measures as proposed by the new CAP proposal (ecological set-aside area increase up to 10-15% of the total crop area; crop diversification with at least 3 crops cultivated and spring cereals cover <40% of field area; grass cover >10% of field area, Table 8.2). The FI-GREENCAP scenario differs from the EU-GREENCAP scenario in that it includes an additional measure of 50% of total crop area under wintertime vegetation.

The FI-FERTRED scenario assumes 100% of the area under reduced fertilization with a nitrogen balance decreased to 20 kg N ha^{-1} and manure spreading allowed only during the growing season.

Nitrogen loading in FI-BAU scenario is 119 ton per year for the Lepsämänjoki catchment and 237 ton per year for the Yläneenjoki catchment. Relative to the FI-BAU scenario, nitrogen loading decreased between 5 and 14% for the Lepsämänjoki catchment, and between 7 and 21 for the Yläneenjoki catchment. However, crop diversification including the maintenance of permanent grassland resulted in higher nitrogen loading relative to the BAU.

Figure 8.12 shows the change in both unit value and total value for each catchment that arises from changed water purification services as a result of implementing the measures under FI-GREENCAP and FI-FERTRED. Unit value (€ km^{-2} of target area) refers to the value that arises from implementing the measures in the target area only. As specific measure ecological set-aside had high unit value, but because target areas for set-aside were relatively small its total value was lower than that of reduced fertilization and wintertime vegetation cover. In the Lepsämänjoki catchment wintertime vegetation cover gave the highest total value but in the Yläneenjoki catchment the highest total value was apparent in for the reduced fertilization measures, probably because of the high amounts of nutrients that are distributed on fields via manure. Crop diversification resulted in either zero or negative benefits. This requires some attention as crop diversification is supposed to be a measure resulting in lower nitrogen leaching. In the FI-BAU scenario spring cereals (mainly barley) were the main crop and they require relatively low fertilization levels. These are not applicable any longer in scenarios where the area of other crops (in particular oilseed) with higher fertilization levels increase in size and result in increased N leaching. Futhermore, there is only one yield per year in Finland, so there is no possibility to have N fixing crops in winter. Wet springs during snow melt therefore increase the risk of high nitrogen leaching under crop rotation schemes that include crops that need higher fertilizer rates than barley.

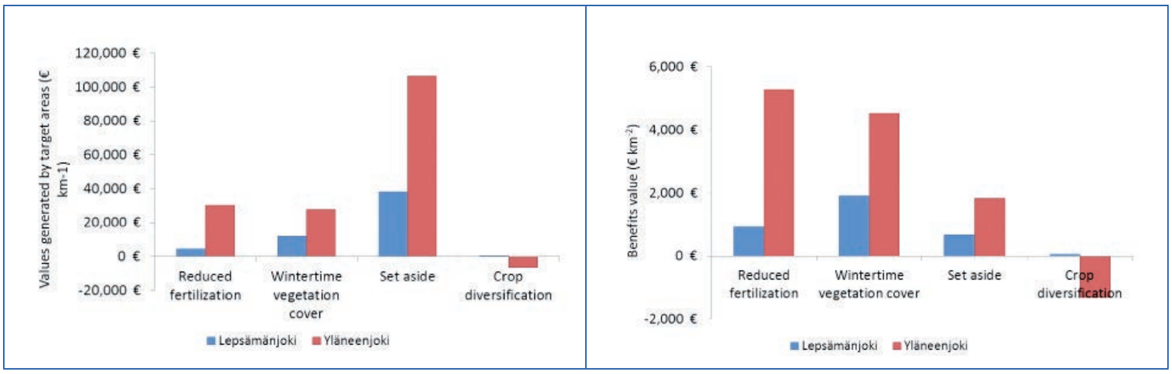


Figure 8.12. Value generated by water purification services assuming measures taken under the FI-GREENCAP and FI-FERTRED scenarios relative to FI-BAU scenario. Left: values per ha of target area. Right: values per ha (based on the entire catchment).

8.5.4. Impact of greening direct payments and river restoration measures on nitrogen retention at catchment scale (UK-GREENCAP and UK-WETRESTORE)

The UK case study on the Yorkshire Ouse catchment involved the analysis of two scenarios. The UK-GREENCAP scenario included two measures: an area measure, the Environmentally Sensitive Area (ESA) scheme and a pro constraint, a farm-level compulsory rate of ecological set-aside. For the baseline situation (UK-BASELINE) and for the two modeled measures, land use profiles were generated using an econometric model developed at the University of East Anglia (in the RELU-funded ChREAM project, reference RES 227-25-0024), based on a profit criterion associated with an optimal allocation of land use. Introduced in 1987 and undergoing various extensions in subsequent years, the voluntary UK Government ESA scheme, for which farmers received monetary compensation, had the purpose of safeguarding and enhancing areas of particularly high landscape, wildlife or historic value. The environmentally-friendly farming practices most widely undertaken were converting arable land to permanent grassland and establishing hedgerows. In the scenario used here it was assumed a 100% uptake rate of this scheme in the Yorkshire Ouse catchment. For the second measure, the compulsory rate of set-aside was fixed at 20%. This UK-GREENCAP scenario was compared to the EU-GREENCAP and EU-BAU scenarios.

The UK-WETRESTORE scenario refers to measures related to the restoration of aquatic habitats through the manipulation of channel hydromorphology were investigated, these were the reintroduction of natural meanders, and the removal or inclusion of weir structures. In practice for the case study, simulation of the reintroduction of meanders involved increasing the river length by 10% in the 27.7 km navigable stretch of the River Ouse upstream of the main tidal limit. This is a purely hypothetical exercise and is not based on potential interventions that are plausible in the context of the actual hydromorphology of the valley and floodplain of the Ouse. The scenario should be viewed more as a sensitivity analysis of the model. However this degree of change in river length could be achievable in rivers/catchments of this size, and such measures have been reported to have a substantial impact on nitrogen retention (Wagenschein and Rode, 2008). Regarding the impact of weirs, a 17 km stretch of the River Nidd (a tributary of the Ouse) was studied. The hydraulic load of the river stretch was calculated in the presence or absence of a weir near the downstream end of this stretch. Due to time constraints the assumption was made that this weir is typical of the 20 weirs in the Ouse catchment. The removal of weirs is a measure that has been included under river basin management planning as a means to comply with the EU WFD. Specifically it has been proposed for improving ecological status of rivers including the Ouse.

The river restoration scenario applications were quantified relative to the baseline represented by the present day land use information (UK-PRESENTDAY), though by a necessity brought about by data restrictions they were calculated for different conditions (under year-specific annual mean flow conditions for 1997-1999 in the case of river re-meandering and under daily flows for 1997 in the case of removal of weirs). For all applications, soil maps used were based on a UK classification of soil properties (Boorman et al., 1995). The input climate data and observed river outputs were based on the period September 1999 - August 2003. The spatial resolution of land-use information differs between the EU based scenario and the UK based scenarios. Continental scale resolution involved 14 units of an average size of 237 km^2 whereas the catchment-scale dataset includes 144 units with an average size of 23 km^2. The estimated spatial pattern of present day land use at catchment scale was derived using the method of Posen et al. (2011) and is based on data from 2000 (satellite imagery) and 2004 (Defra agricultural census). In the 3315 km^2 Yorkshire Ouse catchment the total river network length modelled by NALTRACES was 325 km. Table 8.7 summarises the results of the applications.

Slight overestimation of mean nitrate-N concentration is a feature of all model applications representing present day conditions. However, it is notable that despite this the correspondence between observations and model estimates in tributaries is good (not shown here). The UK-GREENCAP scenarios appear to have significant beneficial effects (as measured by the effectiveness, Table 8.7). However, it is noticeable that the European-scale scenario GREENCAP has negligible impact (-0.3% effectiveness). The reasons for this unexpected difference in effectiveness are unclear, although it should be noted that the influence of spatial resolution in land-use inputs has a strong impact on the NALTRACES model output. Use of the continental-scale data resulted in larger nitrate fluxes from diffuse and point sources. What is also striking is that apparently moving from a fine to a coarse resolution of land-use information brings about a larger proportion of the nitrate-N input coming from headwater areas of long travel time and therefore an increased opportunity for channel retention. The consequence of this is total river retention predicted by the EU-GREENCAP scenario is considerably more than under the UK-GREENCAP scenario. Furthermore, the use of an econometric model to predict present day land use introduces some uncertainty (as exemplified by the difference between diffuse sources derived from an EU scenario and a UK scenario).

The amount and fraction of nitrate-N retained in the channel is estimated to be greatest at low flows. At such times there is a clearly apparent benefit of having a weir present (UK-WETRESTORE). This is due to the deeper and slower flowing water conditions (found upstream of a weir) which would no longer occur if the weir were to be removed. The additional nitrate-N retained attributable to the weir exceeds 1 kg N day^{-1} at low flows, but in relative terms there are still substantial differences at higher flows (0.3-0.5 kg N day^{-1}). In terms of nitrate-N retention the total benefit of the weir in 1997 was estimated to be 0.197 ton. There are 20 weirs present in the Ouse river network. If it is assumed that (a) the impact of the Skip Bridge weir on nitrate-N retention is typical of all the weirs (b) 1997 is a representative year (it was in fact drier than average with total runoff being only 76% of the long-term mean), then the overall impact of weirs in the Ouse might be 3.94 t N/yr. It must be stressed very strongly that further modelling work is needed to estimate other impacts of weir structures on water quality (such as the substantial influence they have on re-aeration and dissolved oxygen levels) before making a comprehensive appraisal of the water quality impacts of weirs.

The results reveal that changes in land management will have negligible impact on the amount of nitrogen retained within the river network. River restoration has some impact on the fraction retained in channel but it would seem this will make little difference to overall fluxes compared to those changes brought about by UK-GREENCAP.

Table 8.7. Scenario assessment of basin-wide nitrate-N fluxes and concentrations for the river Ouse catchment. The table includes the annual sources, loading and the retention by the river network. The overall effectiveness in terms of reducing catchment outlet nitrate-N loads of each scenario is calculated relative to the baseline or BAU.

<table>
<tr><th></th><th>Point sources</th><th>Diffuse sources</th><th>River retention</th><th>River retention</th><th>Output load</th><th>Nitrogen concentration at outlet</th><th>Effectiveness</th></tr>
<tr><td></td><td>ton year^{-1}</td><td>ton year^{-1}</td><td>ton year^{-1}</td><td>%</td><td>ton year^{-1}</td><td>mg L^{-1}</td><td>%</td></tr>
<tr><td colspan="8"></td></tr>
<tr><td>EU-BAU</td><td>734</td><td>8042</td><td>757</td><td>8.63</td><td>8018</td><td>4.25</td><td></td></tr>
<tr><td>EU-GREENCAP</td><td>734</td><td>8069</td><td>761</td><td>8.65</td><td>8042</td><td>4.27</td><td>-0.3</td></tr>
<tr><td colspan="8"></td></tr>
<tr><td>UK-BASELINE</td><td>619</td><td>8961</td><td>783</td><td>8.17</td><td>8798</td><td>4.67</td><td></td></tr>
<tr><td>UK-GREENCAP Environmentally Sensitive Area</td><td>619</td><td>8263</td><td>723</td><td>8.13</td><td>8160</td><td>4.33</td><td>7.25</td></tr>
<tr><td>UK-GREENCAP 20% set-aside</td><td>619</td><td>8044</td><td>707</td><td>8.16</td><td>7956</td><td>4.22</td><td>9.57</td></tr>
<tr><td colspan="8"></td></tr>
<tr><td>UK-PRESENTDAY</td><td rowspan="3">619</td><td rowspan="3">7656</td><td>671</td><td>8.11</td><td>7604</td><td>4.03</td><td></td></tr>
<tr><td>UK-WETRESTORE Meandering</td><td>680</td><td>8.22</td><td>7594</td><td>4.03</td><td>0.13</td></tr>
<tr><td>UK-WETRESTORE Weirs</td><td>667*</td><td>8.06</td><td>7608</td><td>4.04</td><td>-0.05</td></tr>
<tr><td>Observed</td><td></td><td></td><td></td><td></td><td>5809</td><td>3.61</td><td></td></tr>
</table>

UK-PRESENTDAY uses current land use based on an integration of satellite imagery and agricultural census information. UK-BASELINE uses current land use as simulated by the University of East Anglia's econometric model.

8.5.5. Impact of greening direct payments and river restoration measures on nitrogen retention at catchment scale (DK-GREENCAP, DK-FERTRED and DK-WETRESTORE)

The Danish case study considered the Odense catchment as study area and analyzed the outcomes of implementing an integrated approach to nitrogen reduction using water quality in lakes and in the fjord as endpoints for the cost benefit analysis. The overall methodology for the case study was to carry out a land use based scenario analysis linking policy measures, nitrogen and phosphorus leakage and retention modelling to economic valuation. The analysis used high resolution spatial data enabling an analysis of the spatial distribution of the burden and the benefits from alternative land use policies. Through a comparative analysis of alternative policy measures we compared alternative approaches to reducing the negative impacts of nitrogen leakage from agriculture.

The following scenarios were considered:

DK-GREENCAP. The scenario is modelled using two levels of compulsory set-aside. The lower level of compulsory set-aside is 15%, whereas the high level of set-aside is 25%. Each farm is forced to comply with the set requirement when choosing which crops to grow. This means that the lowest output areas will be taken out of production as the model farmers seek to optimise farm net returns. For farms that are unable to meet these requirements due to their percentage of non-rotational fixed crops (e.g. orchards, forests etc.) the requirement is set to their maximum feasible amount

DK-FERTRED. This scenario is modelled using two levels of N taxation, maintaining the relative prices of artificial fertiliser and farm yard manure. The farms respond to these changes by changing their crop distribution and fertilisation in order to maximise their profits under the new conditions. From this maximisation a new map of land use and associated fertilisation can be constructed.

DK-WETRESTORE. The wetland construction scenario is based on identification of 14 sites from the potential wetland areas. The nitrogen leaching from the root zone in the direct watershed is estimated whit the NLES model and the Base Flow Index (BFI) is used to estimate the amount of nitrogen that runs through the wetland via drains (Ovesen et al. 2000, Hoffmann et al. 2005). Approximately 50 % of the drained nitrogen is removed within the wetland. It is also assumed that fields within the wetland are taken out of production and therefore no fertilizers are applied.

We compare the scenarios by mapping their benefits relative to a baseline. The benefits are measured through the benefits from enhanced water quality in the catchments fresh water bodies.

The baseline model DK-BASELINE uses three types of data: spatially-explicit data on crop choice by farmers, data on 2270 farm holdings including area of land cultivated for each crop and the number of 21 types of livestock at each property, and data from an economic valuation study of water quality improvements in three water bodies in the catchment; the fjord, the river and the largest 10 lakes (methodology based on the AQUAMONEY project, http://www.aquamoney.org/). These data stem from a choice experiment valuing changes in water quality using the Water Framework Directive classification; “poor”, “moderate”, “good” and “very good”. Currently the water quality in all water bodies is classified as “poor”. The valuation experiment is designed to value hypothetical improvements from the current status to the different levels of improved quality. The data includes responses from 359 individuals sampled from the island. Socio-demographic variables collected include income and distance to the individual water bodies. The base year of the model calibration is 2005 and all prices and other data are taken from this year unless otherwise noted. In the baseline the compulsory set-aside area is 8% for each farm in accordance with the legal requirements in 2005. The observed crop allocation and fertilisation in the catchment in 2005 is used to calibrate the model. For details on the methodology for calibration see Fonnesbech-Wulf et al. (2011).

Farmers are predicted to shift between winter and spring cereals in response of the four policy measures relative to the baseline (Figure 8.13). The largest shift in crop choice is predicted to be the high nitrogen taxation scenario.

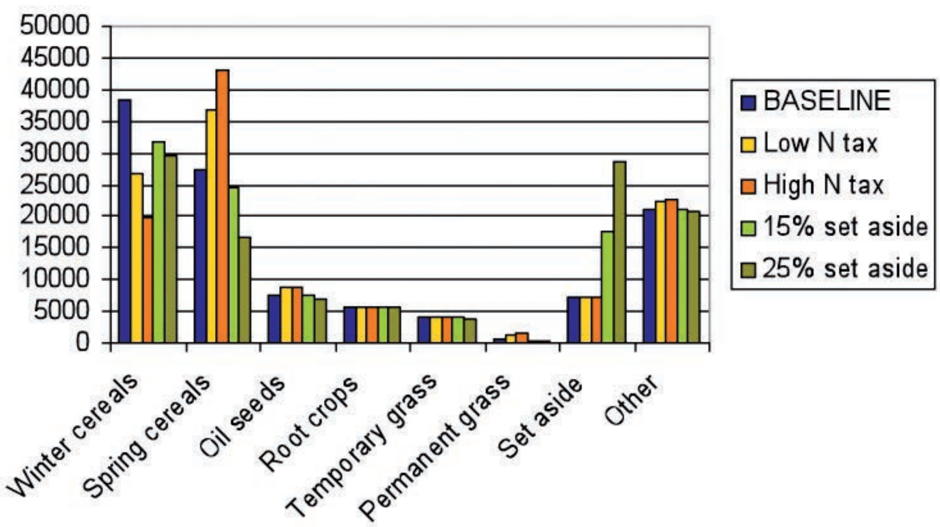


Figure 8.13. Land-use change under the different policy scenarios relative to a baseline (ha)

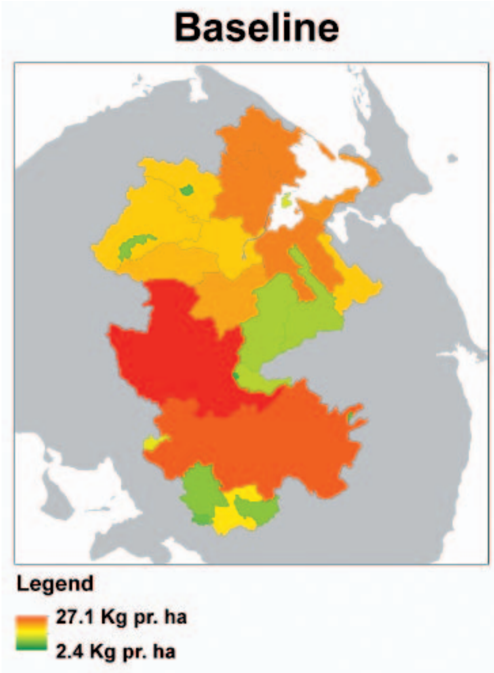
The scenarios also show significant average reductions in fertiliser application. Linking the land use scenarios to the nitrogen retention models the reductions in nitrogen load to the fjord and lakes can be modelled. Table 8.8 shows the reduction in nutrient load in the water bodies and the associated change in water quality status. The nitrogen reduction targets to achieve moderate and good water quality status in the fjord are 385 ton and 769 ton respectively. The phosphor reduction targets to achieve moderate and good water quality status in the lakes are 162 kg and 323 kg, respectively.

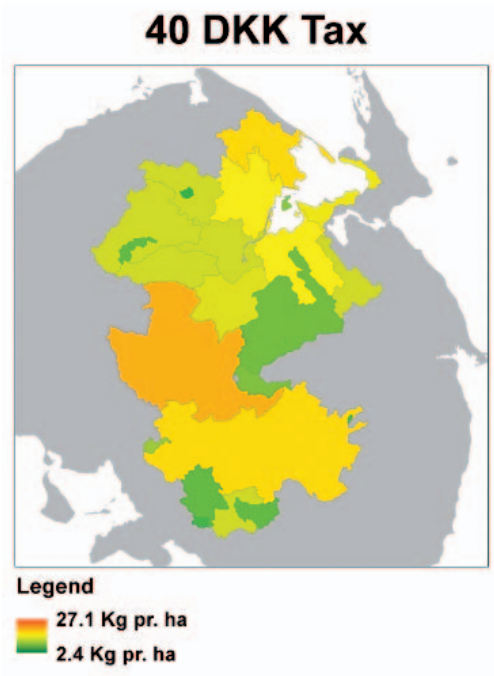
Using the results from the nitrogen retention modelling (Table 8.8) and the WTP function (Table 8.5) we can show the spatial distribution of the demand for water purification services across the case study area resulting from water quality improvements of each scenario.

Table 8.8. Changes in average fertiliser application, N-retention and the benefits in terms of water quality improvements predicted for the scenarios.

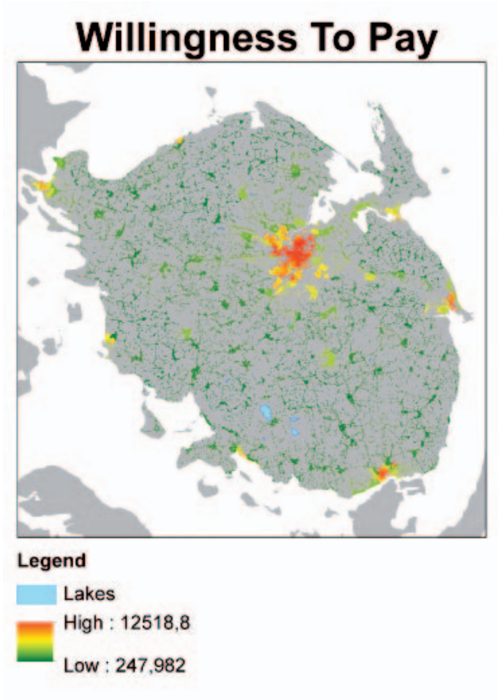
Scenario	Fertiliser reduction (kg/ha)	N load to Fjord (ton)	N retention (ton)	P reduction to lakes (kg)	Water quality Fjord	Water quality Lake	WTP Million € year[1]
Baseline model		1838		n/a	Poor	Poor	
N tax$_L$	79	1479	359	n/a	Moderate	n/a	31.3
N tax$_H$	101	1404	434	n/a	Moderate	n/a	31.3
Set-aside 15%	12	1715	123	342	Poor	Good	34.4
Set-aside 25%	24	1570	268	538	Poor	Very Good	27.9
Wetland		1747	91	n/a	Poor	n/a	

Contribution of catchments to the nitrogen loading to the fjord





Spatial distribution of the economic value per grid cell that arises from implementing the scenario to the left of this table



Values in DKK per gridcel

Figure 8.14. Nitrogen contribution to the fjord for the baseline and the high taxation scenario and spatial distribution of the economic value per grid cell that arises from high taxation.

8.6. Discussion

This study has demonstrated the possibilities to couple biophysical and economic assessments of water purification services using nitrogen as indicator policy scenarios at different spatial scales. The focus of this PRESS study was indeed on exploring methods that calculate the benefits of ecosystem services that arise from policy implementation. Benefit estimates based on the ecosystem services approach are often neglected in impact assessments.

The approach of this study was pragmatic. Each case study used available expertise and models to implement a set of predefined scenarios which all involved land-use change. The scenarios described land-use change that arises from (1) a new agricultural policy aiming to a more sustainable production of crops and livestock or from (2) the restoration of aquatic habitats such as wetlands and rivers. Such policy measures are expected to have beneficial effects on water purification services delivered by aquatic ecosystems through an enhanced self-cleaning capacity and a reduced nitrogen loading.

Table 8.9 summarizes the direction of change of water purification services (as indicated by nitrogen retention) by ecosystems following several policy scenarios. In general, the conclusion is that greening direct payments to farmers, introducing measures to reduce fertilized application and the restoration of wetlands results in positive effects on water purification services increasing the benefits to society as measured via a monetary valuation.

Table 8.9. Direction of change in water purification following the implementation of different scenarios.

Scenario name	Measures	EU	UK	FI	DK
GREENCAP Greening the CAP proposal	Permanent grassland		↗		
	Crop rotation/ diversification	→		↘	
	Ecological set-aside (ecological focus areas)		↗	↗	↗
	Green cover			↗	
FERTRED	Reduced fertilizer application			↗	↗
WETRESTORE	River restoration		→		
	Wetland restoration	↗			↗

→ change in nitrogen retention less than 5%
↘ 5% decrease in nitrogen retention
↗ 5% increase in nitrogen retention

There are, however, some important differences between the studies that warrant some further discussion. In particular the difference between a European scenario on greening direct payments relative to catchment specific scenarios is apparent. At European scale losses in arable land and certain crops in one area are predicted to be compensated for in other areas, since EU food demand is not expected to change substantially. As a result, the summed changes in land use and nitrogen inputs are relatively low. These results are largely in line with two recent publications that have assessed the impact of the proposed greening measures under the first pillar of the EU Common Agricultural Policy. A study by Lavalle et al. (2011, Joint Research Centre) has modeled land use change of an integration scenario (including ecological focus area, permanent pasture and payments for Natura 2000 sites) relative to a status quo scenario with 2020 as time horizon. The focus of this study was to make projections for several indicators including soil carbon storage, green infrastructure and conservation of natural areas. They concluded that greening options reduce the pressure on nature and on environmentally sensitive areas but all in all, the EU averaged impacts are relatively low as similar for our study. A second study (Van Zeijts et al. 2011, PBL, Netherlands Environmental Assessment Agency) has studied ex ante the impact on farmland biodiversity that would arise from implementing the greening measures of the CAP proposal by 2020. According to the study, greening the CAP may result in 3% more species richness on EU farmland, but this must be seen relative to a downward trend in biodiversity.

These studies contrast with the higher impacts that greening measures are predicted to have at local scales in the different study sites. Scenarios and models are not embedded in regional, national or EU scenarios and allow a more rigid enforcement of measures without considering the impacts on other areas. For instance, local restrictions on fertilizer application may increase the demand for food imports which, in turn, results in higher fertilizer rates elsewhere. Accounting for these effects was not possible in this study but it shows the need for embedding local scenarios and modeling in regional to global contexts.

Biodiversity was not included explicitly in the models used in this study. Yet, more and more it becomes clear that biodiversity positively influences ecosystem functions that are essential to provide ecosystem services. For instance, Cardinale (2011) showed that a higher diversity of the community of algal species increased the nitrogen uptake capacity justifying efforts to protect and conserve aquatic biodiversity. Upscaling parameters that describe the biodiversity-ecosystem function relationships to landscape level in order to make inferences on ecosystem services still requires basic research (Cardinale et al. 2012).

Importantly, this study also shows that there are no miracle solutions to be expected from agricultural policy to problems with excess nitrogen. From one side, it can be argued based on this study that the greening options do not go far enough and require larger proportions of ecological set-aside. Furthermore, the Finnish case illustrated clearly that an additional measure which was not retained in the final version of the CAP proposal, green cover during winter, can result in further reduction of nitrogen leaching to the river network. However, any debate on the negative tradeoffs of nitrogen use has to consider synergies as well. Both Table 8.1 and Figure 8.1 already showed the many beneficial services that are related to nitrogen use including food, timber and fish production. So, unless we are able to change considerable our food demand and diet preferences, nitrogen loading of the environment is likely to continue explaining the marginal changes at EU level predicted by this study.

Wetland and floodplain restoration were shown to contribute significantly to the reduction of nitrogen in surface waters and decrease the loading to European coastal zones. Additional benefits are flood protection, increased habitat for species, in particular birds, and enhanced opportunities for particular forms of recreation. Floodplain reconstruction is expected to result in losses in cropland and pasture, which again shift away the problems and increase nitrogen applications on cropland to other regions in our outside Europe. Therefore, also ecosystem restoration can only be part of a more integrated approach to nitrogen reduction in the environment involving all sectors and policies.

9. Mapping and assessment of recreation services

9.1 Introduction

Cultural ecosystem services are defined as "non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experience"(Millennium Ecosystem Assessment, 2005). Examples of cultural ecosystem services are spiritual and religious values, ecosystems as source of inspiration (i.e. for arts and design), aesthetics, recreation and tourism.

Among these, recreation is the ecosystem service identified in PRESS to show how ecosystems can provide, as benefit, a cultural ecosystem service to citizens. More specifically, the type of recreation here addressed consists in the benefit drawn in daily life, from enjoying reading the newspaper sitting in the closest green urban area, to a bike ride after work, to a daily trip to nature. All ecosystems are considered to be potential providers of the service, irrespective from their conservation status, though the range of provision changes accordingly to it. Tourism and long distance (>100 km) traveling is not included in the exercise, since it would require a different approach.

As mentioned in Maes et al. 2011, contrarily to other services such as provisioning and regulating, that are providing their flow of benefits independently from the presence of human beings, recreation has the peculiarity of requiring a human agent who performs the action of recreating. For this reason the ecosystem services cascade model when applied to the recreation service is structured in three parts (Figure 9.1).

First component: the potential ecosystem service (or service stock) is provided in principle by all ecosystems, with a provisioning intensity that ranges from "low" when the ecosystems are heavily managed and the rate of biodiversity is low, to "high" in the case of pristine vegetation or habitats where management intensity is low, and that can host a high rate of biodiversity.

Second component: since humans must recreate in order for the ecosystem service flow to happen, infrastructures are needed to make the sites accessible. In this case as well a range in the degree of accessibility is considered. Infrastructures include facilities for recreating in nature (hiking trails, snow tracks, birdwatching towers, harbours etc.), the road network, the presence of urban centers.

Third component: the action of recreating. This is when the flow of the benefit takes place, and is a combination of potential provision and accessibility. Valuation of the service is part of this component.

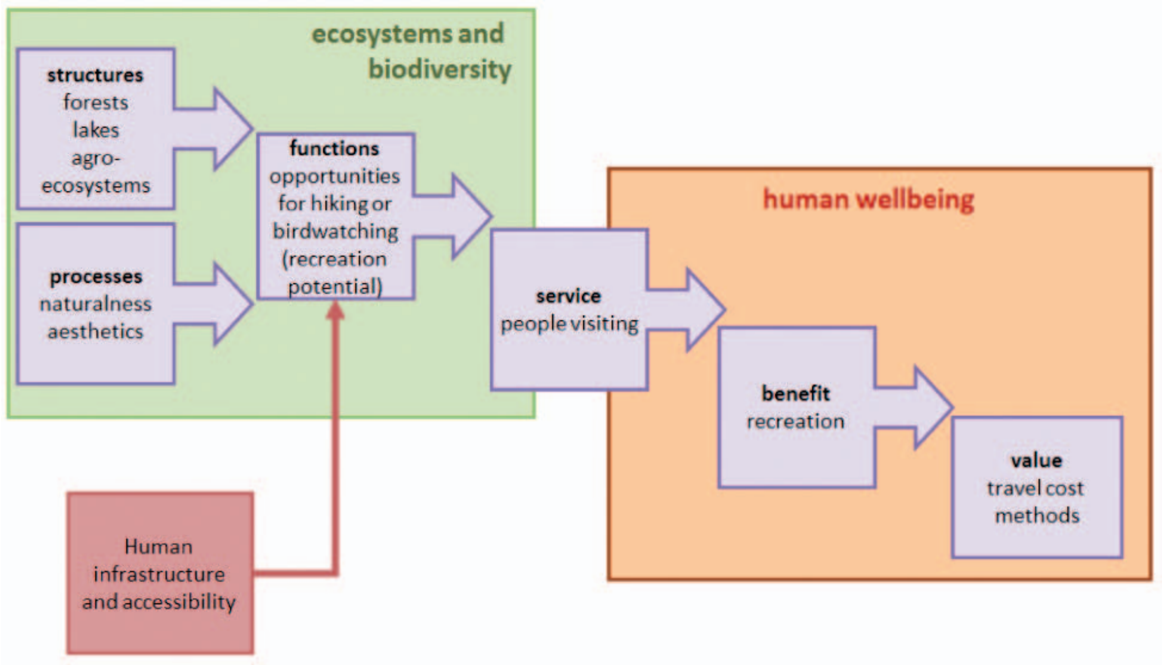


Figure 9.1. Application of the ecosystem services cascade model to frame indicators for mapping recreation services

In this study recreation is addressed in its different components. The approach presented in Maes et al. 2011 has been refined and applied at the EU level and at national level on Finland. These concern recreation in nature in daily life. A specific study was carried out on green urban areas, as these are a main source for recreation in towns and cities. A scenario of land use change including demographic projections to 2030 has been modelled and the change in provision of the benefit to Finnish population has been calculated. Valuation of the service has been done through test cases in Finland and Denmark. Visitor surveys have been used both to model the behaviour of people when they recreate (i.e. in terms of travelled distance and preferred habitat types), and in the valuation process.

9.2 Estimating visitors number and patterns of recreation trips

One of the aims of the research carried out in PRESS is to test the applicability of national recreation inventory data for mapping recreation as ecosystem service. Visitor surveys are used to estimate people's preferences for ecosystems when they recreate plus related information on travel distance, and to valuate recreation as ecosystem service through travel-cost and willingness to pay methods. These are approaches worth developing also from the European perspective as an EU-wide visitor survey is not available, but national inventories of outdoor recreation have been conducted in several European countries (Sievänen et al. 2008).

9.2.1 Finland

9.2.1.1 The National outdoor recreation demand inventory

To analyse the recreation and rural tourism demand the presented study makes use of data from the National outdoor recreation demand inventory (LVVI2) by the Finnish Forest Research Institute. Statistics Finland, on an assignment of Finnish Forest Research Institute (Sievänen & Neuvonen 2011), conducted a LVVI2 population survey in 2009–2010. During the data collection a total of six survey rounds was performed, three times per year: in winter, in spring and in fall.

A random sample of Finnish citizens aged 15 to 74 years was drawn from the Census of Finland. In each round 4000 (24 000 in total) respondents were contacted. The data was collected using a web-based survey supported by mail questionnaire (mixed-mode method). After sending the first request to respond to the internet survey a reminder was sent, and after that a mail questionnaire (including still a possibility to answer the web survey) was sent to those who had not answered to the internet survey. The fourth contact was a reminder postcard for those who had not returned the mail questionnaire. The response rate was 37% and consequently data were received from 8 895 respondents. Of the sample 23% answered via internet and 14% via mail questionnaire.

The respondent's received questions about participation in outdoor activities, some basic descriptive questions of the most recent recreation visit close-to-home (day visits), and most recent nature trip (including overnight stay). According to which survey round they answered they had also questions about different sub-themes of the research: health and well-being effects of outdoor recreation, how recreationists relate to environmental changes, and how they use private-owned land for outdoor recreation. Variables describing respondents' socio-economic background were either measured, e.g. employment status, household size, and monthly household income, or obtained from registers, e.g. residential region, gender and age.

To avoid the response burden about two thirds (69%) of the respondents were asked more precisely about their most recent close-to-home recreation visit and around one third (31%) of the most recent nature trip. Thus information about day visits and overnight trips was obtained from 6131 and 2761 respondents respectively. The characteristics of the most recent close-to-home recreation visit or nature trip measured were the duration of the visits or length of the trip, activities, companions, mode of transportation, destination region and site type, distance to the destination, and facilities and services available at the destination. Also the number of previous visits was asked to be reported.

First the respondents were asked if they had made at least one such visit or trip during the previous 12 months. This information formulated the variable describing the participation rate for close-to-home visits or nature trips. If the respondent had made such a visit or trip, more information of the latest trip was asked. The information of how many days ago the previous visit or trip was conducted and the information about the intended timing of the next visit were used to estimate the annual number of close-to-home recreation visits and nature trips for each respondent.

Interesting results that can be drawn from the survey and that provide a clear indication on the behaviour of residents when they recreate concern their preference for the destination type, and the traveled distance. Survey statistics show clearly that areas owned by private landowners, municipalities or state where the use is based on public access to the land (so called "Everyman´s right") are very important for recreation by Finnish population. (Figures 9.2 and 9.3), that second homes also play a relevant role in recreation activities (Figure 9.4), and they also show that 80% of respondents travel a maximum of 8 km for recreating (Figure 9.5). This highlights the importance of the potential provision of recreation by ecosystems in the surroundings of places of residence.

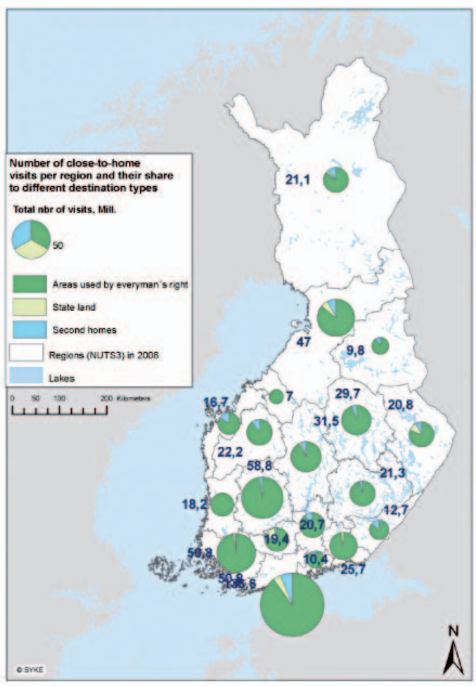


Figure 9.2. Close-to-home recreation visits and the destination types reported by survey respondents. Source: Metla/LVVI2 data.

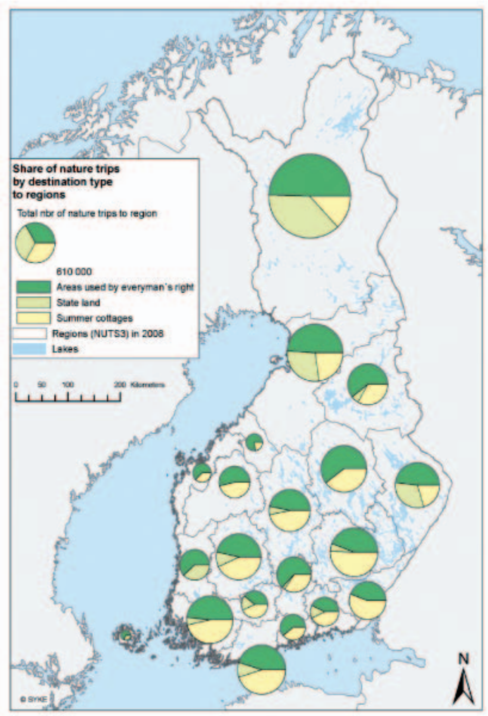


Figure 9.3. The total number of nature (overnight) trips to a region and the share of destination types. Source: Metla/LVVI2 data.

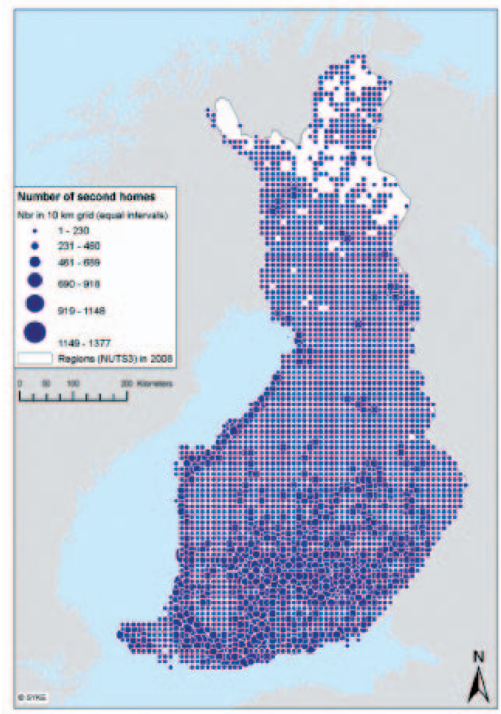


Figure 9.4. Number of second homes and their use regionally. Source: SYKE, Population Register Centre 4/2010 and Metla/LVVI2 data

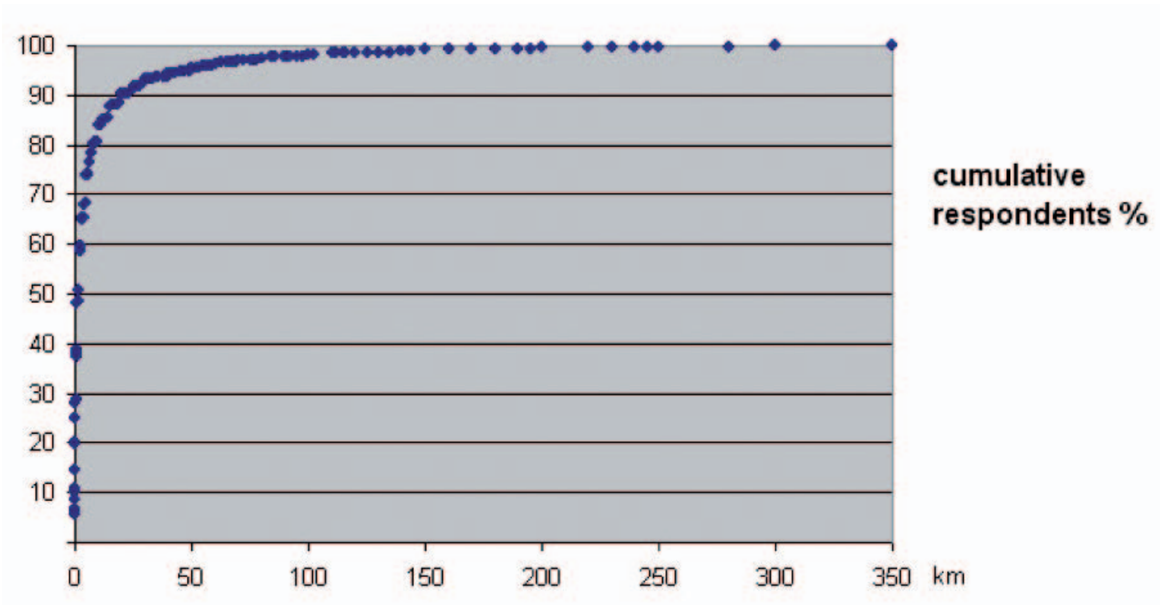


Figure 9.5. Cumulative % of respondents in relation to travelled distance in close-to-home recreation visits.

9.2.1.2 Number of trips

In this study the aggregate number of day visits and nature trips per region was calculated. The total number of day visits was obtained regionally by multiplying the number of adult citizens with the share of participants and with the average number of day visits based on survey data. The distribution of day visits was derived from the respondent reported distance, which is typically calculated from home to close-to-home recreation areas. Four classes of distance were identified for the day visits, on the basis of the statistical distribution of data, and correspond to the quartiles of the cumulative distribution (25% of the cumulative distribution accounts for trips up to 250 m from home to the recreation site, 50% accounts for trips up to 1.5 km, 75% accounts for trips up to 6 km, the 100% of the cumulative distribution is reached at 360 km, truncated to 50 km in Table 9.1). This means that the great majority of trips is made in the immediate surroundings of the place of residence. The 'type of location' classification was constructed so that it corresponded with the available spatial information (see Maes et al., 2011) of the existing recreation model. The first category is represented by private areas or areas owned by municipalities or state where the use is based on public access to the land (the so called "Everyman's right"), the second category is related the State-owned areas identified for recreation and nature conservation purposes, and the third category corresponds to leisure homes (summer cottages) and areas surrounding them. Furthermore, the Helsinki metropolitan region was analysed more in detail. In this case the postal code areas and the distance classes were used to locate the day visits. Such database contains altogether data on 510 respondents, 22 postal code areas, and 4 municipalities in the Helsinki Metropolitan region.

The number of overnight nature trips was obtained by sharing the total national number of nature trips to the destination regions (Nuts3 level) based on the distribution of destinations as reported in the data. The number of trips was further divided into three area categories similar to the areas used for close-to-home visits.

Three quarters (75%) of the day visits lasted 0.25–2.0 hours and two thirds of the visits (68%) took place only at a walking distance from the starting point which in most cases was the respondents' place of residence. The average duration of a day visit was 2.1 hours and the standard deviation was 2.37 hours. The average length of overnight trips was 5.2 days and the standard deviation 6.48 days. Average distance travelled were 296 km, but more than half (57%) of the trips were done maximum 200 km from the respondents' permanent residence.

9.2.1.3 The recreational use

The recreational use of nature per region is reported in Table 9.1. The table shows the number of close-to-home recreation visits per region. Although there is some variation in the activity of close-to home recreation between regions the main driver of the total number of trips is the number of population per region. Already these first results show the importance of green areas in the most populated parts of the country (i.e. Uusimaa, the Helsinki region). When close-to-home recreation visits are further divided into the three categories mentioned above (everyman's right, State land, summer cottages), the importance of the everyman's right can be clearly seen in the regional distribution. On every region the areas used on the basis of everyman's right collect considerably more visits than State areas or summer cottages. The distance based distribution of close-to-home trips varies regionally, while the importance of the closest green areas is emphasized in the southern (and most populated) part of the country.

Table 9.1. Number of day visits per region by area types for Finnish citizens aged 15 to 74 years (break down of total visitor statistics over different types of land and over the distance to home).

				Visits, million							
Nuts 3	Population, milj.	Participation, %	Visits per year, avarage	total, million	everymans right	state areas	summer cottages	0-250 m	251-1000 m	1000-5000 m	5000-50000 m
Uusimaa	1.09	97	129	136.4	121.8	5.2	8.3	40.0	32.6	35.6	28.2
Varsinais-Suomi	0.35	94	154	50.4	49.1	0.7	0.6	12.5	10.5	14.0	13.5
Satakunta	0.17	95	113	18.2	18.2	-	-	4.6	4.9	4.5	4.3
Kanta-Häme	0.13	90	166	19.3	14.8	3.8	0.7	6.0	3.7	3.8	5.8
Pirkanmaa	0.36	100	162	58.8	57.3	-	1.6	14.5	18.6	16.1	9.6
Päijät-Häme	0.15	95	142	20.5	18.2	-	2.3	7.1	4.1	4.5	4.8
Kymenlaakso	0.14	100	187	25.7	24.9	0.8	-	7.3	4.7	6.7	7.0
Etelä-Karjala	0.10	97	129	12.7	10.9	-	1.8	4.3	3.1	2.1	3.2
Etelä-Savo	0.12	97	188	21.3	19.6	-	0.8	5.8	6.1	5.5	3.9
Pohjois-Savo	0.19	97	164	29.7	28.2	-	1.5	10.2	6.6	6.5	6.4
Pohjois-Karjala	0.13	97	171	20.8	16.9	2.3	1.7	5.2	3.5	4.7	7.4
Keski-Suomi	0.20	97	158	31.3	29.0	0.5	1.8	8.2	7.7	8.7	6.8
Etelä-Pohjanmaa	0.14	96	163	22.1	19.8	-	2.3	5.5	4.6	6.1	5.9
Pohjanmaa	0.13	96	135	16.7	14.0	-	2.6	3.0	2.9	6.6	4.1
Keski-Pohjanmaa	0.05	96	140	7.0	7.0	-	-	2.2	1.7	1.7	1.4
Pohjois-Pohjanmaa	0.28	100	166	47.0	40.4	2.8	3.8	14.8	8.6	11.6	12.0
Kainuu	0.06	97	162	9.8	8.8	-	1.0	2.4	2.7	2.8	1.9
Lappi	0.14	95	159	21.0	18.0	0.6	2.4	4.6	3.4	7.0	6.0
Itä-Uusimaa	0.07	92	163	10.4	9.6	-	0.9	5.2	0.7	1.2	3.2
Ahvenanmaa - Åland	0.02	100	120	2.5	2.5	-	-	0.6	-	1.1	0.8

Table 9.2 shows the number of nature trips per region of destination. In this type of trips, beyond to the most populated areas, such as Uusimaa, that reach a high share in the total number of trips, the role of the most resource rich areas in northern Finland, particularly Lapland, is outstanding. The areas which are visited based on everyman's right are still the most important destination category, but particularly in the eastern part of the country the share of trips directed to summer cottages becomes significant. In the northern part of the country the areas identified in Maes et al., 2011 as important for their potential of recreation provision, i.e. for the presence of State areas such as national parks, show a high number of trips.

Table 9.2. Nature trips (which include an overnight stay) to each region and area type, population Finnish citizens aged 15 to 74 years.

	Visits, million			
Nuts 3	total numer of visits, million	everymans right	state areas	summer cottages
Uusimaa	0.92	0.42	0.09	0.42
Varsinais-Suomi	0.86	0.41	0.04	0.40
Satakunta	0.36	0.22	0.14	0.00
Kanta-Häme	0.27	0.11	0.05	0.12
Pirkanmaa	0.81	0.38	0.08	0.35
Päijät-Häme	0.47	0.30	0.01	0.16
Kymenlaakso	0.32	0.14	0.05	0.14
Etelä-Karjala	0.54	0.24	0.00	0.30
Etelä-Savo	0.90	0.40	0.05	0.46
Pohjois-Savo	0.83	0.50	0.00	0.33
Pohjois-Karjala	0.78	0.37	0.24	0.16
Keski-Suomi	0.68	0.32	0.04	0.32
Etelä-Pohjanmaa	0.38	0.20	0.00	0.17
Pohjanmaa	0.13	0.08	0.00	0.05
Keski-Pohjanmaa	0.11	0.08	0.00	0.02
Pohjois-Pohjanmaa	1.25	0.61	0.35	0.28
Kainuu	0.64	0.38	0.04	0.21
Lappi	2.68	1.33	1.00	0.35
Itä-Uusimaa	0.25	0.16	0.00	0.10
Ahvenanmaa - Åland	0.04	0.03	0.01	0.00

9.2.2 Denmark

9.2.2.1 Household survey and socio-economic data

A national household survey from 1994 is used to estimate how many trips per year people make to forests for recreation (Jensen and Koch, 1997). This is the latest representative household survey made in Denmark in this area. 2916 people between 15 and 76 years were randomly sampled from the national register and surveyed. The response rate was 83.7%. For the purposes of this case study, we retain only questionnaires of people living in the regions of Copenhagen and Frederiksborg (north Zealand), totalling 662 people.

Demographic data were derived from a national digital dataset of 2116 parishes with information on male and female population divided into 6 age classes. Population segments distributed on nodes in the road network were available from the Danish Centre for Forest, Landscape and Planning using a urban land use map. Data on average household income and car ownership were available from Statistics Denmark on parish and local authority level, respectively. Distance to the nearest forests was calculated as the Euclidian distance through road network from home address of respondents to the nearest of the 52 forests that were investigated.

The household survey asked people how often they visited forests during the past 12 months and which mode of transport was used during the latest visit. In the dataset six modes of transport are considered. Frequency of total trips to forests during the past year varies from 0 to 730 with an average of 33.9 trips annually to forests. Assuming that all visits during one year would be made using the same mode of transport as during the latest visit, the distribution of trip frequency by mode of transport can be approximated as shown in Table 9.3.

Table 9.3. Use of transport modes to forests

Mode of transport	Share of sample (N/%)	Avg. trip frequencies
Car	254 (38.4%)	24.7
By foot	211 (31.9%)	61.6
Train	98 (14.8%)	12.3
Bike	84 (12.7%)	22.5
Moped/scooter/MC	11 (1.7%)	20.1
Horse	4 (0.6%)	55.3
Total	662 (100%)	33.9

9.2.2.2 On-site survey data

The estimation of preferences for forest sites is based on a national on-site recreation survey in 592 forests and other natural areas from 1996/1997 (Jensen, 2003). This is the latest survey of its sort carried out in Denmark. The dataset is restrained to state-owned forests in North Zealand, where 93% of the forest area are state-owned and to visitors who come from the regions of Copenhagen and Frederiksborg. The final sample of visitors surveyed in the North Zealand forests is 6987, representing a response rate of ca. 46%.

The survey was based uniquely on people visiting forests on day-trips by car. From the household survey, evidence shows that ca. 49% of visits to forests were made by car, the most frequent mode of transport, followed by going by foot (32%) and by bike (11%).

The actual observed distance is calculated from the home address to the forest that people visited, as well as a distance matrix from the home address to each of the other 52 forests in the region, for all home addresses. Home addresses were treated as the nearest node in the road network and distance calculated using a 1:200 000 scale vector road map (Kort & Matrikelstyrelsen, 1995).

Modelling includes the analysis of data describing the characteristics of the forests. These are based on official forest data of the Danish Forest and Nature Agency and are comparable across forests. Selected characteristics include: travel distance, distance to coast, slope, distance to view point, forest area, planting year, species (family level), presence of water, presence of open spaces (landscape type).

9.2.2.3 Estimating welfare effects of access to forests

In order to establish the welfare effects of having access to forests in the region, the linked site selection and participation model first suggested by Bockstael, Hanemann and Strand (1984) was applied. The model consists of two linked models:

- a discrete choice model based on the random utility approach (RUM), which allocates trips to different sites based on the site attributes; and
- a count data model that predicts total demand of recreational trips to forests. Together they estimate total number of visits and willingness to pay (WTP) per year per site.

Only car-borne visits are included in this model. This type of model is a demand driven recreation model that is dependent both on the socio-demographic characteristics of citizens and the characteristics of sites available such as location, accessibility, size and other site-specific features. The discrete choice model framework allows for taking into consideration the fact that people can choose the destination among a pool of possible choices, and what type of site characteristics they prefer. Combined with a GIS analysis, it also allows for a spatially explicit evaluation of attractiveness and use of forests. For more information on the application of this model, please refer to Zandersen Termansen and Jensen (2007).

Results show that preferences towards species diversity are positive and negative towards fraction of open land in forests. The opposite is the case regarding trees older than 60 years, where the fixed parameter model does not appear to be significantly worse than a mixed model over the 1997 sample. Preferences for species diversity and degree of openness in forests, however, vary with 62% preferring a species diverse and 38% a non-diverse forest and 76.2% a dense forest and 23.8% open forests. Preferences on fraction of trees older than 60 years stay fixed in the 1997 model with a clear preference towards forests with older trees.

More than 60% of the sample populations in northern Zealand appear to prefer coniferous forests to broadleaf forests. Sloped terrain and presence of water bodies also increase the likelihood of a forest being selected. As expected, larger forests appear to be more popular than smaller forests, however with a declining marginal effect. Also sites close to the coast are more attractive than inland forests as the coefficient on the distance from coast is negative. The error term on distance to coast indicates a common substitutability between forests close to the coast and a difference in the substitutability with other forests.

The parameter estimates and the probabilities of the count data model are based on a zero inflated negative binomial model. The inflation function, which estimates the probability of a zero count, confirms that owning a car and increased distance to the forests in the choice set also increases the probability of travelling by car to forests. The negative binomial shows that an increase in inclusive value leads to increased number of car-borne trips taken in a year. Also, the amount of car-borne trips per year increases for people older than 39 years. Income has a significant, albeit small influence on choice of transport mode or number of car-borne trips to forests in the region.

These results, combined with demographic data on the total population and forest attributes, are used to generate total welfare results of ensuring access to these forests. Access is however only valued for car-borne visits. Valuation results are reported in 9.4.3.1.

9.2.2.4 Estimating total visits to forests with all modes of transport

While the on-site survey of trips to forests has the benefit of being based on observed data, the survey was limited to car-borne visits. In order to include non-car-borne visits to forests while keeping a spatially account of forests visits, the approach proposed by Terza and Wilson (1990) was applied.

The approach allows for a combination of a flexible, generalised Poisson model with the multinomial distribution to jointly predict households' choices among modes of transport and frequency of trips to recreation sites. This is a so-called multinomial Poisson model that firstly estimates the choice of mode of transport (Table 9.4) and secondly estimates the number of trips with each mode of transport (Table 9.5).

Table 9.4. Predicted mean probabilities of choice of transport

	Household survey	Regional scale up
Variable	Mean	Mean
Pr of car vs. All other categories	0.388	0.375
Pr of Foot vs. Car category	0.318	0.254
Pr of Horse vs. Car	0.006	0.009
Pr of Bike vs. Car	0.123	0.150
Pr of Moped/MC/scooter vs. Car	0.017	0.026
Pr of Train vs. Car	0.147	0.185
Observations	665	1,131,379

Table 9.5. Observed and predicted frequency of trips

Summary	Observed	Prediction on sample	Prediction on region
Mean	33.9	33.1	23.22
Median	10	28.7	21.9
Minimum	0	0.36	0.78
Maximum	730	76.6	68.4
N	646	665	1,131,379

Table 9.4 lists the mean probabilities for each mode of transport. For the regional population, 37% of trips would be taken by car followed by 25% by foot; 18% by train and 15% by bike. Table 9.5 shows the stated number of trips from the household survey in the region ('Observed') as well as the prediction based on the regression results on the survey sample. The last column shows the prediction for the whole population in the region. Predictions for the whole region are generally lower than the prediction on the sample. This may indicate a higher share of the population living in the municipality of Copenhagen, where the share of the population without a car and with longer distance to the nearest forest is higher. This circumstance lowers the frequency of trips made to forests per person.

The results of the model are then used to rank forests by their popularity as destinations for day-visits from the whole population in the region. Finally a comparison of results provided by the EU-wide model is made.

9.2.2.5. Scaling-up the predictions of visits

In order to distribute trip frequencies to the forests in the region, it is assumed that for non-carborne trips, all trips during the year would take place to the nearest forest. The predicted frequency of trips shown in Table 9.5 was therefore combined with the nearest forest and multiplied with population data (number of adults assigned to the nearest road junction according to census data).

For carborne trips, the total number of visits per forest using a combined random utility model and a count data model was estimated according to Zandersen, Termansen and Jensen, 2007. Results show that the total of yearly car-trips to the 52 forests amounts to 14.5 million and trips with other means of transport sum to 12.1 million trips. A total of 26.6 million trips are made by the population in the region to the 52 forests. On average, each adult in the region makes 23,5 trips per year to these forests per year.

The relationship between car and non-carborne trips is very much in line with national observed share of car borne and non-carborne trips. Jensen and Koch (1997) foundnd that 49% of all trips to forests in Denmark are made by car.

Popularity differs significantly across forests depending on the characteristics such as size, accessibility, presence of water, species and openness. The most popular forest receives some 4 million visits per year compared to ca. 6000 visits per year for the least popular forest (See Table 9.6).

Table 9.6. Total number of forest visits

	Scaled-up number of visits per year
Total 52 forests	26 597 150
Minimum	6 480
Maximum	4 326 447
Average	511 484
Median	179 270

9.2.3 England

For England, the Monitor of Engagement with the Natural Environment Survey (MENE) was used (Natural England Commissioned Report NECR084). This is a national survey on people and the natural environment. The survey provides the most comprehensive dataset yet available on people's use and enjoyment of the natural environment. It includes information on visits to the natural environment (including short, close to home visits) as well as other ways of using and enjoying the natural environment. This dataset relates to the first two years of surveying from March 2009 to February 2011. The survey was undertaken by TNS Research International on behalf of Natural England, the Department for Environment, Food and Rural Affairs (Defra) and the Forestry Commission.

9.2.3.1 On-site survey data

The survey of countryside visitors was used to derive information on preferred habitat types and travelled distances. A first analysis shows that in the case of England the ecosystem type surrounding the trips origin is important, in fact classes like suburban, improved grasslands and arable and horticulture are mostly represented as destinations. On the other hand people travel longer distances to reach extensive/ seminatural environments (i.e. acid grassland, inland rock, heather, bogs, mountain habitats). Statistics on travelled distances (Table 9.7) show that 80% of visitors travel a maximum of 15 km to recreate.

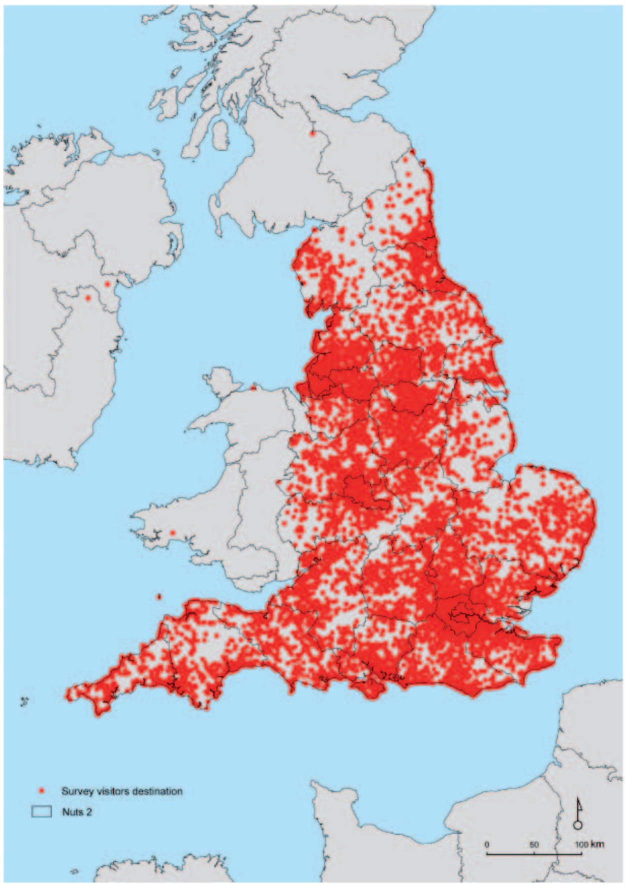


Figure 9.6. England visitor survey – destination sites

Table 9.7. Statistics on travelled distance

Distance (m)	Count	Cumulative	Percent	Cumulative
< 1500	6829	6829	23.4	23.39
1500-3000	6085	12914	20.9	44.24
3000-5000	3897	16811	13.4	57.59
5000-15000	6031	22842	20.7	78.26
> 15000	6345	29187	21.6	100

9.2.4 Collecting visitors data at the EU level

An approach that has been tested to analyse visitors' behaviour at continental scale is based on a collection of information from visitor-monitoring studies available in literature.

For the analysis of a variety of surveys covering different European countries a total of more than 51 visitor-monitoring studies were collected. Each visitor survey was analysed regarding the study design and quality. If it was judged to be qualitative and if all relevant information could be acquired, it was entered into a geo-database. The final database (Figure 9.7) includes 189 visitor estimates, which were collected from 27 publications. Visitor estimates are spread across the UK (120), Denmark (52), Austria (6) and Germany (11). Such data are used in combination with explanatory variables to model visitors behaviour; such explanatory variables are biophysical and socio-economic GIS data (i.e. habitat type, accessibility, population density etc.) as explained in 9.3.1.2.

Figure 9.7. Distribution of collected visitors monitoring sites

9.3. Mapping recreation potential – The Recreation Opportunity Spectrum

9.3.1 EU-wide analysis

9.3.1.1 A Recreation Opportunity Spectrum for Europe

The methodology to address recreation as ecosystem service is explained in detail in Maes et al. 2011 and summarized in Figure 9.8. New developments in the analysis of the degree of naturalness (i.e. Rüdisser et al., 2012) have brought to the revision of the EU-wide hemeroby indicator used in Maes et al. 2011, therefore the whole analysis has been repeated, with some improvements concerning also population pressure.

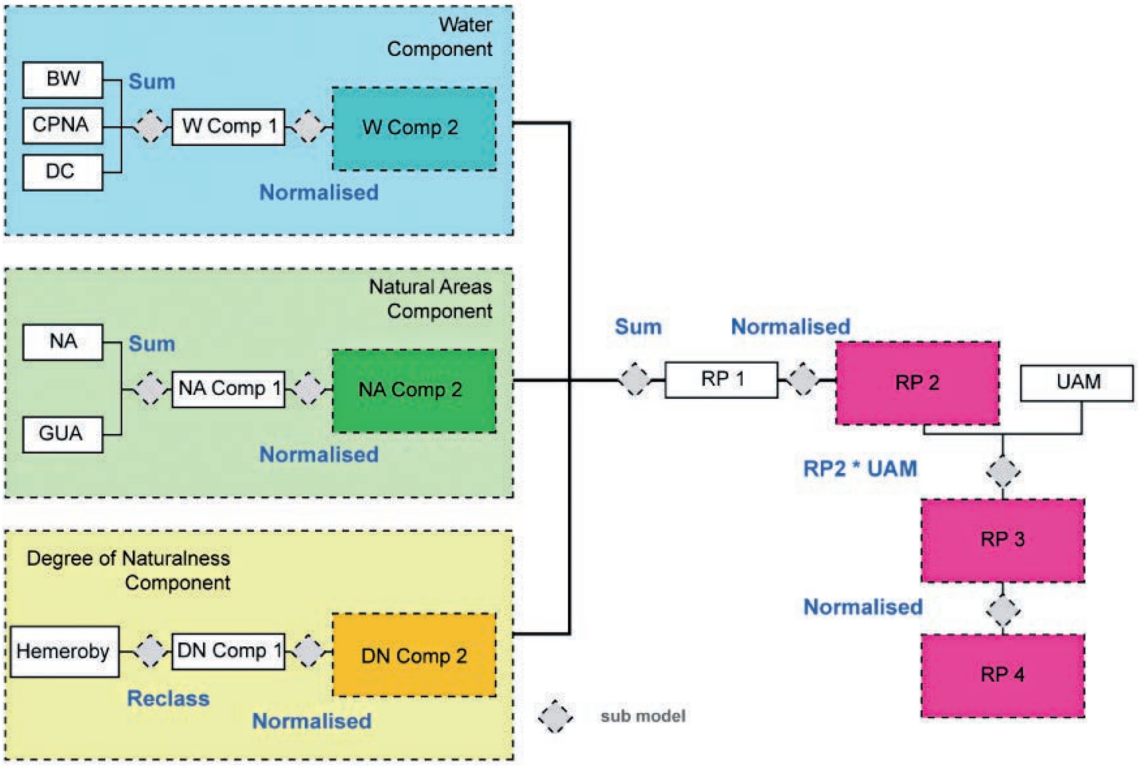


Figure 9.8. Flowchart of the procedure to obtain recreation potential where:

NA: natural areas
GUA: green urban areas
BW: bathing water
DC: distance to coast
CPNA: coast proximity -natural areas
UAM: urban areas mask
W: water
DN: degree of naturalness
RP: recreation potential

In synthesis, recreation potential is mapped with the assumption that it is directly related to ecosystem components that are attractive for leisure: the degree of naturalness, the presence of protected sites which are indicators of valuable habitats and of recreation facilities, proximity of coast and protected marine areas, water quality. These can be grouped in three main components (naturalness, protected areas, andwater) that are assumed to have equal weight in producing the final composite indicator which shows recreation potential (dimensionless) on a 0-1 scale. The selection of these main components of the model tries to optimize on one hand data availability at the EU scale, and on the other findings from the above mentioned surveys, which indicate the preference of people for natural environments, the attraction exerted by the presence of water (whether lake, river or sea), and the fact that people do not seem to travel far away to recreate, but rather look for what it is available in the surroundings of their homes.

The concept used to map how the flow of the benefit can take place is based on the Recreation Opportunity Spectrum (ROS) (Clark and Stankey, 1979; Joyce and Sutton, 2009). This is a an approach used to identify, delineate, classify and record areas within a region or country into recreation opportunity classes based on their current state of remoteness, naturalness and expected social experience. In practice the ROS developed for the PRESS project is a zoning of the EU in terms of proximity vs. remoteness, based on the recreation potential index, and distances from the road network and urban areas as proxies for accessibility.

The ROS provides information both on the quality of recreation provision and its accessibility in nine different zones (Figure 9.9). As pointed out this result is largely based on the degree of naturalness, therefore agricultural areas on the average have a low score. This is in part underestimating recreation potential in areas where semi-natural vegetation (i.e. hedgerows, ditches, woodlots) contributes in increasing the ESS provision, and could not be modeled because of lack of data at EU scale on landscape elements. Overall, results clearly show the role of semi-natural and natural vegetation, and of protected areas in providing opportunities for recreation to EU citizens.

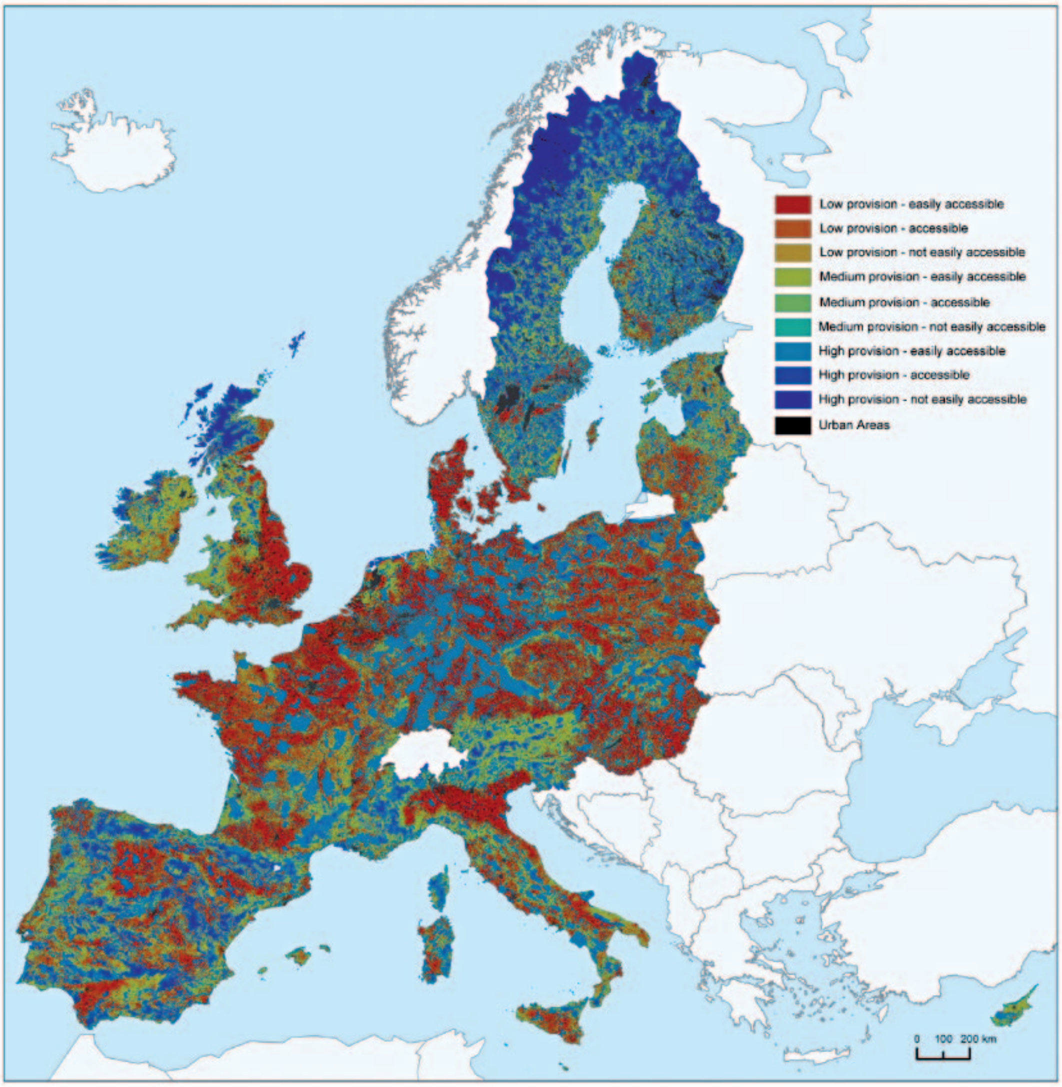


Figure 9.9. The Recreation Opportunity Spectrum for the EU (Romania, Bulgaria and Greece not included because of lacking detail in the road network).

9.3.1.2 Recreation potential as ESS benefit to European citizens

The analysis of population data allows estimating the quality of recreation provision to residents. Population pressure on ecosystems is modeled by applying a smoothing function that describes how population travels to reach destinations for recreation. The function is described in Figure 4 and assumes that the average citizen has higher probabilities to travel to sites that are closer compared to those that are farther away. Research presented in this report focuses on recreational activities that happen daily, either for a short time, or for the whole day (i.e. in the weekend), therefore two travel distances are identified: around 80 km for daily travels, and around 8 km for short travels. Population distributed according to these models is presented in Figure 9.10.

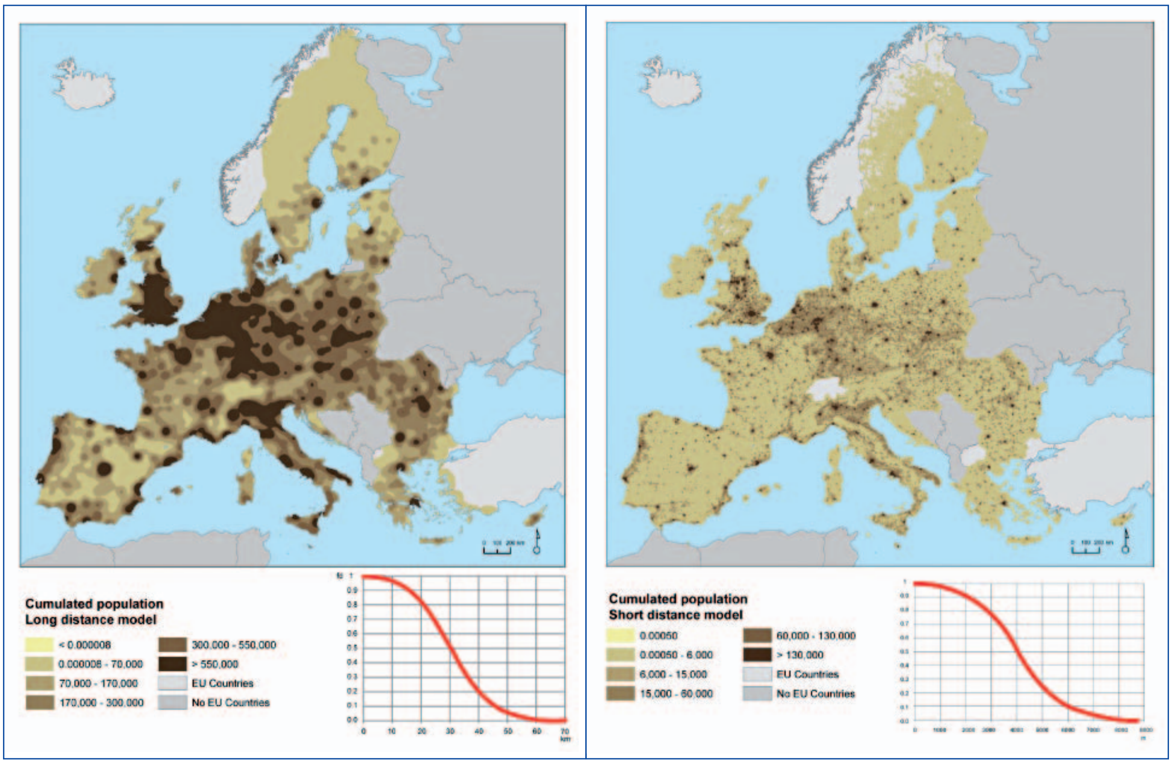
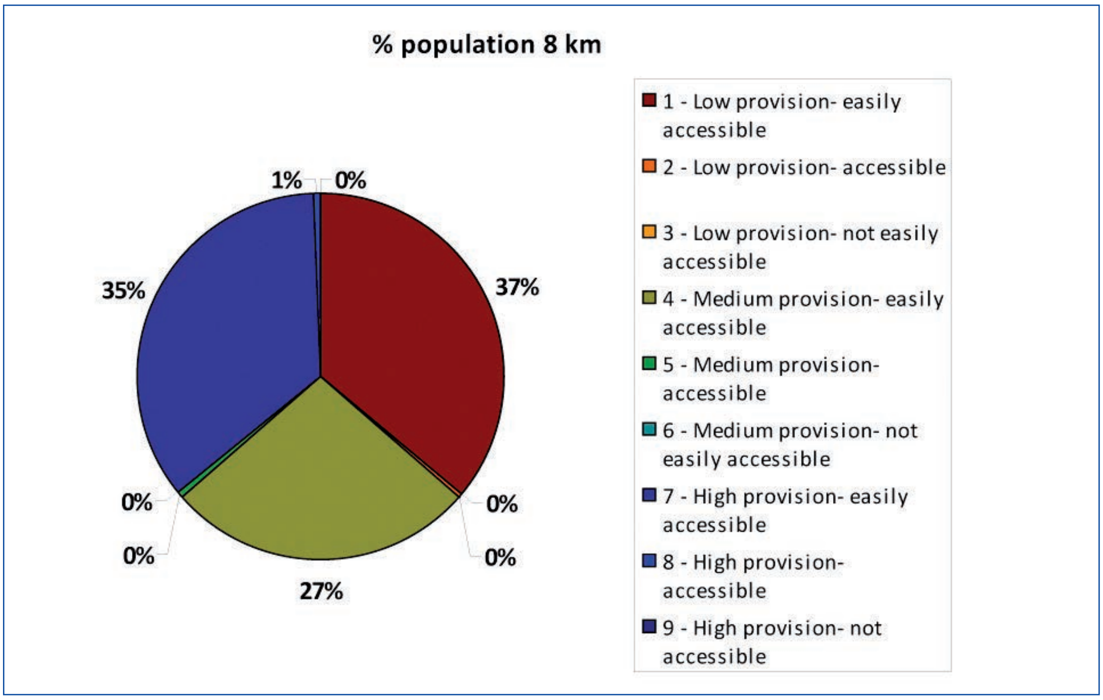
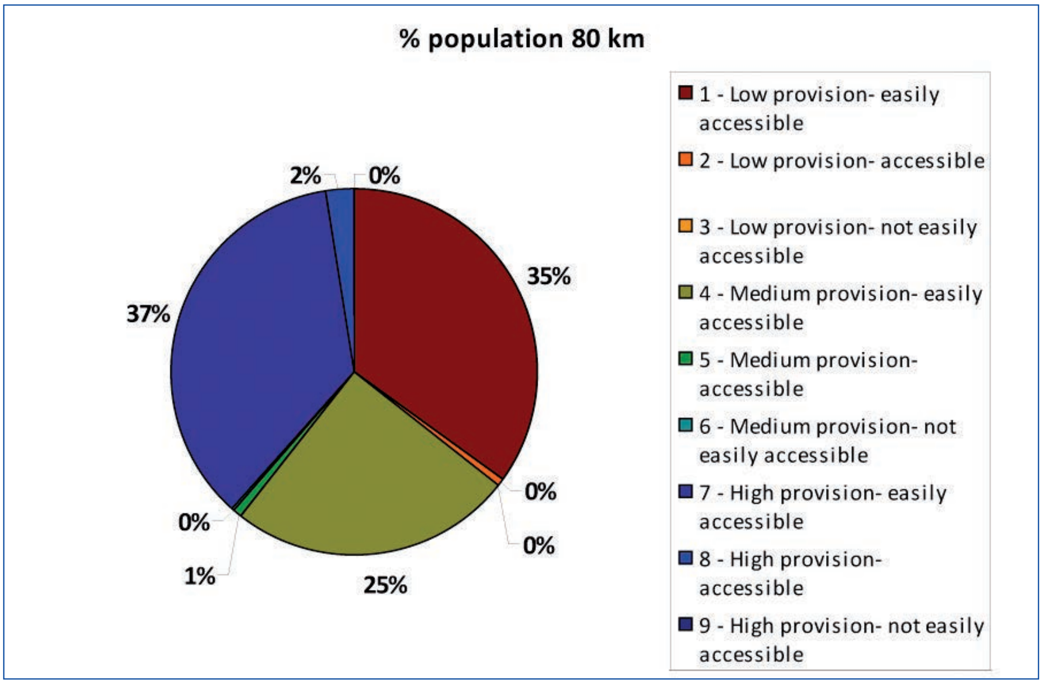


Figure 9.10. Potential population pressure on ecosystems assuming a 80 km travel for daily trips (by car) and 8 km for short trips (e.g. walking, running, cycling)

On the basis of how population is (potentially) travelling in order to reach recreation destinations, statistics can be calculated on the ecosystem service flow, or benefit that population can -in average- draw from recreation in the different ROS zones. Figure 9.11 shows respectively the share of population that has access to the ROS zones in the 23 analysed EU countries, in the case of short (a) and long (b) travel distance.



a)



b)

Figure 9.11. Share of EU population having access at the ROS zones, on short (a) and long (b) recreation travels.

There are no substantial differences between the two graphs; the accessibility model is based on the distance from urban centers therefore as expected the percentages remain very similar and are strongly dependant from the degree of accessibility. The share of population having access to the intermediate "accessible" class increases when people can travel longer distances.

The analysis can be repeated at different scales of analysis, for example statistics can be drawn at national level.

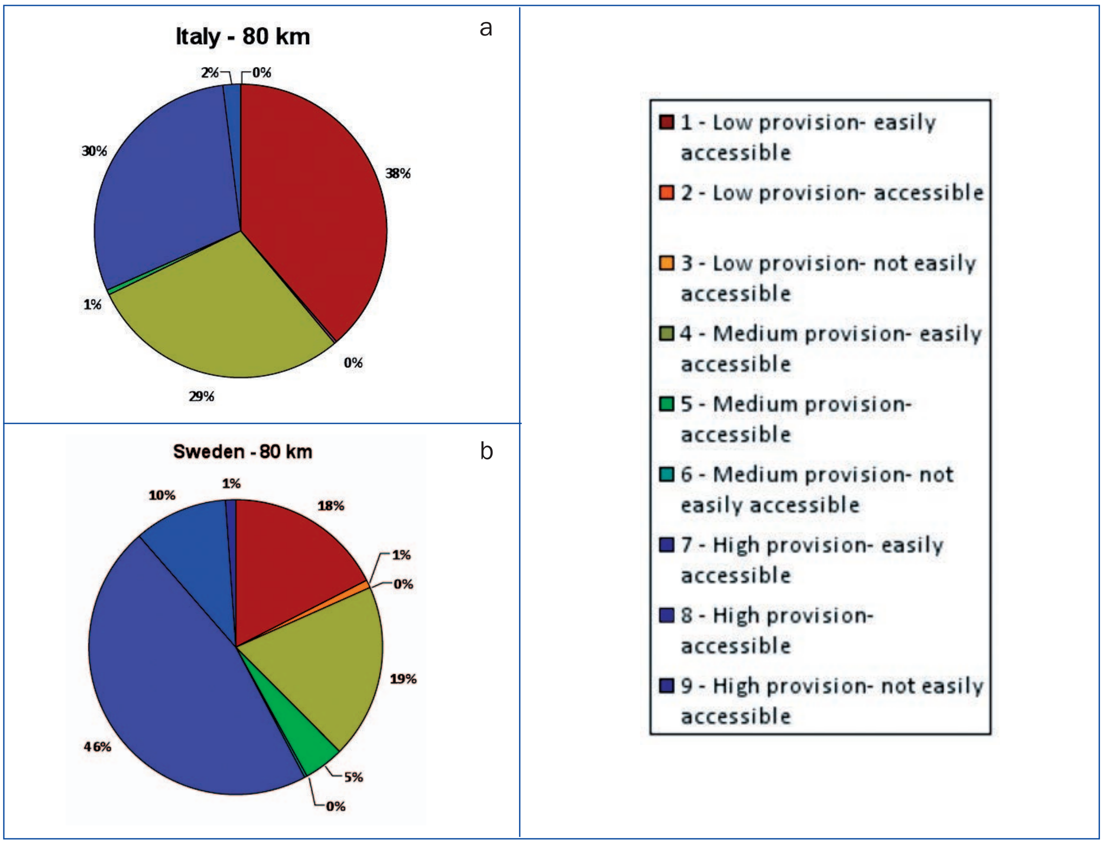


Figure 9.12. Share of population having access to the ROS zones in Italy (a) and Sweden (b)

As an example Figure 9.12 shows that in Italy a smaller percentage of population (30%) has access to areas characterised by a high provision of recreation potential compared to Sweden (46%). This can be explained by the spatial distribution of population that in Italy mostly lives in the highly productive flatlands, while natural areas and protected sites are mostly located in the mountainous areas (classified as less accessible). This type of results also highlights the role not only of the mere presence of natural vegetation and of protected areas as suppliers of high recreation potential, but especially of their spatial distribution pattern. This is particularly true for protected areas in environments characterised by a low degree of naturalness. An optimal spatial distribution of the sites can in fact guarantee the residents a possibility to reach recreational spots characterised by a high recreation provision in terms of quality of nature.

9.3.1.3 The use of ROS analysis in meta-analysis on visitor-monitoring studies

Results from the ROS analysis can be used to develop a visitor function by conducting a meta-analysis on visitor-monitoring studies. The visitor function is calculated based on multiple visitor-monitoring study results in combination with a set of explanatory variables. By statistical regression analysis, parameters are estimated for each explanatory variable. The function can then be used for predicting visitor numbers by plugging in the values of each explanatory variable for the site of interest (see equation 1). Typically, explanatory variables are distinguished into three main categories: (1) study characteristics, (2) site characteristics and (3) context characteristics. Site characteristics are the characteristics of each location itself (e.g. land-cover, hemeroby, etc.). They can be interpreted as recreational supply indicators. Context characteristics are the characteristics of the surrounding of each pixel (e.g. population density, substitutes). They could be interpreted as recreational demand indicators. Study characteristics are methodological variables from the visitor monitoring studies.

Meta-analysis is a widely applied methodology in environmental economic value transfer in order to transfer ecosystem service values, which were derived at multiple study sites to a policy site (Bergstrom 2006). Since recently, it is also used to map ecosystem service values spatially explicit across larger areas (Brander et al. 2011).

The advantage of a meta-analytic visitor function results from the fact, that it is based on multiple primary visitor estimates, which are collected across a large area and by diverging methodologies. Thereby, meta-analytic visitor functions allow capturing the impacts of a greater heterogeneity within site and context variables. Furthermore, it can be accounted for impacts of methodologies in primary data collections. Whereas visitor functions based on single survey results may be appropriate for mapping visitors across smaller areas, they may be limited in predicting visitor estimates for sites within different geographical and cultural context as no information is available on whether the model's parameters stay the same across larger study areas. Therefore, meta-analysis is appropriate for estimating visitors across a large and heterogenic area (Johnston & Rosenberger 2010; Rosenberger & Phipps 2007).

The following site characteristics were used: (1) degree of naturalness, (2) Recreational Potential Index (RPI), (3) protected areas and (4) coastal protected areas. Context characteristics used are: (5) shape area of the recreation site, (6) distance to road, (7) distance to urban areas, (8) population within 60km, (9) distance to water bodies and (10) Country. The use of site characteristics and context characteristics is constrained by the availability of biophysical and socio-economic indicators, which are available in high resolution at European scale.

Defining methodological variables is not straightforward, in the sense that to the authors' knowledge no meta-analysis on visitor monitoring studies exists. Therefore, no information is available on which methodologies may have a considerable impact on the final visitor number estimate. Visitor monitoring manuals and guides were then analyzed in order to extract potential methodological variables for the regression analysis (Muhar & Arnberger 2002; Kajala et al. 2007) and each visitor survey was coded in order to capture values for the methodological variables. Methodological variables captured bibliographic information of the publications, counting methods, spatial and temporal counting resolutions, counted objects, temporal and spatial up-scaling methodology and total number of visitors counted.

A linear regression was used in order to test the explanatory power of different variables and for estimating a visitor arrival functions. Results show that the database of total annual visitor numbers per hectare contains sufficiently large numbers, and that log transformation results in an approximated normal distribution of the dependent variable. Also the explanatory variables fulfil the requirements for linear regression.

Results are presented for different subsets of variables. The first regression analysis of the semi-logarithmic model (with a multiple R^2 of 0.6238) shows that the model fits the real data relatively well. However, no significant estimates were found for the degree of naturalness, protected areas, coastal protected areas, distance to coast and the national dummy variables. The degree of naturalness and protected areas were expected to correlate positively with visitor numbers, but this hypothesis could not be proved, as the sign in the regression was negative (contrary to expectations) at a non-significant level. Also marine protected areas and distance to coast were expected to have positive influences on visitor numbers, but even if signs show in the expected direction, they are not statistically significant. Note that distance to coast was calculated by an inverse distance function resulting in higher values as closer to the coast.

After stepwise elimination of all variables not proving to have a statically significant impact, the model still remains with a high overall explanatory power (multiple $R^2$of 0.6161, Figure 9.13). Again population in the surrounding of the sites remains the most important variable for predicting visitors, followed by the distance to urban areas, the shape size area and the distance to roads. However, also distance to coast and marine protected areas show a statistically significant impact.

Results indicate that accessibility, in terms of number of people which can access a site with a limited effort in terms of distance and time, is the most important predictor for recreational use. Here, accessibility is represented by the variables population within 60km, distance to urban areas and distance to roads, which together explain most of the variance in visitor numbers across sites.

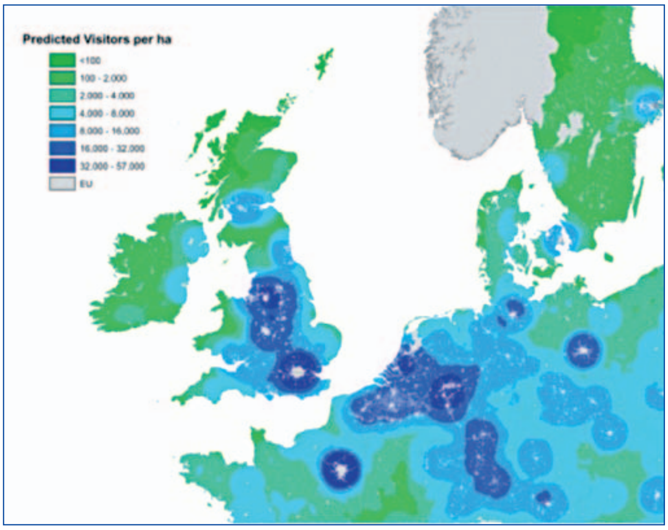


Figure 9.13. Predicted recreational visits

The variable shape area shows a negative sign at a highly significant level. It could be interpreted as the availability of substitutes (i.e. other recreational sites reachable with the same effort), which negatively affect the numbers of visitors per hectare. Each additional hectare of recreational area causes visitors to spread across a larger area and thereby average visitors per hectare decrease. The positive impact of the presence of coasts (variable distance to coast) can be interpreted as a complementary positive effect, meaning that people are attracted by water bodies and therefore tend to be encountered more frequently in areas close by rivers, lakes and sea. The positive impact of protected coastal areas indicates that visitors may be attracted by the amenity of more natural coastal areas and by a higher environmental quality in terms of biodiversity and water quality.

Such findings confirm the assumptions taken in the construction of the ROS for Europe for what concern accessibility. Difficulties remain in showing the impact of individual environmental quality indicators, such as the degree of naturalness and the presence of protected areas. Both variables could be expected to have a positive impact on recreational use, but show opposite signs at not significant level. This may indicate that people do not notice differences in environmental quality or do not judge these as important in order to influence their recreational behaviour in a substantial manner, or simply that data resolution is too coarse to capture such variations. However, marine protected areas and the Recreation Potential (which is anyway synthesising environmental quality) show positive correlation at a 0.5 level.

9.3.2 Analysis at country level

9.3.2.1 A Recreation Opportunity Spectrum for Finland

The Finnish case study of mapping recreational ecosystem services focuses on national level with regional partition. In this case study the recreational ecosystem service is approached by applying the ROS model described in 9.3.1.1, but some improvements can be made by addressing actual use of nature for recreation measured with the visitors survey described in 9.2.1.

As mentioned, results show that for Finnish population areas owned by private landowners, municipalities or State where the use is based on public access to the land (so called “Everyman´s right”) are very important for recreation, therefore the methodology presented in Maes et al. 2011 has been improved in order to take this characteristic into account. The Everyman’s right areas have been included in the ROS model by identifying the land use types that characterise them (i.e. forests, moors and heathland, marshes, transitional woodland/shrub, fallow land) and including the corresponding areas in the model flow-chart as described in Figure 9.14.

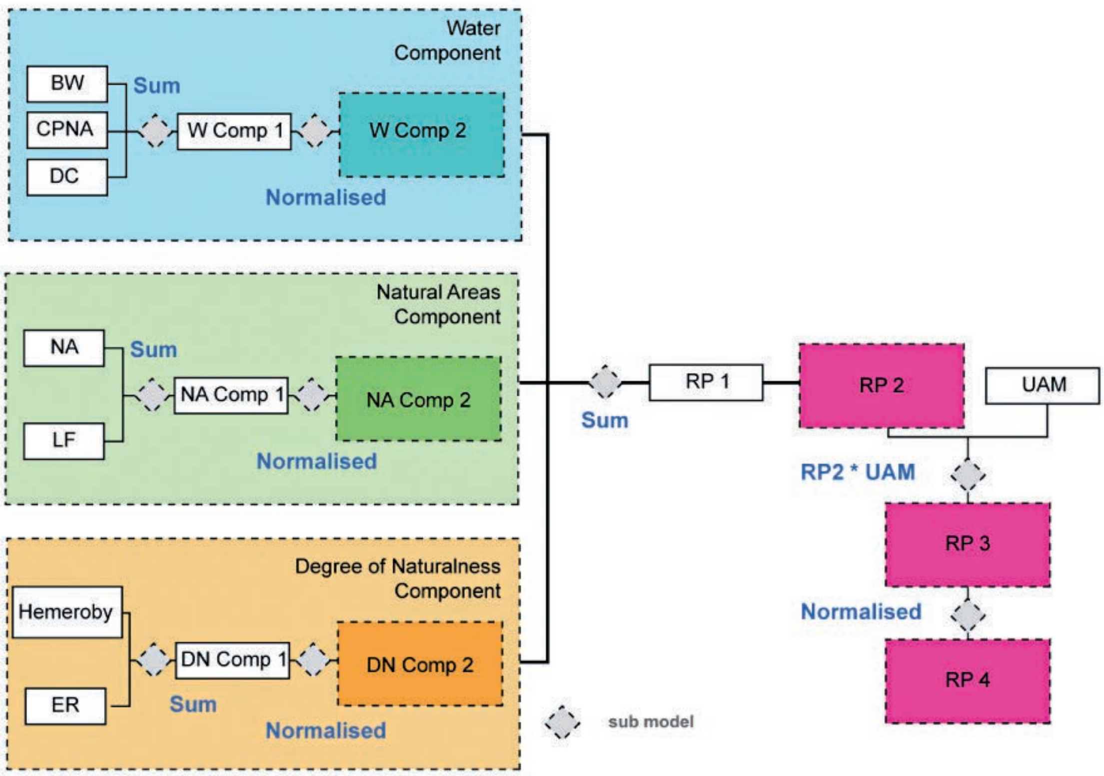


Figure 9.14. Flowchart of the procedure to obtain recreation potential where:

NA: natural areas
GUA: green urban areas
BW: bathing water
DC: distance to coast
CPNA: coast proximity -natural areas
UAM: urban areas mask
W: water
DN: degree of naturalness
RP: recreation potential
LF: leisure facilities
ER: everyman's right

In practice the Everyman's areas are added to the component on the degree of naturalness, to highlight the higher value that natural areas acquire when they are freely accessible.

The resulting Recreation Opportunity Spectrum for Finland, calculated according to Maes et al., 2011 is shown in Figure 9.15.

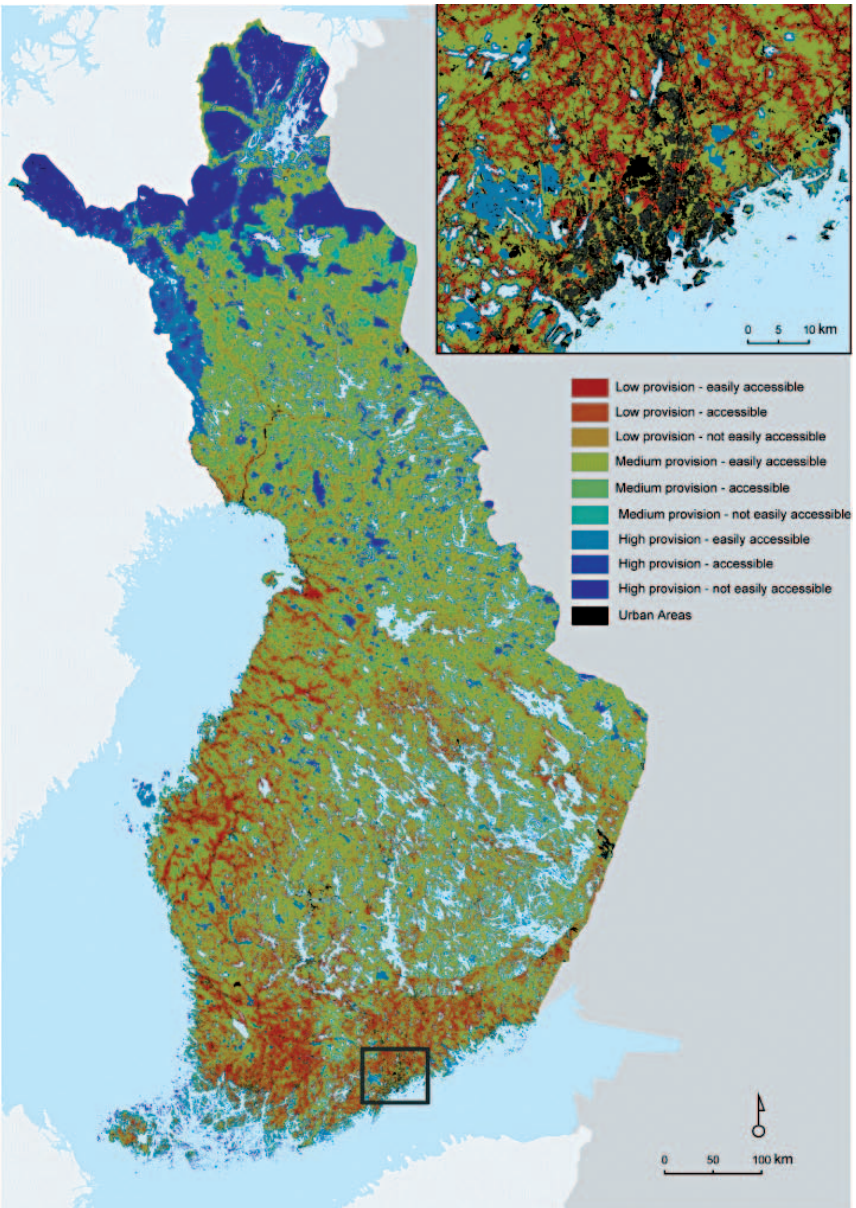


Figure 9.15. The Recreation Opportunity Spectrum for Finland

An analysis of population pressure has been made using the same approach as in the EU exercise, but based on the results of the survey for what concerns travel distances for close-to-home and overnight trips. Figure 9.16 shows population pressure on areas near the place of residence, for trips that have a length of about 2 hours. The applied function is derived from the survey (data are rescaled in the 0-1 range in order to be used as weights when calculating the cumulative distribution). For overnight stays the distance of 80 km was applied.

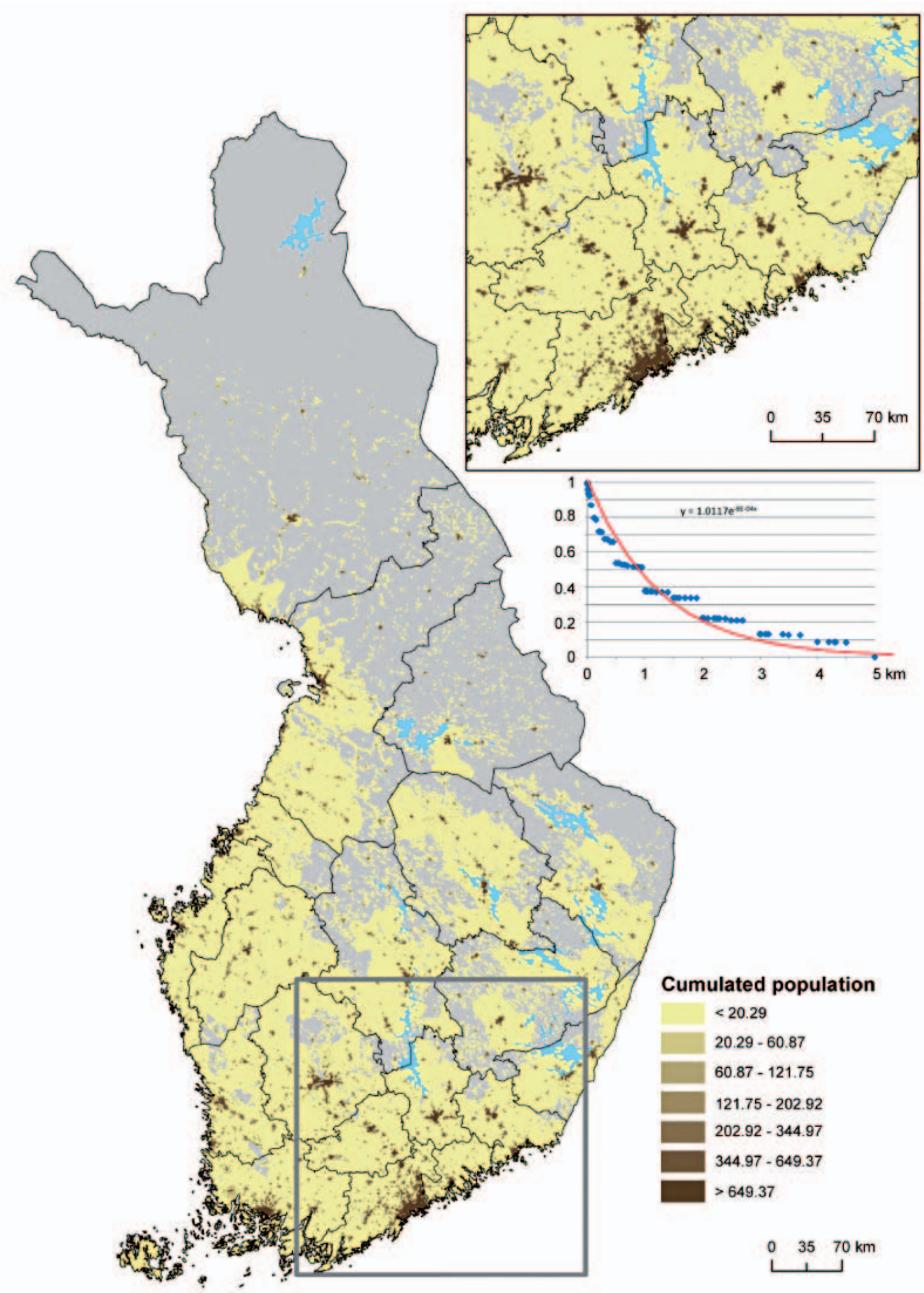


Figure 9.16. Potential population pressure on ecosystems for close-to-home trips calculated on the basis of the function derived from the visitors survey

Results calculated at NUTS3 level show that the share of population having access to medium recreation provision sites is much higher than the EU average, and very often exceeds 50%. Table 9.8 shows results for two different regions, the region of Helsinki and Lapland. Also in the case of densely populated areas such as the metropolitan region, access to recreational areas due to the Everyman's right, combined with a high degree of naturalness of the overall environment, guarantee a high recreation provision to citizens.

Table 9.8. Share of Finnish population having access at the ROS zones, on close-to-home and overnight recreation travels.

Nuts3	Recreation provision	% population 5 km			% population 80 km
Uusimaa	1 - Low provision- easily accessible	23.66		1 - Low provision- easily accessible	28.26
	4 - Medium provision- easily accessible	63.44		4 - Medium provision- easily accessible	56.42
	5 - Medium provision- accessible	0.00		5 - Medium provision- accessible	0.02
	7 - High provision- easily accessible	12.90		7 - High provision- easily accessible	15.29
Lappi	1 - Low provision- easily accessible	16.99		1 - Low provision- easily accessible	2.71
	2 - Low provision- accessible	0.02		2 - Low provision- accessible	0.10
	4 - Medium provision- easily accessible	58.61		4 - Medium provision- easily accessible	48.01
	5 - Medium provision- accessible	0.56		5 - Medium provision- accessible	26.17
	6 - Medium provision- not easily accessible	0.00		6 - Medium provision- not easily accessible	0.50
	7 - High provision- easily accessible	23.78		7 - High provision- easily accessible	11.10
	8 - High provision- accessible	0.05		8 - High provision- accessible	8.25
	9 - High provision- not accessible	0.00		9 - High provision- not accessible	3.16

9.3.2.2 Comparison of estimated visitors trips in with the ROS model in Denmark

The spatial distribution of the modelled total number of recreation trips to the 52 forests in the region is illustrated in Figure 9.17 along with the categorisation of the same forests according to the ROS methodology.

The most popular forest sites, receiving more than one million visits per year, are large attractive forest sites located at the fringe of Copenhagen. Forests receiving between 0.5 and 1 million visits are either large attractive forests located far from Copenhagen or quite attractive forests located at the urban fringe of Copenhagen. The least visited forests with below 100 000 visits per year are generally small remote sites.

The same forests are in the ROS model categorised as all being easily accessible with low, medium and high provision. Low provision is only found in edges of the forests, and the largest forest area is categorised as high provision.

Comparing the modelled results with the ROS categorisation a similar pattern is found, though at a coarser level. In general, forests receiving more than 500 000 visits are categorised with predominantly high provision, i.e. forests close to Copenhagen or large attractive forests far from Copenhagen. Forests categorised as medium provision covers predominantly forests with less than 500 000 visitors.

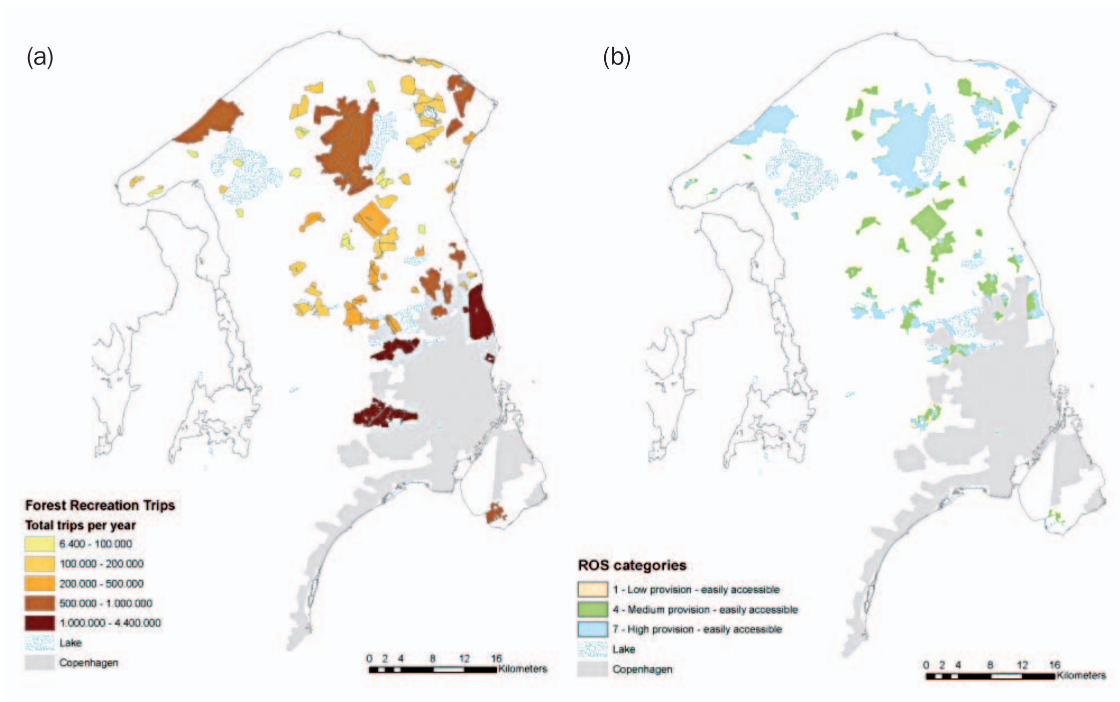


Figure 9.17. Total Number of Forest Recreation Day-trips per site (a) and ROS categorisation of forest sites (b)

9.3.3 Mapping the potential of Green Urban Areas (GUAs) to provide recreation ecosystem services

9.3.3.1 Identification of GUAs in the Netherlands

The methodologies illustrated so far focus on the natural environment in the wide sense. Results from the surveys, though, clearly show the strict relation between recreational activities and the origin of recreational trips (the places of residence of people recreating). Under this perspective, the role of Green Urban Areas (GUAs) cannot be neglected. GUAs are in fact main sources of recreation provision by ecosystems for population living in urban centres, and not having natural areas easily accessible for daily recreation. Therefore, a methodology was developed to quantify and map the potential that GUAs have to provide recreation ecosystem services, structured on the following steps:

- Definition of the urban space and its related boundaries. After reviewing different definitions of urban areas, Urban Morphological Zones (see Box 9.1) were selected because they are available for EU27 and cover all urban areas and not only the major cities. All zones larger than 20 km2 and lying within the Netherlands were selected and used as a mask.
- Definition of the green areas within the urban space that provide recreation services. A green urban area is defined as any vegetated land or water within or adjoining a urban area, and it is characterised by the following elements (a) green corridors like paths, rivers and canals; (b) parks, gardens, playing fields, children's playgrounds, forests, grassed area sand allotments; and (c) countryside immediately adjoining a city which people can access from their homes.
- Quantification of the green space using a similar approach as Maes et al. (2011) to quantify recreation provision by nature areas in Europe. In the present study green urban areas are quantified in a similar way as nature areas in the previous study. For the Recreational Potential Index new factors were introduced, like the size of green areas. These factors were derived from the data available for the Netherlands (CBS-BBG) and for the EU27 (Green Urban Areas, based on CORINE Land Cover data). For accessibility, different methods were considered, e.g.cost-distance algorithms (ESRI 2006, Verburg et al. 2010) or spatial buffering, since the available transport infrastructure networks were evaluated as too coarse for this study. Information on preferences of people for the typology of green urban areas is neither available at national nor at European level, and obtaining these was beyond the scope of this study. In the present study all green urban areas have been considered, as indicators of the service provided by ecosystems in towns and cities. In a further step a distinction should be made on the basis of the natural value of such areas. Distance in time to green urban areas is of varying lengths, and therefore a distinction was made between 'green' being close, intermediate and far. With this definition the method will reveal green urban areas that provide potential service for a short recreation period, e.g. making a short walk, read the newspaper in the park or walk the dog. 'Short distance' was defined as 'within 10 minutes walking distance', which was calculated as 500 m assuming a 6 km/h walking speed. Accessibility was calculated using as basis population density datasets for the Netherlands and for the EU27, and differences were assessed between the two datasets.
- Finally demand-supply ratios were calculated by comparing the potential number of people within a certain distance in time – defined by accessibility - of a green area (demand), with the size of the green urban area (supply). A number of indicators can be calculated to qualify the recreation services provided by green urban areas. For example, number of people within reach of green (percentage of total population of a city or urban zone), the amount of green area per person, the percentage of green areas in the city. The final ROS is a combination of the different factors. Finally, the results can be classified according to city size or level of urbanisation.

BOX 9.1. Urban Morphological zone

A Urban Morphological Zone can be defined as "A set of urban areas laying less than 200m apart". Those urban areas are defined from land cover classes contributing to the urban tissue and function. The CORINE Land Cover classes used to build the Urban Morphological Zone dataset are the following ones:

Core Classes 111 – Continuous urban fabric; 112 – Discontinuous urban fabric; 121 – Industrial or commercial units; 141 – Green urban areas.

Enlarged core classes: 123 (Port areas), 124 (Airports) and 142 (Sport and leisure facilities), are also considered if they are neighbours to the core classes or to one of them touching the core classes.

122 (Road and rail networks) and 511 (Water courses), when neighbours to the enlarged core classes, cut by 300m buffer.

Forests & scrub (311,312,313,322,323,324), when they are completely within the core classes.

9.3.3.2 Potential number of citizens per Green Urban Area

As a proxy to valuate the potential of Green Urban Areas to provide recreation ecosystem services, the potential number of people per GUA for the urban zones was calculated and mapped. On the maps both the distribution of green and the distribution of the inhabitants is reflected. Figure 9.18 shows the city of The Hague, lying at the Dutch coast and adjacent to dune areas. The map shows that both the green areas situated in the city centre and the dune areas in the urban periphery close to the coast provide potential recreational service to many people within 500m distance.

Compared to The Hague, the potential recreational service by GUA in the city of Amsterdam is provided more by the small GUAs in the city centre (Figure 9.19). The surrounding area of Amsterdam is more rural, and therefore provides less recreational service.

9.3.3.3 Amount of green urban area per person

A second proxy to valuate the potential of GUA to provide recreation ecosystem services is the amount of green area per person. Figure 9.20 shows the area of the GUA divided by the number of people within 500m from the GUA, as previously calculated for Figure 9.18, in the Dutch city of The Hague. This shows that the dune areas provide a higher service in terms of area per person than the green areas in the city centre.

9.3.3.4 Supply/demand ratio

Considering the number of people within 500 m from a GUA as the demand, and the area of that GUA as the supply, a selection of GUA can be made. In Figure 9.21 the areas with:

- high demand and high supply (thus potentially providing a high amount of green to many people) are marked in green
- high demand and low supply (thus potentially providing a low amount of green to many people) are marked in red.

Compared to Figure 9.20, showing the number of people within 500 m from GUAs, this map provides a different interpretation of recreation provision. Some sites like the dune areas, for example, provide recreation potential to many more residents than the smaller green areas in the city, which may result less congested.

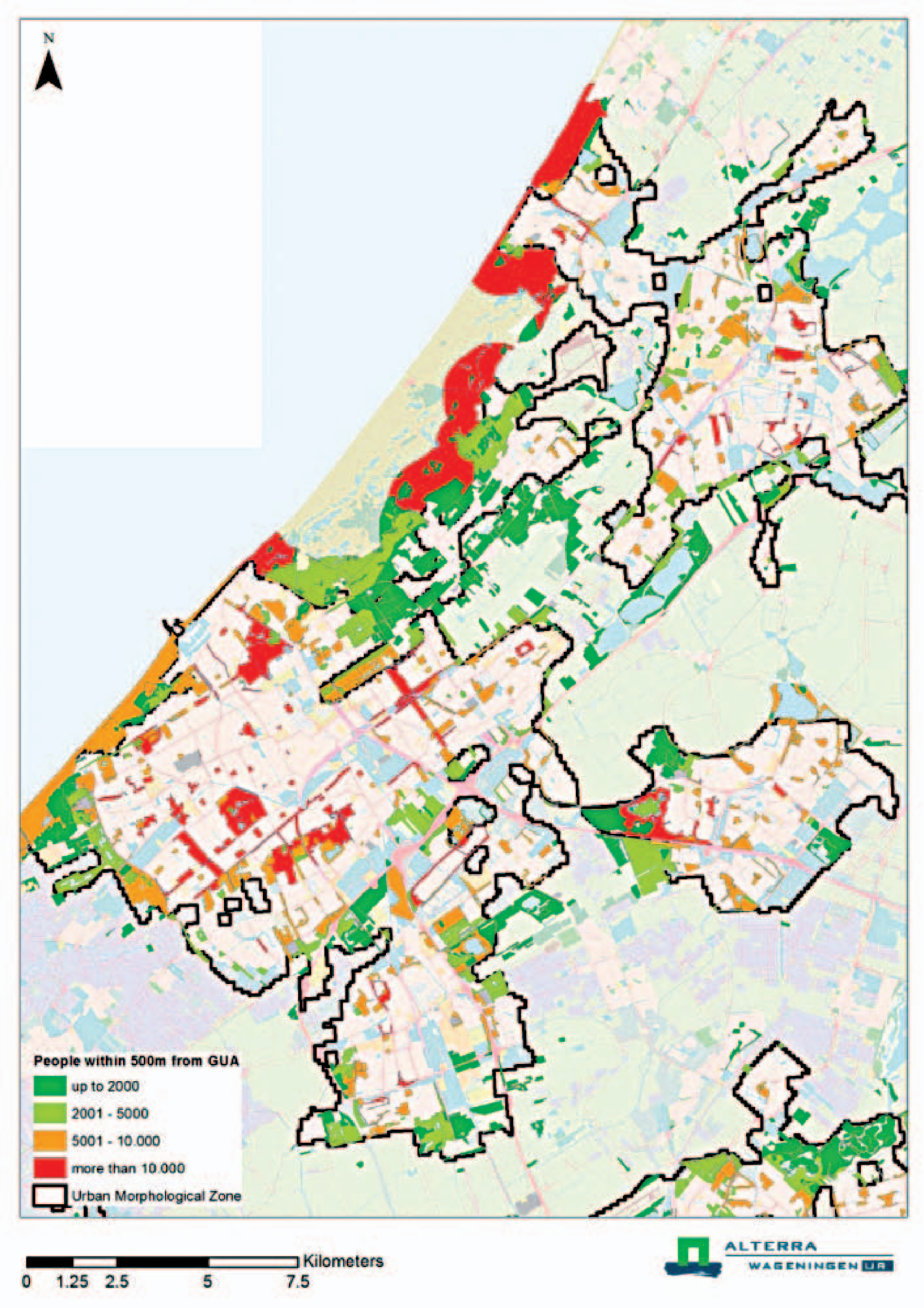


Figure 9.18. Number of people within 500m from GUAs in the Dutch city of The Hague

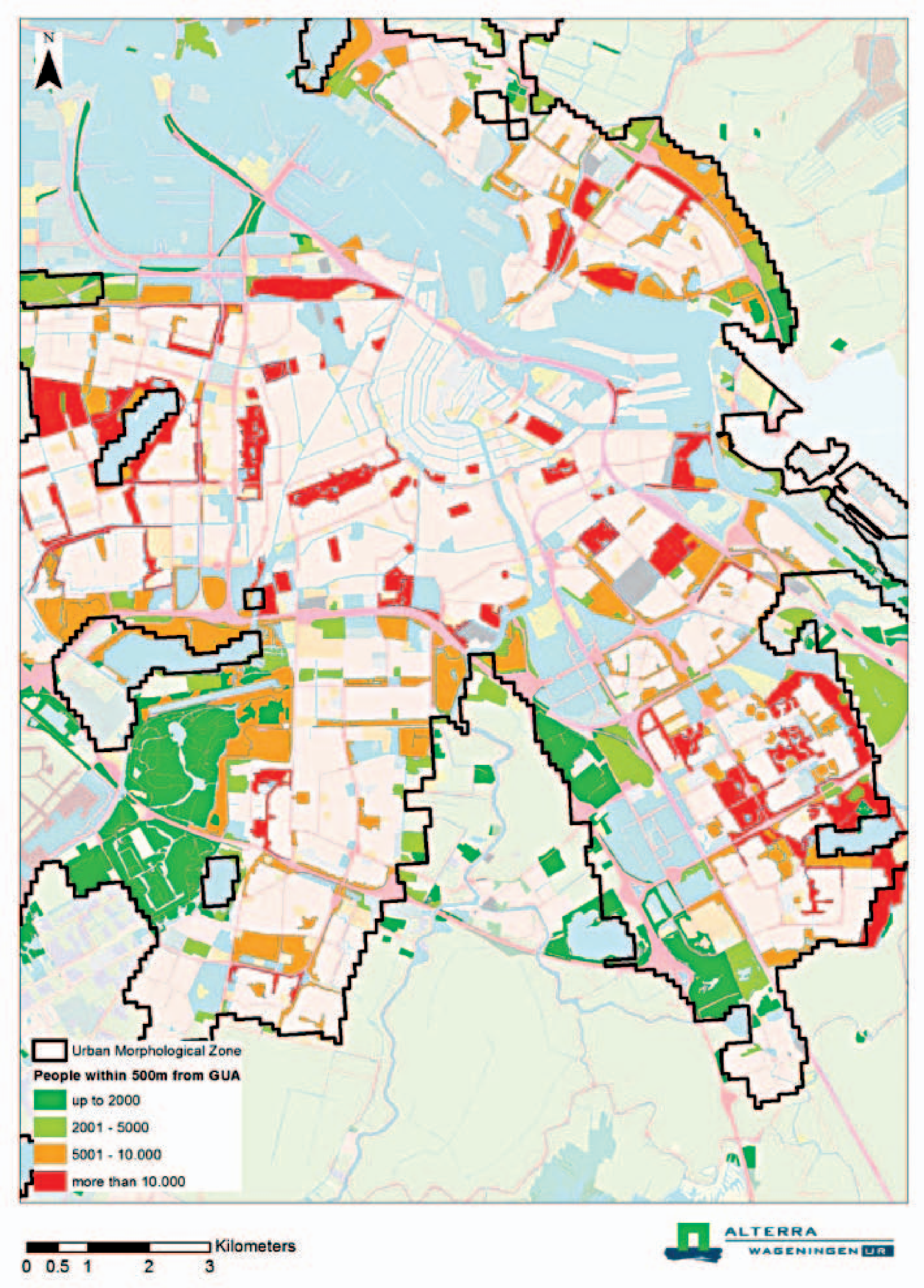


Figure 9.19. Number of people within 500m from GUA in the Dutch city of Amsterdam

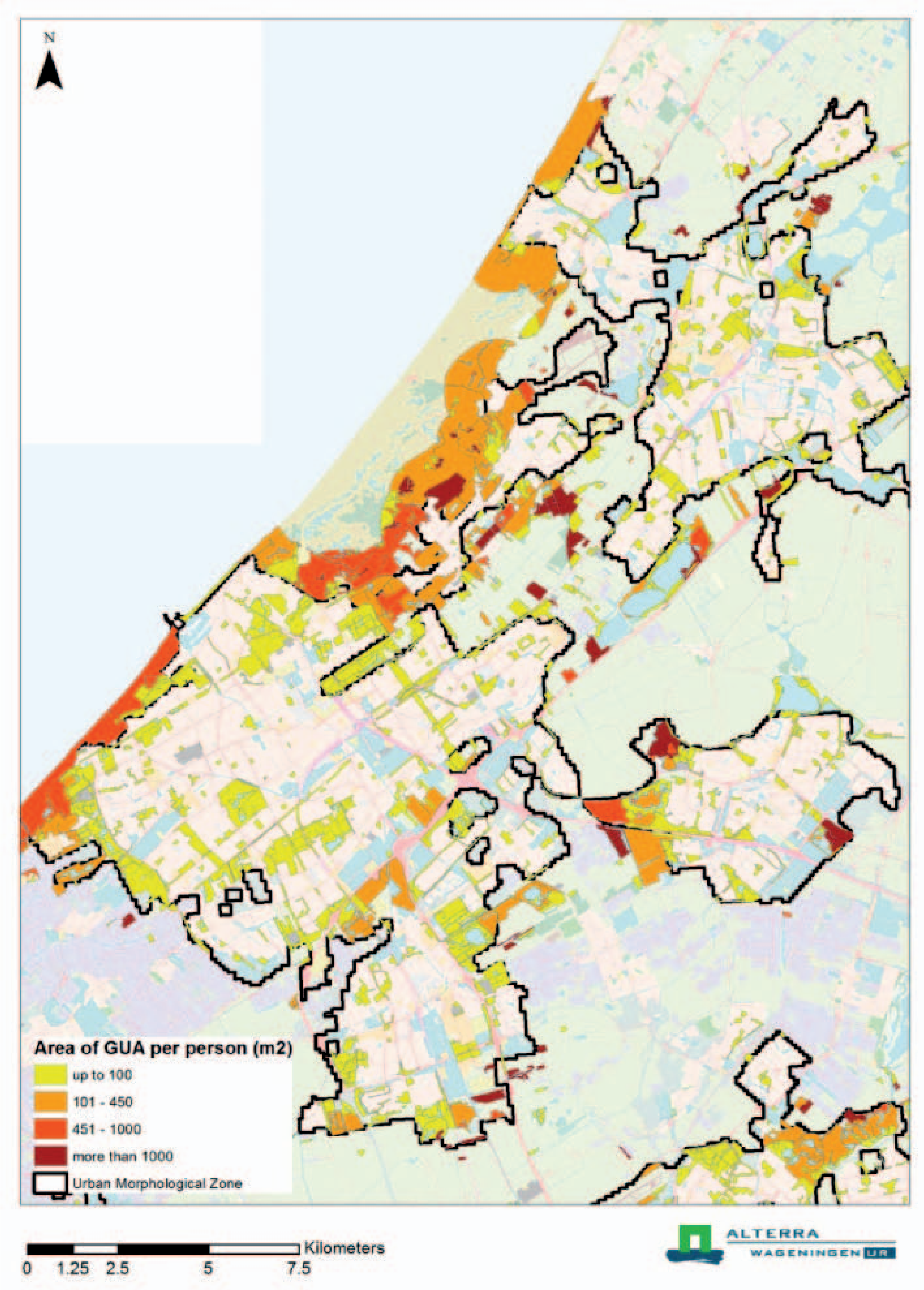


Figure 9.20. Area of GUA per person within 500m (in m2) in the Dutch city of The Hague

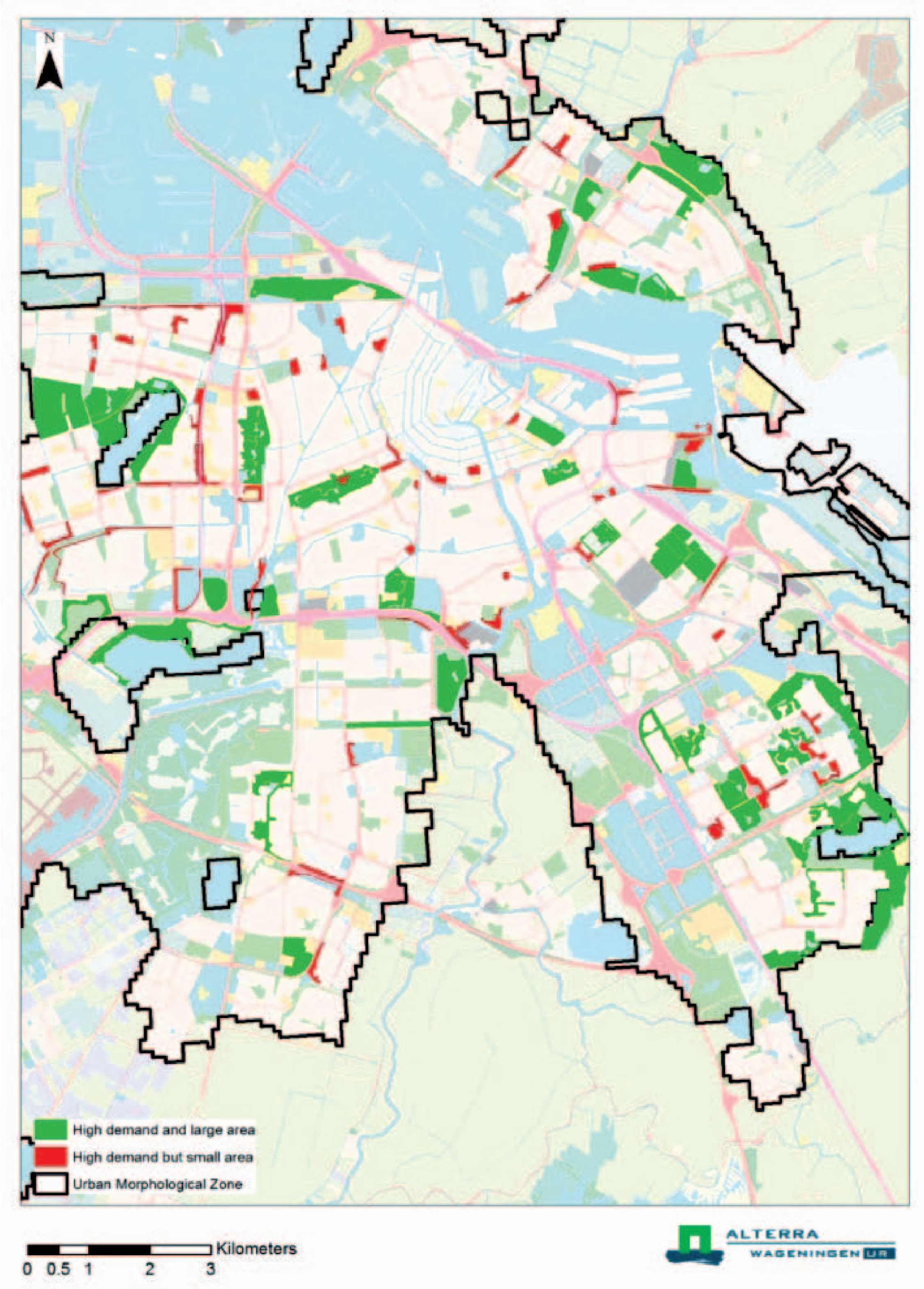


Figure 9.21. Demand/supply ratios for GUA in the Dutch city of Amsterdam

9.3.3.5 Statistics on the role of GUA to provide recreation ecosystem services in the Netherlands

Averages on the proportion of the total GUA/inhabitant in a province were calculated for the 12 Dutch provinces. Figure 9.23 shows the average amount of GUA per person within 500 m for each province, resulting from dividing the total surface area of the GUAs in each province by the total amount of people living within 500 m from the GUAs.

In Figure 9.24 the average number of people within 500 m from a GUA is shown, calculated as the total number of people within 500 m from a GUA divided by the number of GUA.

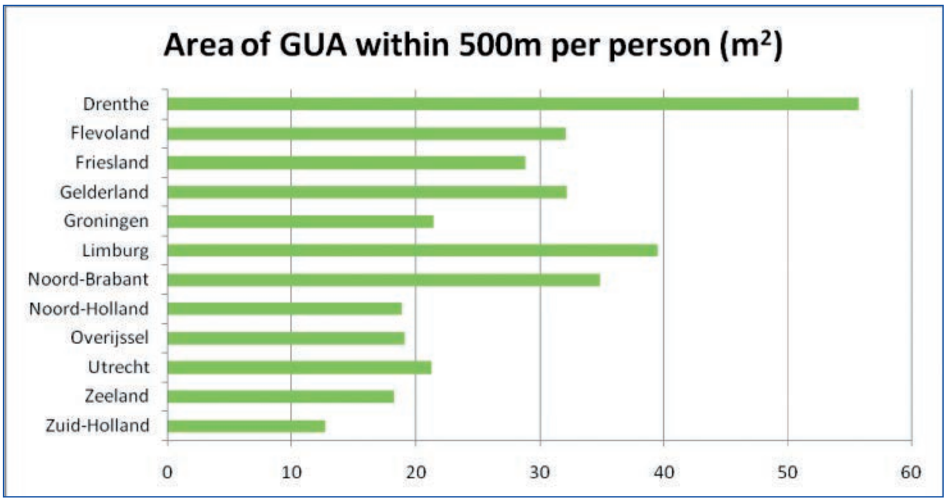


Figure 9.23. Average area of GUA per person for the 12 Dutch provinces

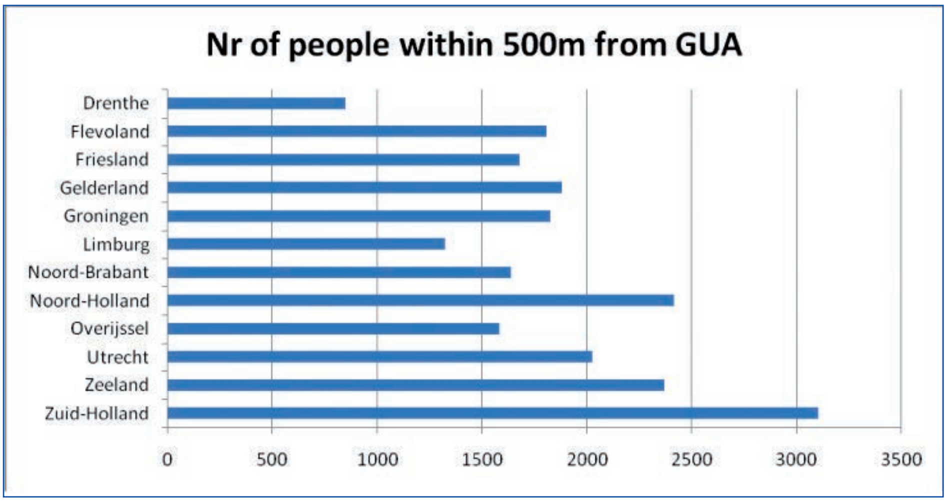


Figure 9.24. Average number of people within 500 m from a GUA for the 12 Dutch provinces

9.3.3.6 Comparison between European cities

A similar analysis can be made to estimate the provision of recreation potential to inhabitants of European cities. An example is presented hereafter on Berlin and Milan. Figures 9.25 and 9.26 show the number of people living within 500m from GUA in the cities of Berlin and Milan. The results clearly show not only the much larger number of GUA in Berlin compared to Milan, but also the more homogenous distribution along the city and the larger diversity in GUAs size in Berlin. Milan has only few small GUA in the city centre and the large GUA are clustered together. These results could be analysed considering the contrasting population densities of Berlin and Milan, respectively 3,914 inh/km2 and 7,360 inh/km2 in 2011, which make the existing GUAs in Milan city centre even more relevant from the point of view of sources for recreation.

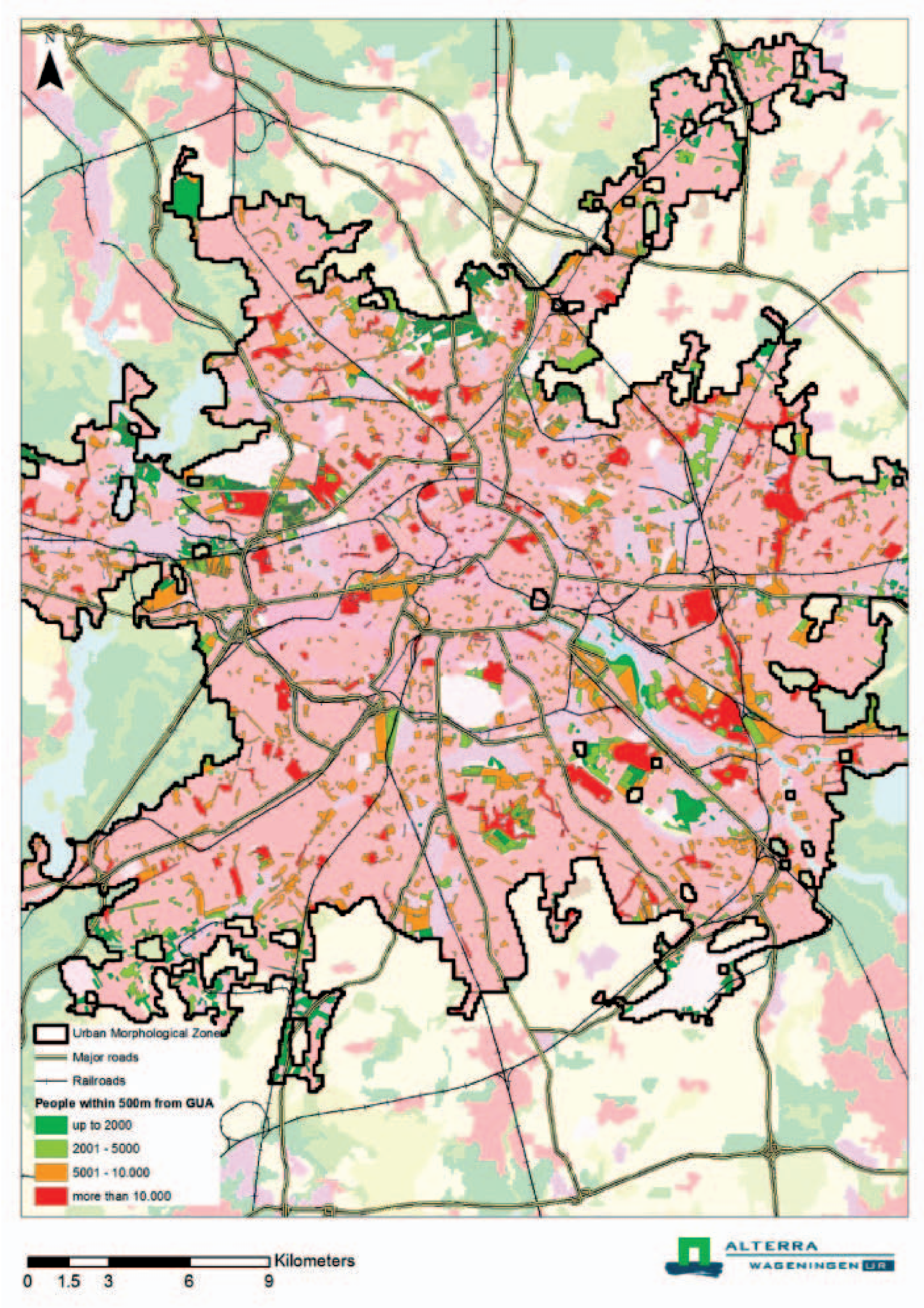


Figure 9.25. Number of people within 500m from GUAs in Berlin

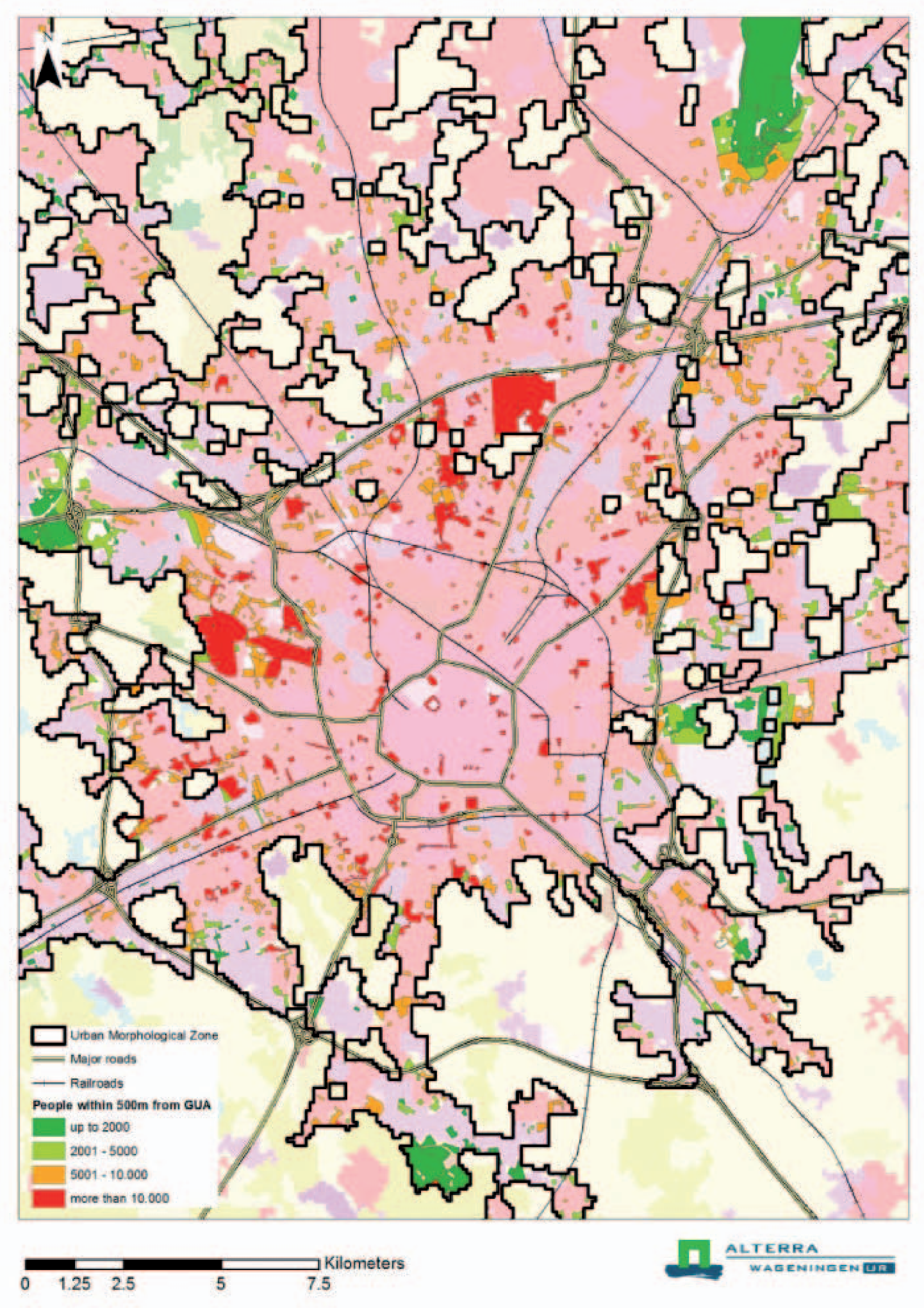


Figure 9.26. Number of people within 500m from GUAs in Milan. It must be noted that two main city parks in Milan are not reported in this analysis. Therefore results must be considered as illustrative of the methodology.

9.3.3.7 Discussion

The methods developed in this study to quantify and map the potential that green urban areas have to provide recreation ecosystem services follows a pragmatic approach, i.e. use of available datasets in a simple and transparent way that can be applied at European level, building on the former work by Maes et al. (2011). This implies that the recreation ecosystem services provided by green urban areas are analysed based on general assumptions about which green areas can be potentially used for daily recreation, rather than analysing which type of recreation can be performed and where, and considering the preferences of people and local situation. In addition, the calculations are based on the population living in the cities, and do not take into account the people working in the cities. This is important to consider when interpreting the results since many European city centres are mainly occupied by offices and residential areas are located in the peri-urban areas. While during daytime many people are present, the number of inhabitants is low according to the population density statistics. Consequently the results of this study show a lower potential recreational service of GUA in these areas than it may be in the real situation, when a larger number of people use them during the day.

Another point of discussion is the distance considered from the living areas to the GUA. The distance of 500 m was based on the assumption that people will walk to the GUA, while in some countries cycling, or going by car or public transport will be more common. Taking these factors into account will require a more detailed study, so as gathering information on citizens preferences using questionnaires.

9.4 Valuation of the recreation service

After mapping recreation potential and estimating visitors numbers and trip characteristics, valuation of the ecosystem service is the necessary conclusive step of this analysis. Two approaches are applied in detail in this study, based on the Travel cost analysis, and the Willingness to Pay method.

9.4.1 Travel cost method – an application for Finland

9.4.1.1 Method

For valuation of close-to-home visit and nature trips the travel cost method was applied which is widely used in the estimation of recreation benefits. It is based on the idea that even if there is no explicit price for recreation, individual visiting a recreation site have to face costs from travelling to the site and back. Utilizing the fact that individuals travel different distances to recreation sites and the number of recreation trips they make varies, the demand curve for recreation trips can be determined on the basis of travel costs and other relevant variables affecting the trip frequency. Value of a trip is then calculated on the basis of the demand curve.

Such data are available in the Finnish visitors survey described in 9.2.1. The frequency data for travel cost models were gained from the questions related to the last recreation trip respondents had made. With regards to close-to-home recreation visits respondents were asked to state how many times they had visited their last visited site in the last 12 months. For overnight nature trips, the question concerning the number of visits focused on the last 5 years but was converted to an annual number of trips similar to close-to-home visits, by dividing the number of trips made during last five years by five.

Information about the expenditures incurred in connection with the visit or trip was elicited by asking the respondents to separate their personal travel, accommodation and activity expenditures (e.g. rental and participation fees, access fees, permit, equipment). In both of the models the travel cost variable was created from reported travel expenses incurred from nature trip. Reported travel expenses from traveling by own car and by public transport were summed together and the average cost per kilometer was calculated. The average kilometer cost was then used in both of the models as kilometer cost for the respondents who had used mainly own car or public transport to travelling to recreation site. Travel cost variable was set to zero for walkers and cyclists. Time cost was not included, because it is usually measured on the basis of hourly wages and only five percent of respondents reported that in the case they had not done the trip they would have worked for salary.

The number of trips is available in positive counts. An often used model for a count data is the Poisson regression model. It is based on discrete distribution and limits the values of the dependent values to be non-negative integers whose mean is conditioned on the independent variables. The model assumes, in addition, that the conditional mean equals variance. This is often not the case with recreation demand, but the variance is often larger than mean which means that there is overdispersion in the data. The problem of overdispersion can be solved with negative binomial model, that allows the variance to differ from mean and thus negative binomial model is often preferred and also applied in this study.

The questionnaire elicited information on only those who had made at least one close-to-home recreation trip in the last 12 months, thus no data are available for those who do not spend time outdoors for recreation and the sample is therefore truncated. The problem is not present with the over-night trips, because when converting the number of trips in last five years to annual frequency those who had made one or more trips in last five years got value of zero as the annual trip frequency.

The estimated demand model allows defining the value of a recreation trip i.e. consumer surplus per trip. It is important to underline that the independent variables identified for the purpose of the present analysis in addition to travel cost variable are interaction variables between travel cost and site type (everyman's right areas, state land and leisure home) and region. Interaction variables were used to calculate the region and site type specific values for trips. Further, socio-demographic variables were included in the models.

9.4.1.2 Valuation

On the basis of the described methodology travel cost models for estimating the value of a close-to-home visit and nature trip were defined. In both trip types as demand theory predicts the travel costs affects the number of trips negatively. This allows deriving an ordinary demand curve for both trips and consumer surplus estimates can be calculated.

In demand models for cclose-to-home recreation activity visit frequency was found to be positively associated with age 35 or older, being not active in the working life and living in rural areas. Being employed was found out to decrease the number of close-to-home recreation visits, as found also in the study by Neuvonen et al. (2007) that was based on the first Finnish national recreation inventory data. The most obvious explanation is that people who are not working have more leisure time available than others. It is as well probable that people living in rural areas live closer to recreation areas and it might be that there are not as many other leisure activities available as in urban areas. The positive effect of age on recreation activity can be likely explained at least partly by the fact that people around 30 have often small children and therefore less leisure time than older people.

Estimation results suggest also that women are more active in outdoor recreation than men and the more there are persons in a household the lower is the outdoor recreation occasion frequency. Also in the study by Neuvonen et al. (2007) females turned out to be more active in close-to-home outdoor recreation, but the effect was not statistically significant. According to the results, income does not affect close-to-home outdoor recreation activity statistically significantly.

Travel cost – home region interaction variables suggest that people living in eastern Finland are willing to pay more in order to reach a recreation site than others. southern Finland being the region of comparison, the model also suggests that people living in Western and northern Finland are willing to pay less to get to a recreation site than people living in southern and eastern Finland. With respect to region types, model suggests that people are ready to pay most for recreation at leisure homes and least for recreation at state land.

Results suggest that over-night nature trips are most popular among older people that are not working at the moment. In addition, trip demand seems to be higher for people living in urban areas than others. It is possible that people living in rural areas do not feel that much need to travel in order to enjoy nature. Income affects trip frequency positively and statistically significantly, albeit the coefficient is very low. In addition, as expected the trip frequency decreases when length of the trip increases.

Coefficients for interaction variables suggest that people are ready to travel longer distances and thus pay more in order to get to a leisure home than other types of sites. From the regional perspective people are willing to pay more to get to northern Finland than other parts of the country. This was expected as people are ready to travel long distances to Lapland in order to enjoy the unique nature of the region. Furthermore many resorts providing wide range of services to tourists make it convenient to travel to northern Finland, especially to Lapland.

Consumer surplus estimates for close-to-home trips and nature trips are represented in Tables 9.9 and 9.10. Tables represent separate per trip values for both close-to-home visits and over-night nature trips for every site type and region combination. A trip to a specific region and site type gets a unique value if the corresponding interaction variables were statistically significant in the model.

In the close-to-home visits model there were four distinct region – travel cost interaction variables, specifically for eastern Finland, western Finland, northern Finland and capital area and two site type – travel cost interaction variables, i.e. for leisure homes and state land. Southern Finland and everyman's right area were the base cases. In the model for over-night nature trips there were five combined region – site type - travel cost interaction variables that turned out to be statistically significant. Some problems arose with the model for close-to-home recreation trips with respect to trips at leisure homes in southern and eastern Finland. The model provided negative consumer surplus estimates for a visit at leisure home in eastern Finland and implausible large estimates for a visit at leisure home in southern Finland. In order to tackle the problem the estimates were calculated from the model that excluded regions and included only the travel cost – site type interaction variables. Other variables in that model were the same as in the close-to-home recreation model.

Table 9.9. Consumer surplus per trip (€) estimates for close-to-home recreation visits at different regions and site types

	Everyman's rights	State land	Leisure home
Southern Finland	13.6	7.5	62.5
Western Finland	9.3	6.0	24.7
Eastern Finland	21.8	9.4	62.5
Northern Finland	8.5	5.6	19.4
Captial area	8.0	5.4	17.2

Close-to-home recreation visits at leisure homes have clearly greater value than recreation occasions at everyman's rights areas and state land. Recreation at state land has the lowest per trip value. From regional perspective recreation seems to have greatest per trip value in southern and eastern Finland.

Table 9.10. Consumer surplus estimates per trip (€) for nature trips at different regions and site types

	Everyman's rights	State land	Leisure home
Southern Finland	55.5	55.5	55.5
Western Finland	55.5	55.5	118.2
Eastern Finland	55.5	55.5	189.3
Northern Finland	81.6	100.3	166.0

Considering values of over-night nature trips, trips to leisure homes and northern Finland stand out from the others (Table 9.10). Per trip value of a trip to state land in northern Finland is almost twice as big as value of a trip to state land in other parts of the country. Trip to everyman's right area in northern Finland provide consumer surplus that is about 45 percent bigger than trips to same type of site elsewhere in Finland.

Aggregate values, i.e. number of visits and trips multiplied with corresponding consumer surpluses have also been calculated. The pattern in the value of close-to-home recreation and nature trips per region follow the pattern of actual use. In the value of close-to home recreation the main driver of was again the number of population per region. The importance of green areas in most populated parts of the country, Uusimaa and is easily observed. The value of the areas used on the basis of everyman's right is important also here.

9.4.1.3 Mapping the use and the value of recreation ecosystem

Mapping the use and the value of recreation ecosystem started with the identification of natural and semi-natural areas that can be seen as green areas providing recreational use for free according to the Finnish legal concept of everyman´s right. Finnish national CORINE Land Cover 2006 data (25 m x 25 m grid) was used to extract these areas (Söderman et al. 2011). All pixels of identified classes were merged to form separate green areas after which all areas smaller than 1,5 ha were removed to get recreational areas of recommended size (Niemelä et al. 2010, Söderman et al. 2012). As a result, a data layer of areas used on the basis of everyman´s right was created. State-owned protection areas were extracted from Finland´s protected areas database and State land hiking areas from the VIRGIS database on recreation opportunities. Second homes (summer cottages) were derived from the Finnish Population Register. All three data layers of destinations of recreational use were then joined to Region (NUTS 3) data.

Recreational use and value data were joined to spatial data to allow their mapping. Data on State land use could not be visualized spatially explicitly due to the small size of State land areas in most of Finland. The quantile classification scheme in which each class contains an equal number of features was selected to better present the data. Furthermore, in order to minimize distortion and to avoid misleading representations of results, the maximum sensible number of classes was used.

In the case of the Metropolitan region of Helsinki, recreational use and value data were joined to partly dissolved postal code areas. This allows the comparison of availability of green areas in respondents´ home area and the actual recreation in different distances from home.

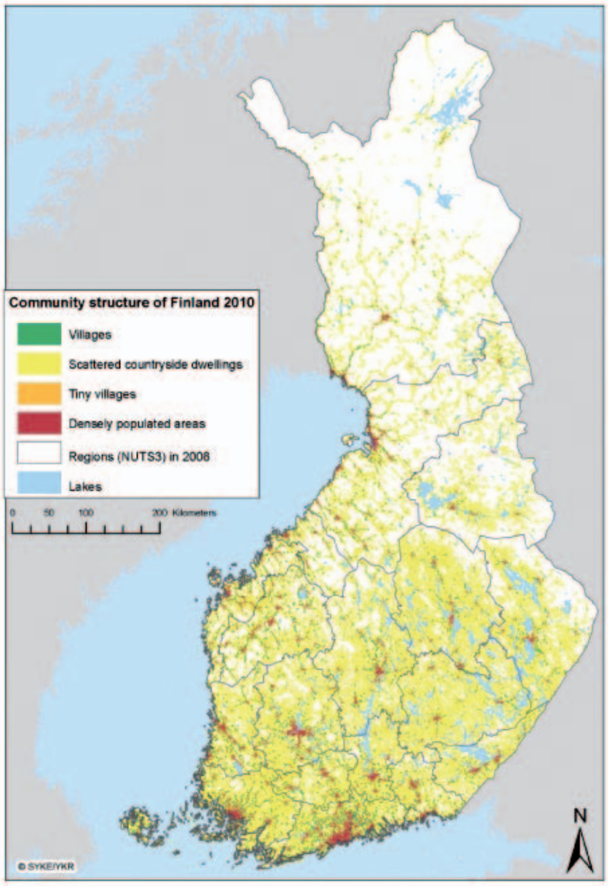


Figure 9.27. The Community structure of Finland in 2010. The capital region of Helsinki is located in the Region of Uusimaa in the southern coast (largest densely populated area). It hosts one fifth of the Finnish population.

Nature trips

Figure 9.27 shows the Community structure of Finland in 2010.

Focusing on areas used based on everyman's right Figure 9.28 shows how the number of trips, trips per square kilometer, total value and value per square kilometer vary regionally.

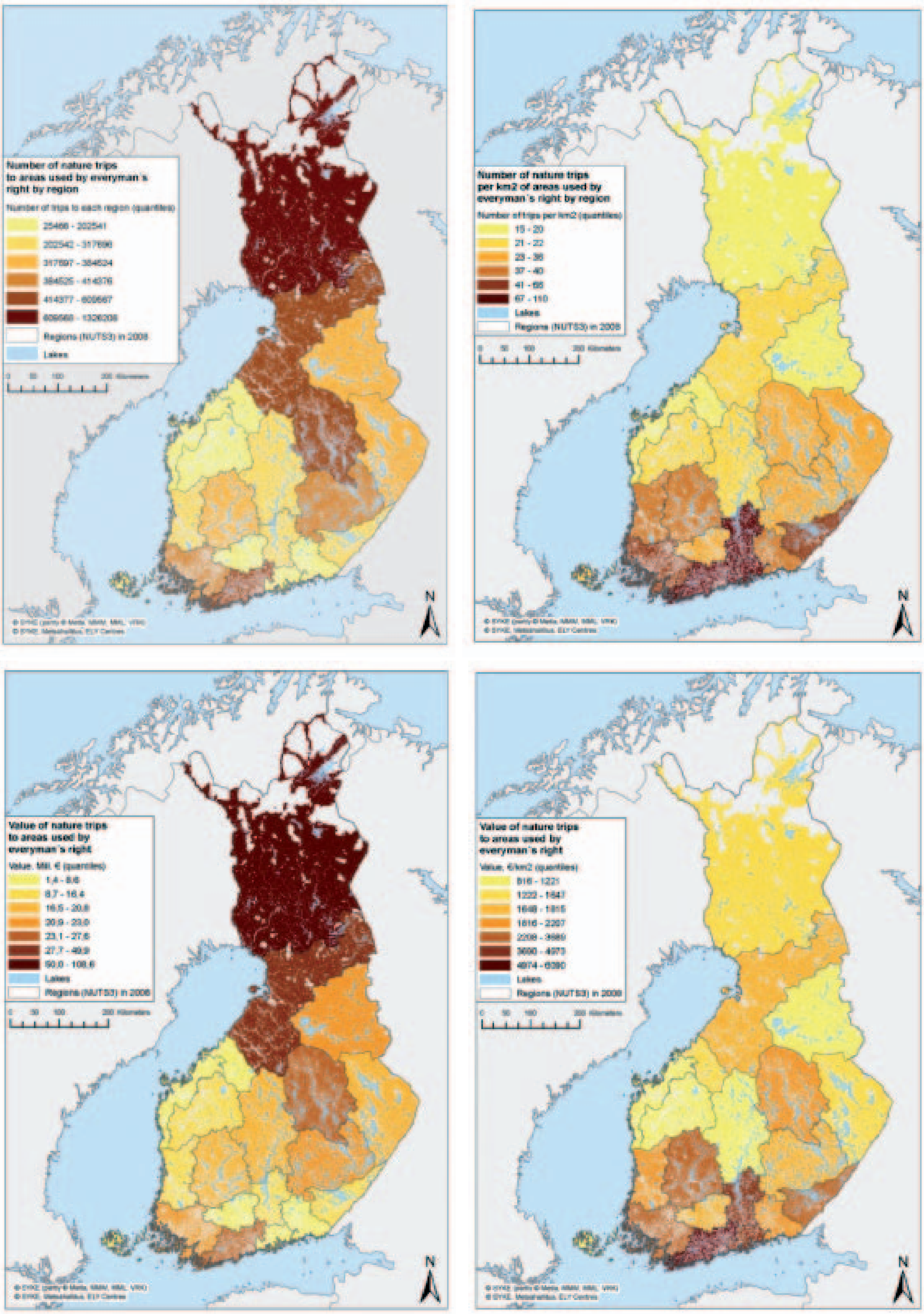


Figure 9.28. Nature trips to areas used based on everyman's right. Source: Metla/LVVI2 data.

The pattern in the regional total value is linked to the number of trips. Correspondingly the pattern in area-based use and area-based value are similar. In the south of the Country the number of users is high and the population pressure is visible when use and values are targeted to the quantity of areas supplied. The total use and value are particularly high in northern Finland where beyond the popular national parks the areas used based on everyman's right are widely used for nature tourism. Figure 9.29 shows the importance of State areas in northern Finland. Figure 9.29 also reveals the reason for the importance of everyman's right areas and summer cottages in other parts of the country, where State areas are very scarce.

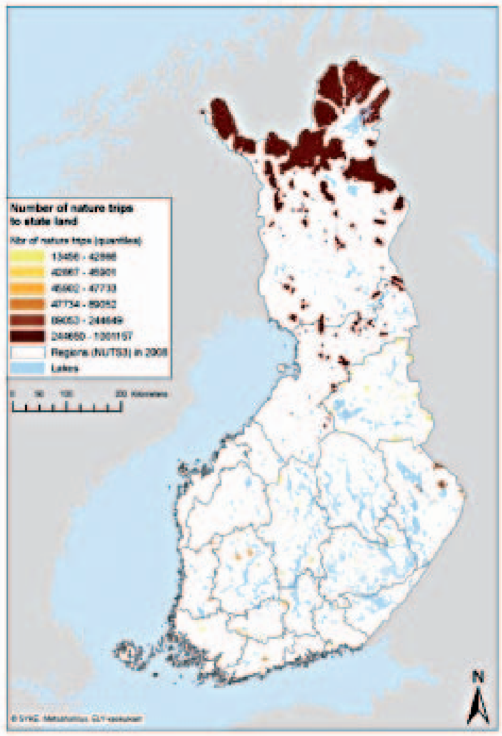
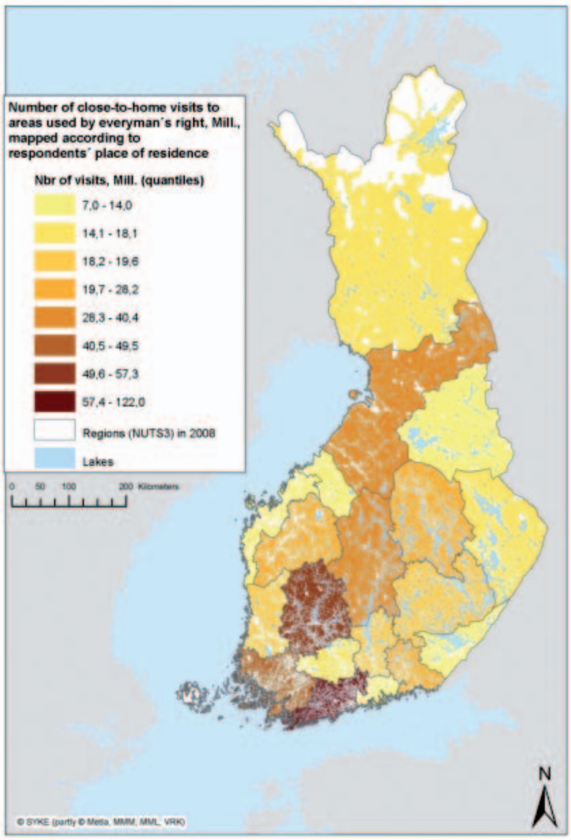
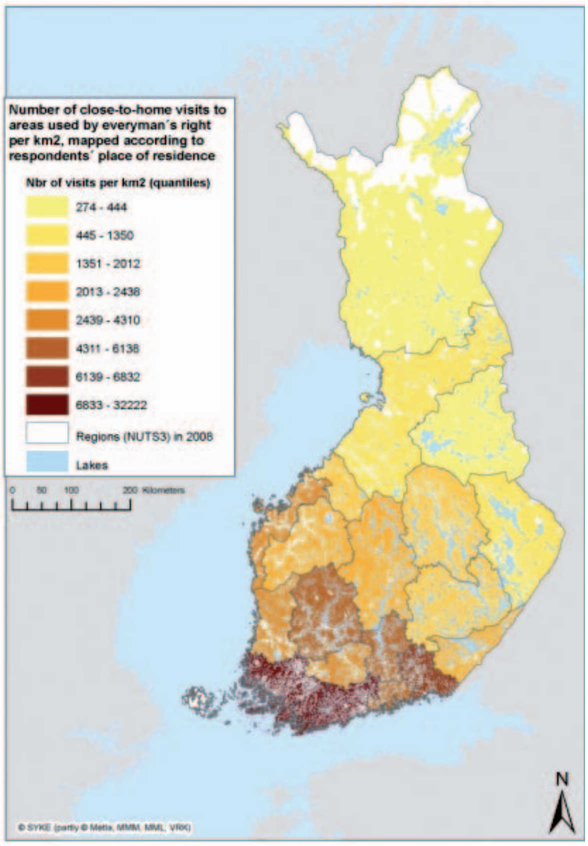


Figure 9.29. The use of State protected and hiking areas for recreation. Most protected areas on state land together with state land hiking areas are located in northern Finland. Source: Metla/LVVI2 data

Close-to-home recreation

As mentioned in 9.2.1 the main driver of the total number of recreational close-to-home visits is the number of inhabitants per region, and the importance of the everyman´s right can be seen in all regions.





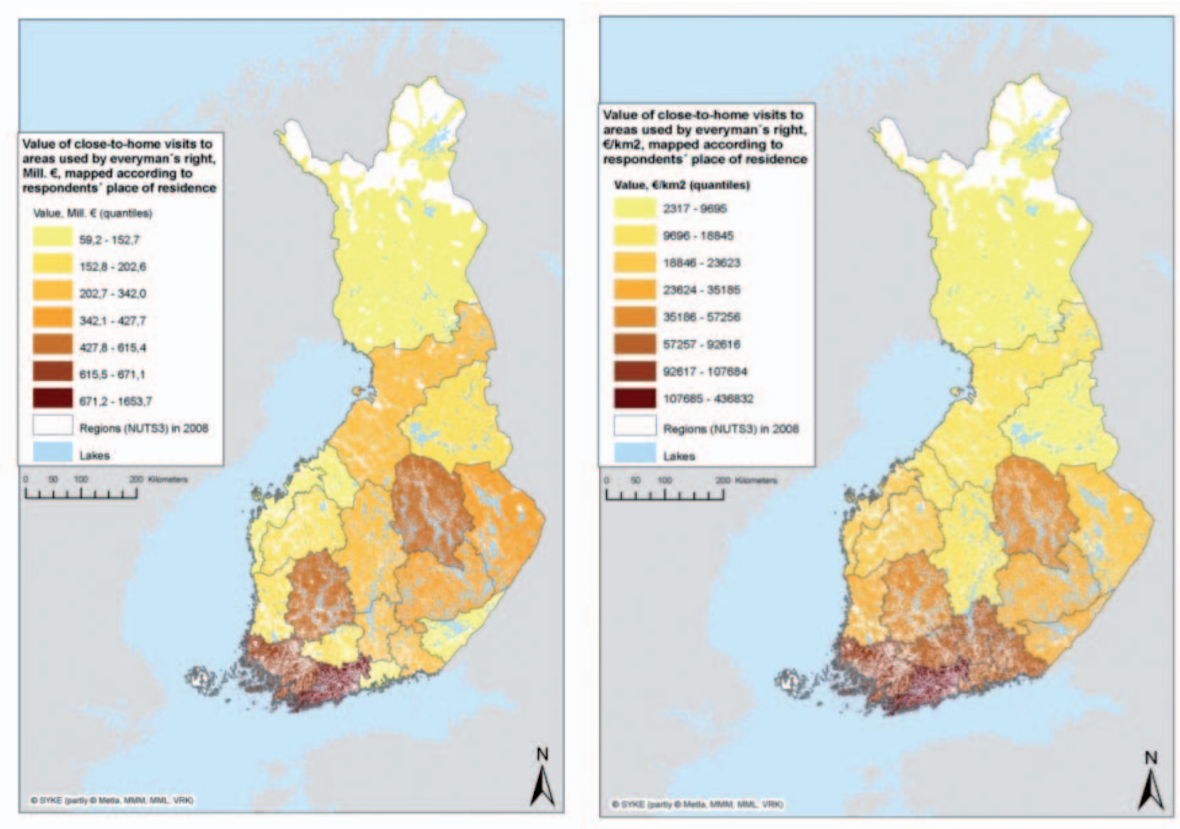


Figure 9.30. The number and the value (million euros) of close-to-home visits to areas used by everyman´s right in total and in proportion to area (km2) of everyman´s right areas. Source: Metla/LVVI2 data.

The regional aggregate number of close-to-home visits based on everyman's right and corresponding values are reported in Figure 9.30. Even though there is some variation in participation rates and number of visits between regions, in the regional close-to-home recreation visits the main driver is the number of inhabitants per region. This implies that the most populated south-west corner shows the highest number of visits. The pattern in the value of close-to-home recreation per region follows the pattern of actual use. The use per square kilometer and the area-based value is proportionally higher than the total regional value of close-to-home visits in the western and southern agricultural areas where the share of open green areas is lower.

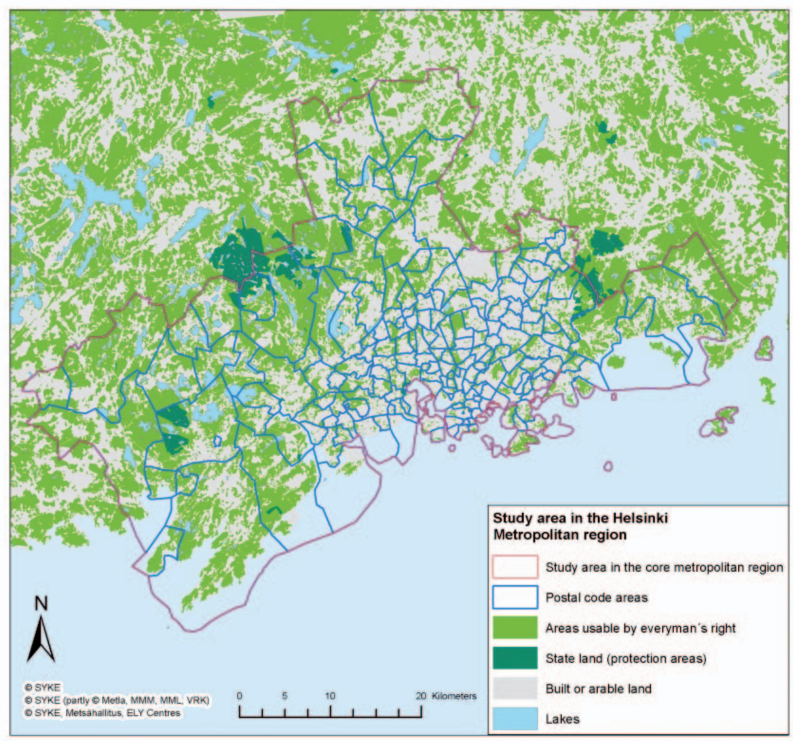


Figure 9.31. Study area in the Helsinki Metropolitan region including neighbouring cities of Espoo, Vantaa and Kauniainen. Source: Metla/LVVI2 data

The in-depth analysis for the Helsinki region is reported in the following Figures 9.31 to 9.34. It confirms that around three quarters of close-to-home recreation trips take place within a distance of 5000 m, and that the number of trips and the value are directly linked to population density. The total value of the recreation service is estimated in several hundreds of M€ for the capital city.

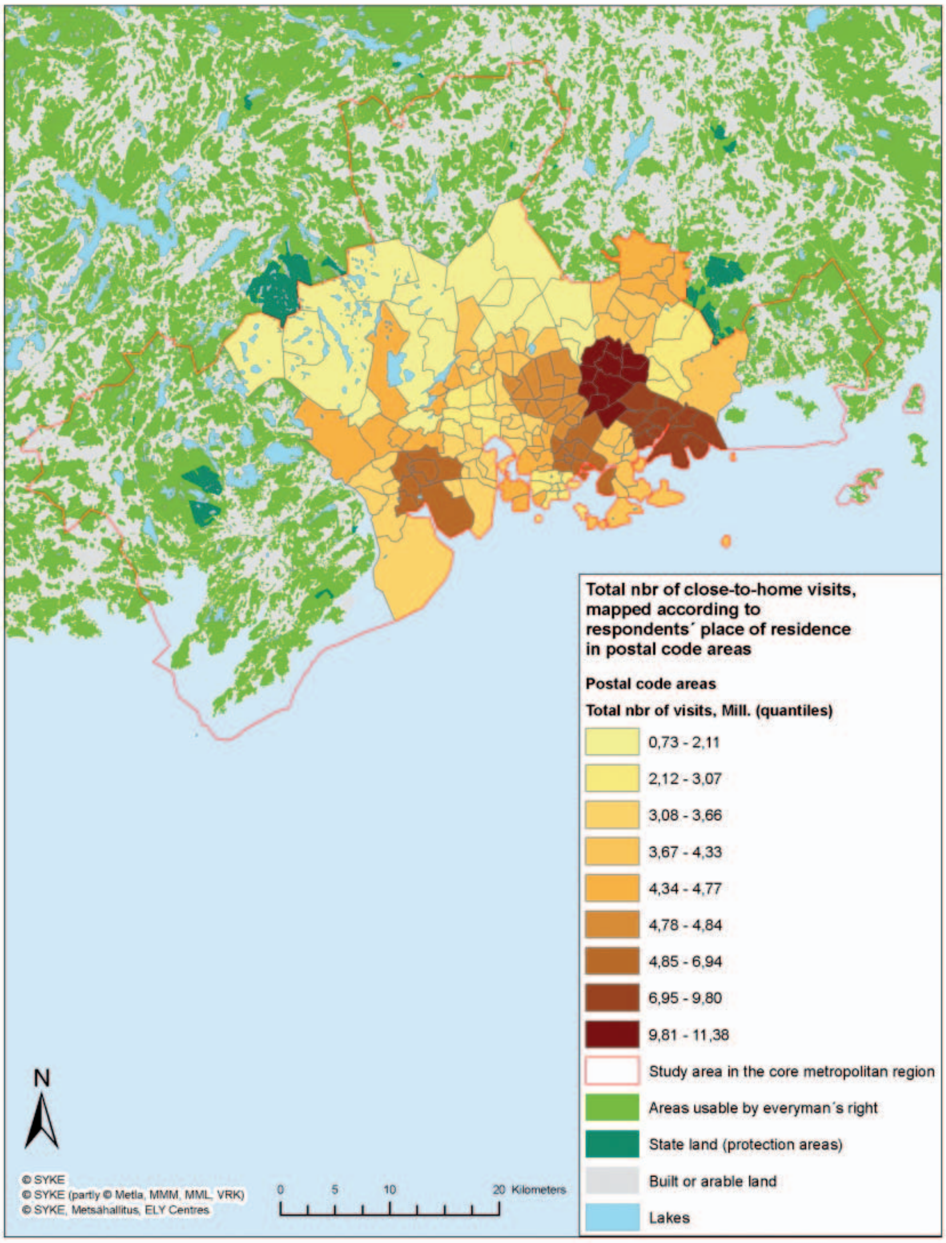


Figure 9.32. Total number of close-to-home visits. Source: Metla/LVVI2.

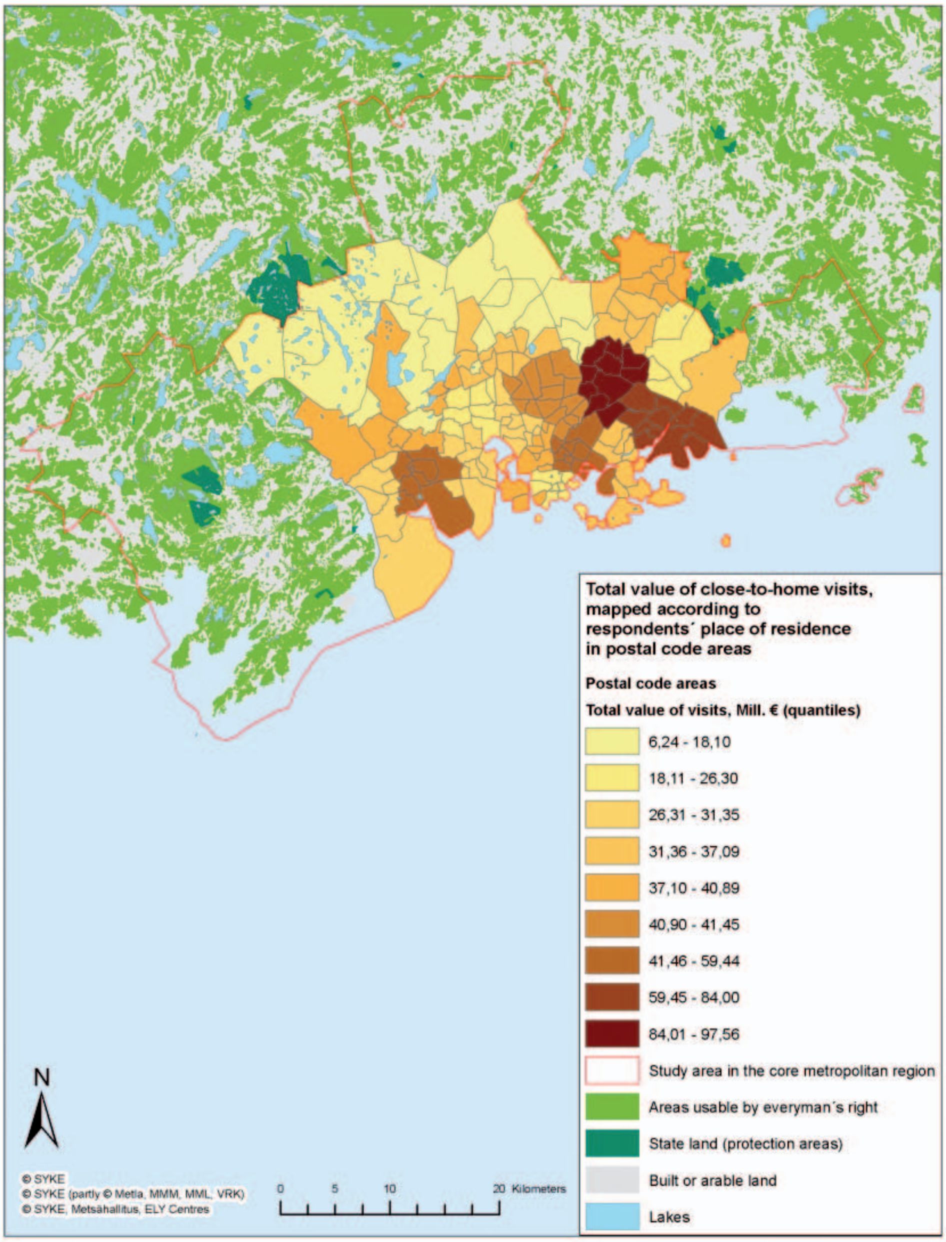


Figure 9.33. Total value of close-to-home visits. Source: Metla/LVVI2 data.

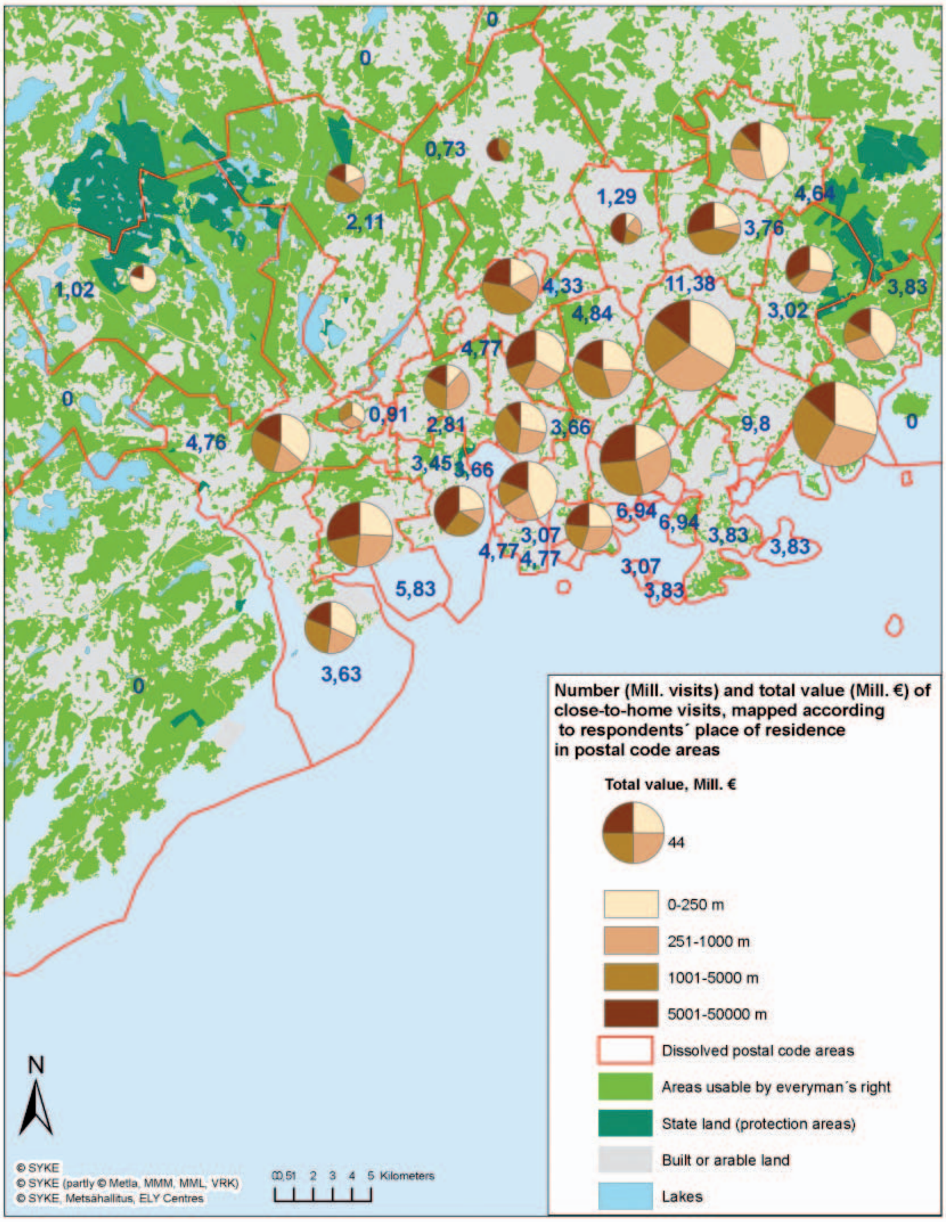


Figure 9.34. Number and total value of close-to-home visits, according to travel distance. Source: Metla/LVVI2 data.

Overall, the results of the number of visits and the aggregate values of visits and trips clearly show the importance of close-to-home recreation. The relative importance of close-to-home recreation is high compared to nature trips with overnight stay in total number of visits and values. The spatial allocation of close-to-home visits and values follow the location of population. The results emphasize the importance of everyman's right as the clear majority of the daily visits and nature trips and their values distributes to areas that are used based on the everyman's right. The recreational use of nature based on everyman's right is emphasized also because State areas that can provide recreation sites are mostly located in northern Finland on sparsely populated areas far away from the population centers of southern Finland. Further links between the availability and quality of different green areas around the place of residence and the distances people travel to reach different types of destinations for recreation need to be studied more closely to find out the interaction between place of residence and recreational environments people use.

9.4.3 Willingness to Pay – an application for Denmark

9.4.3.1 Scaled-up value of access for car-borne visits

The most valuable site (willingness to pay of car access close to 12 M€) is a unique site, being a former royal hunting forest and is today the most visited natural area in Denmark. Other very valuable sites generating a WTP for car access of more than €3 million per year comprise a large urban site at the fringe of Copenhagen and two sites located close to coast and lake towards the north in the region. Sites representing €1-3 million per year are some-what smaller sites located but located either at the fringe of Copenhagen or close to the coast in the north. Small remote forests range as expected as the least valuable forests. The same pattern is found in Figure 9.35, depicting the spatial distribution of total visitor numbers, including non-carborne visits.

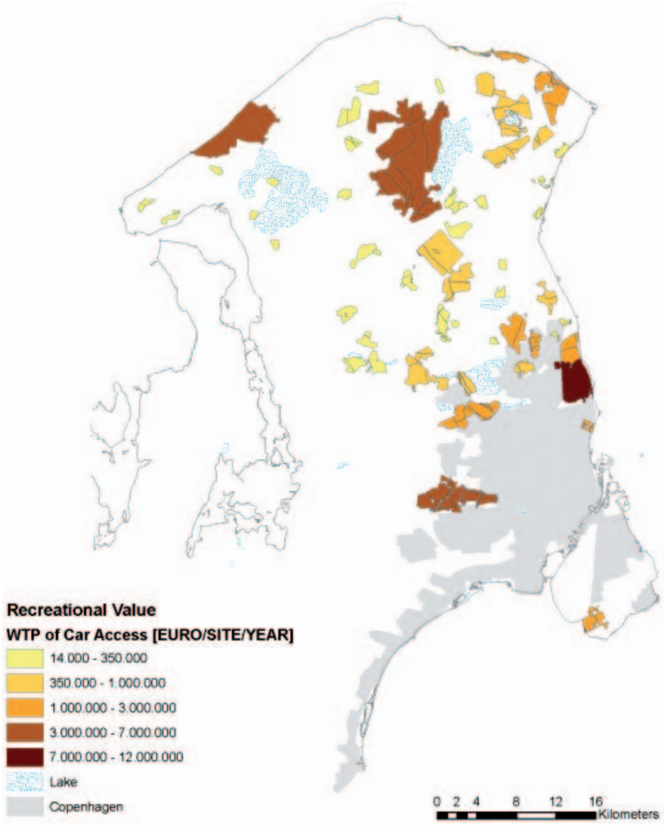


Figure 9.35. WTP of Car Access (€/site/year)

9.5 Scenario analysis

In order to verify how the described methodologies can be applied in a context of changing provision of ecosystem services, a test with scenario analysis has been carried out, on land use scenarios for Finland and Denmark.

9.5.1 2030 Scenario for Finland

The analysis for Finland has been carried out on the whole Country, on the basis of results achieved by applying the ROS methodology, coupled with a population and land use change scenario for 2030.

9.5.1.1 Land-use changes for the year 2030

The projected land use map for year 2030 constitutes the main output of the Land Use Modelling Platform (LUMP), based on the methodology described in Lavalle et al.(2011b). In the scope of the current case study, the configuration of the model implements the Integration policy option, which builds on the current policy provisions a specific set of greening measures/options from the environmental part of the CAP reform and particularly on the greening component of Direct Payments. It is noteworthy the fact that the present modelling exercise does not consider the whole CAP policy provision for all greening measures, in accordance with Lavalle et al.(2011b).

LUMP integrates diverse and specialized models and data into a coherent workflow. It has a modular structure and is organized in three main components (see Figure 9.36): the amount of land claimed per land-use type(Land Demand Module), a set of rules to allocate the requested land (Land AllocationModule, EUCS100) and the computation of indicators to facilitate the analysis of results (Indicator Module).

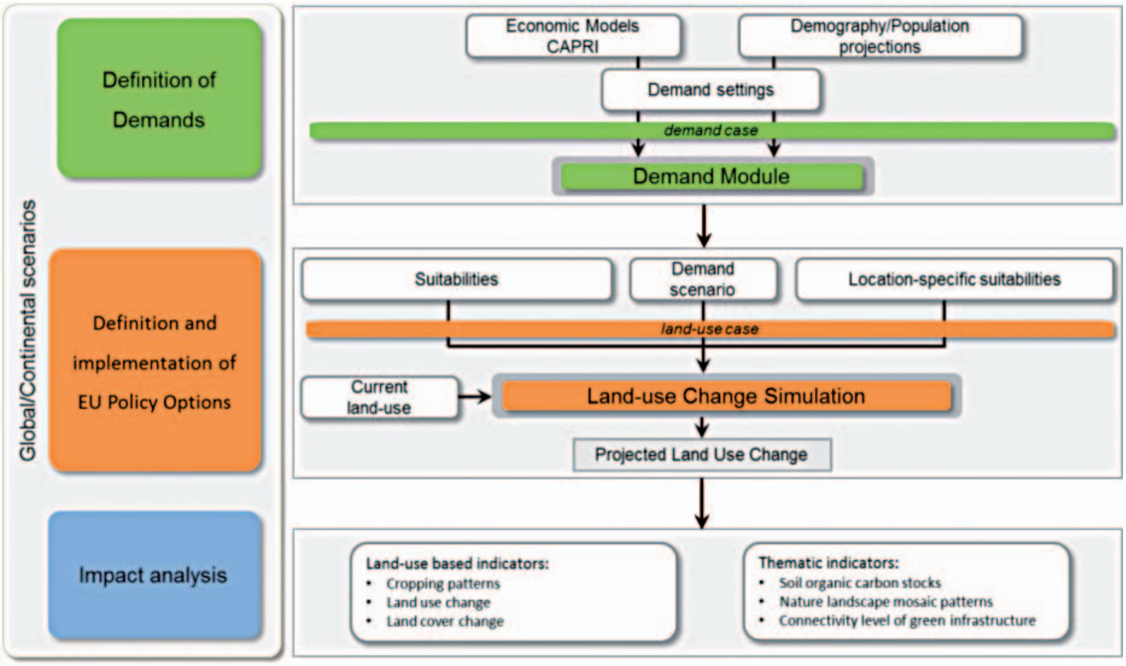


Figure 9.36. Overall workflow of LUMP highlighting the three main modules of the model (Source:Lavalle et al., 2011b)

At the core of the LUMP is the EUCS100 model operating at 100 meters spatial resolution (Lavalle et al., 2011a). EUCS100 is based on the dynamic simulation of competitions between land uses. Its spatial allocation rules build on a set of locally influencing factors which together define the suitability of each land parcel for each land use type.

The current land use and starting state for the simulation is a refined version of CORINE Land Cover 2006 (CLC_r) (Batista e Silva et al., in press). The Simulated land use/cover classes are subject to change over the simulation period (in this work from 2006-starting state, to 2030) according to the above workflow, whereas the non-simulated classes are fixed throughout the time span. The legend for the present modelling exercise has been defined as follows (Table 9.11). Arable land includes cereals, maize and root crops. Additionally, abandoned agricultural land (abandoned arable land, abandoned permanent crops and abandoned pastures) is modelled: nevertheless, in the scope of the present case study, it is included in the arable land use class, given the not relevant amount of land classified as such.

Table 9.11. Simulated and Non-simulated land-use/cover classes

Land use classes		
	Urban	Simulated
	Industrial/Commercial/Services	Simulated
	Arable	Simulated
	Permanent crops	Simulated
	Pastures	Simulated
	Forests	Simulated
	Semi-natural vegetation	Simulated
	Infrastructure	Non simulated
	Other nature	Non simulated
	Wetlands	Non simulated
	Water bodies	Non simulated

Land Demand Module

The land claims in the LUMP are computed at the level of NUTS2 regions. The main inputs are:

- Common Agricultural Policy Regionalised Impact Modelling System (CAPRI) for agricultural land;
- Historical trends from Corine Land Cover for arable land, permanent crops, pastures and forest;
- Population projections for urban land and industry/commerce/services(provided by Ymparisto and detailed at commune level).

The supply data of crops from the CAPRI model are used to define the demands for agricultural land (i.e. arable land, permanent crops and pastures) in LUMP. The crop types as detailed in CAPRI are aggregated in accordance with the legend used in EUCS100.

Land claimed for urban areas is given by a measure of residential density, computed using the population projections given by Ymparisto and detailed at commune level. A similar approach is applied to derive land claims for industrial areas. Forest land claims are extrapolated from historical trends of CLC data (METLA projections for forest in Finland do not forecast major changes over the 2006-2030 period). All of this data is merged within the LUMP configuration to provide input to EUCS100.

Semi-natural vegetation is simulated, although no specific claims are provided for this land use class. Changes to this class are governed primarily by the dynamics of the active classes and by specific policy-driven layers (when provided for the specific Policy Option implemented).

Land Allocation Module

The actual transformation from the current land-use state to a future state is computed considering the most suitable land use for that specific location at each specific time. The probability that a specific land use will be allocated to any given cell is defined according to the combination of three main factors:

1. land-use conversion rules:t hey are implemented as a matrix that defines which land-use transitions are allowed: these may be either natural (natural succession) or anthropogenic. In some cases the conversions may be constrained by succession maps that specify the locations where they are allowed to take place (e.g. Natura2000 sites). The matrix entails all the possible conversions between the modelled land use classes;
2. bio-physical and geographical properties: they include accessibility and biophysical properties such as topography, soil characteristics and crop suitability maps (provided by the JRC-IES AGRI4CAST Action, Baruth et al., 2006);
3. neighbourhood effect: it refers to the attraction and repulsion relationships between land-use types.

The factors contributing to this probability can be altered (enhanced or reduced) by specific combinations of spatial policies or measures (e.g. subsidies). This alteration is dependent on the type of spatial policy and on the possible overlap of different policies.

In the scope of the present case study, the current policy provisions are detailed as follows:

- Natura 2000: Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora and Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds;
- Nitrate Vulnerable Zones (NVZ): Council Directive of 12 December 1991concerning the protection of waters against pollution caused by nitrates from agricultural sources (91/676/EEC);

- Erosion sensitive areas: the current GAEC framework (Council Regulation (EC) No. 73/2009, Annex III);
- Less Favoured Areas (LFA): this payment scheme promotes agriculture production in areas with natural handicaps (Articles 18 and 20 of Council Regulation (EC) 1257/1999).

Each of the issues listed above contributes to enhance/discourage the probability of occurrence of specific modelled land uses(i.e. Arable Land, Permanent crops and Semi-natural vegetation).

In addition to the current policy provisions, the Integration policy option implements the following greening measures (Lavalle et al., 2011b):

- Ecological focus areas (up to 7% of the UAA);
- Permanent pastures: maintaining the land in its current status;
- Natura 2000: maintaining the land in its current status (support to all designated agricultural Natura 2000 areas).

Furthermore, Arable land, Permanent crops, Pastures and Semi-natural vegetation land-use/cover classes receive an enhanced probability of occurrence in areas classified as high nature value (HNV) farmland (Paracchini et al., 2008). For a detailed dissertation on the rationale, refer to the methodological section of Lavalle et al., 2011b.

Finally, the allocation of urban land is influenced by the spatial dynamics as given by the population projections: the probability of occurrence of urban expansion is enhanced in those communes that, compared to the average population change in the respective NUTS2, have a higher population increase. On the contrary, in communes characterised by a sharper decrease in population compared to the respective regional trend, urban expansion is less likely to occur. Thus, location specific weights are assigned to each commune based on the projected increase/decrease in population computed at NUTS2 level between 2008 and 2030.

9.5.1.2 Population distribution maps for Finland

Two high resolution population distribution maps were produced for Finland: one for the reference period 2006-2008, the other for the year 2030. Both maps have a spatial resolution of 100x100 meters (pixel size) and estimate the number of residents (night time population) per pixel. The technique employed to obtain such high resolution maps is called 'dasymetric mapping'. It consists of a "cartographic technique whereby ancillary thematic data is used to refine the geographical representation of a quantitative variable reported at coarse spatial aggregations" (Batista e Silva et al., submitted).

Instead, if total population aggregated at commune level was considered for the analysis, several distortions and inaccuracies would propagate. Considering the whole population per commune has the main following limitations:

- Population is assumed to be equally distributed within the commune;
- Vast remote and unpopulated areas are assumed to be inhabited;
- Communes vary greatly in size, which distorts the overall population density per commune.

The above mentioned issues are particularly relevant for countries like Finland where urban areas occupy a rather small share of the entire territory, and where communes are very big in size compared to most European countries. By producing high resolution population distribution maps, with estimates at a regular grid level, all these effects are removed and population is depicted more closely to ground truth.

The creation of these maps required two main inputs: a) source population data at commune level; and b) ancillary data, i.e. land use/cover data. The source population data was provided by Ymparisto for the year 2008 (population estimate) and for the year 2030 (population projection). As for land use/cover data, a refined version of CORINE Land Cover 2006 (CLC_r) and the Soil Sealing Layer 2006 (SSL, EEA, 2006) were used. The CLC_r captures urban settlements with a minimum mapping unit of 1 hectare. The SSL describes the degree of imperviousness of the soil (0-100%), and is herein used as a proxy for housing density.

To generate the finer population grid map, source population figures are disaggregated from the commune level to the urban fabric pixels (as mapped by the three urban fabric classes of CLC_r). Population is redistributed with different weights for each urban fabric class in each commune. The weights are directly derived from the average soil sealing degree of each urban fabric class in each commune in 2006.

Table 9.12 summarizes the main inputs used to produce the current and the projected population distribution maps.

Table 9.12. Summary of the main inputs used to produce the two population grid maps

Source population data	Ancillary data	
	Land use/cover map	Soil Sealing Layer
Population estimate for 2008 at commune level as given by Ymparisto (commune boundaries as of 2009)	As captured in CLC refined 2006 (three urban fabric classes: high density urban fabric, medium density urban fabric and low density urban fabric).	The average soil sealing degree is computed for each urban fabric class in each commune, as of 2006.
Projected population for 2030 at commune level as given by Ymparisto (commune boundaries as of 2009)	As simulated by the land use model, EUClueScanner100.	

The resulting maps are comparable because similar input data and disaggregation rules were applied, and are therefore suitable for time series analysis. Figure 9.37 illustrates the results for the reference period and for the simulated year.

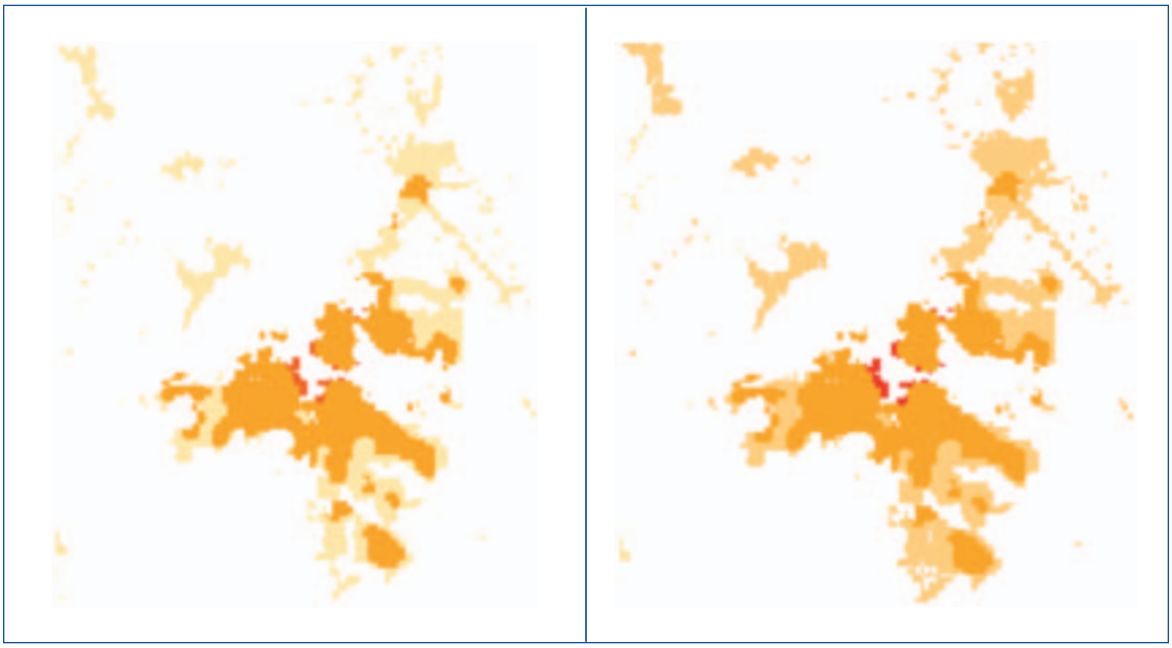


Figure 9.37. Results obtained for a small town in Finland. On the left, population distribution in the reference period 2006-2008. On the right, projected population distribution of the year 2030. Note the changes in the extent of the urban settlement and in its population density

9.5.1.3 Scenario analysis: change in recreation provision

In order to analyse changes in recreation provision due to changes in land use pattern and demography, the ROS method has been applied. Since the input data are slightly different from those described in 9.3.2.1, the ROS has been calculated for the simulation year (2030) and re-calculated for the base year 2006, so that results can be compared. The methodology had to be simplified, according to the simplified legend of the land use projections, and the lack of data to calculate the degree of naturalness. Therefore some assumptions have been taken in order to relate the classes in the land use maps and their corresponding degree of naturalness. The map derived from detailed data and presented in 9.3.2.1 was used as reference in the exercise. Protected areas and coastlines have been considered invariant. Figure 9.38 shows details of the resulting ROS for 2006 and 2030.

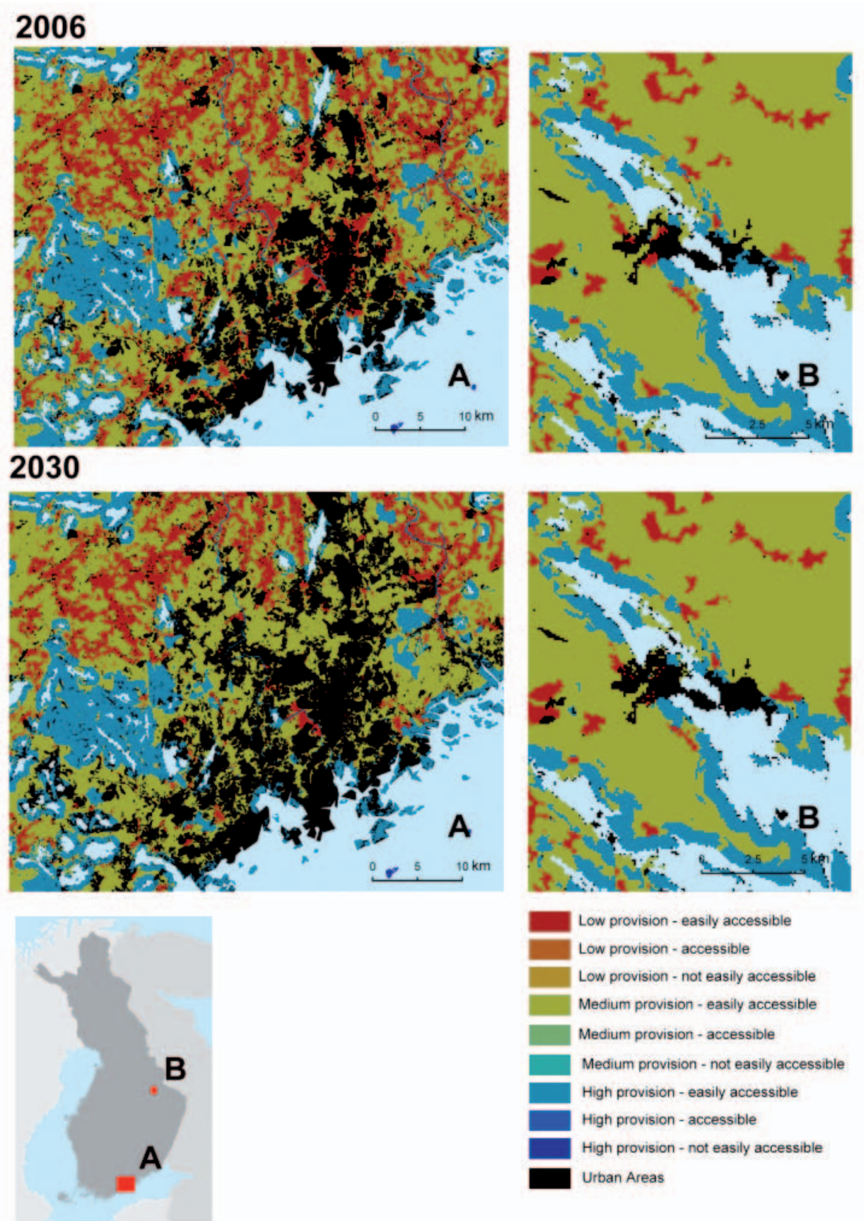


Figure 9.38. Details of a land use scenario for Finland

The methodology to calculate population pressure and the distance thresholds described in 9.3.2.1 was applied to the population density maps described in 9.4.1.2.

Changes are mostly linked to the dynamics of population and are summarized in Table 9.13 in the four NUTS2 Finnish regions.

Table 9.13. Population scenario for Finland

		population		
NUTS2	AREA (sqkm)	2006	2030	% difference
Lapland	1415370000	640150	694670	+ 9 %
East FI	851696000	655670	627069	- 4 %
South FI	445581000	2625830	2989020	+ 14 %
West FI	644677000	1348830	1466740	+ 9 %

Table 9.14 summarises changes in recreation provision in the ROS zones.

Table 9.14. Changes in recreation provision in ROS zones for Finland

	ROS zones	2006	2030	% difference
South FI	1 - Low provision- easily accessible	29.7	28.4	-1.3
	2 - Low provision- accessible	0.0	0.0	0.0
	3 - Low provision- not easily accessible	0.0	0.0	0.0
	4 - Medium provision- easily accessible	53.5	55.1	1.6
	5 - Medium provision- accessible	0.0	0.0	0.0
	6 - Medium provision- not easily accessible	0.0	0.0	0.0
	7 - High provision- easily accessible	16.7	16.5	-0.2
	8 - High provision- accessible	0.0	0.0	0.0
	9 - High provision- not accessible	0.0	0.0	0.0

The population scenario that has been used in this study is not foreseeing extreme changes, but is rather following current trends. Therefore it can be concluded that under the considered conditions (CAP greening scenario, small changes in forested areas, stable surface of protected areas), recreation provision to the Finnish population remains stable.

9.5.2 Scenario of increased urbanisation for Denmark

Over the past years, the number of citizens in the municipality of Copenhagen is growing by net 1000 person per month. This development is expected to continue and poses a range of challenges to the physical, social and economic structures of the capital. We use this observed trend as the basis for a scenario of increased urbanisation to estimate the effects on visits to regional forests. We assume that people arrive to Copenhagen from outside the region. The population in the remaining municipalities in the region investigated is therefore assumed to remain constant.

Under such scenario, the municipality of Copenhagen would grow by 240 000 adults over a 20 year period. We distribute these people on the nodes in the municipality, scaling up the number of people relative to the existing number of people on each node. Within the municipality of Copenhagen, there are no forests.

Assuming the same preferences and transport patterns in 20 years as they are today, our results indicate an average increase of 6%, ranging from a reduction in trips of 6% to an increase in yearly number of trips of 72%. This covers both people travelling by car and by other means of transport. For people using other means of transport than cars, three forests located the closest to the municipality of Copenhagen are chosen: these forests would receive between 10% and 32% more visits, equivalent to between

106 000 and 1 million additional visits per year. For people travelling by car, fewer would visit the urban forests towards the north of Copenhagen area (none of which would have received any additional visits by foot) and we would experience a more than 20% increase in visits to the three urban forests that are also preferred by people not travelling by car. A 10% to 20% increase in trips by car would occur to large forests located in north east direction from Copenhagen, whereas all urban forests towards the north of the region would receive up to 10% more trips per year. Across the 52 forests, the population growth scenario would in some places lead to a drop in visits by car by as much as 200 000 trips per year and in other locations to an increase of more than half a million visits by car, compared to today. Figure 9.39 shows the differences in number of visits per year including both car and non-car based visits after a population growth of 240 000 people. Please refer to Figure 9.17 for the total trips per year in the baseline.

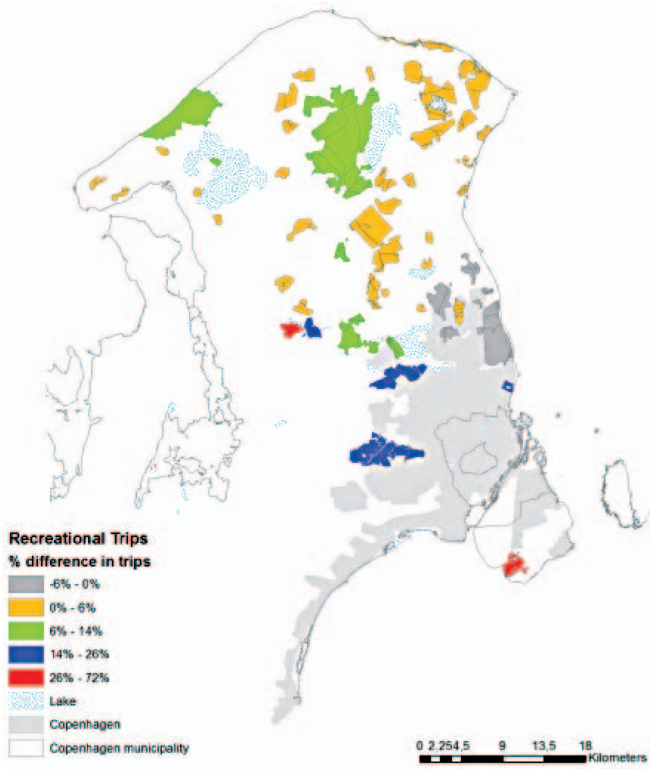


Figure 9.39. Differences in number of trips under scenario of population growth.

In terms of changes in the value of car access, results show that in some locations, forests recreation services would be reduced by as much as €134 000 per year while in other locations recreation services would yield as much as €2.8 million more if compared to the baseline. Large increases above 20% in benefits are found for forests close to Copenhagen with the exception of forests to the northern fringe of Copenhagen. Figure 9.40 shows the spatial variation in recreation service benefits due to a population growth in the municipality of Copenhagen.

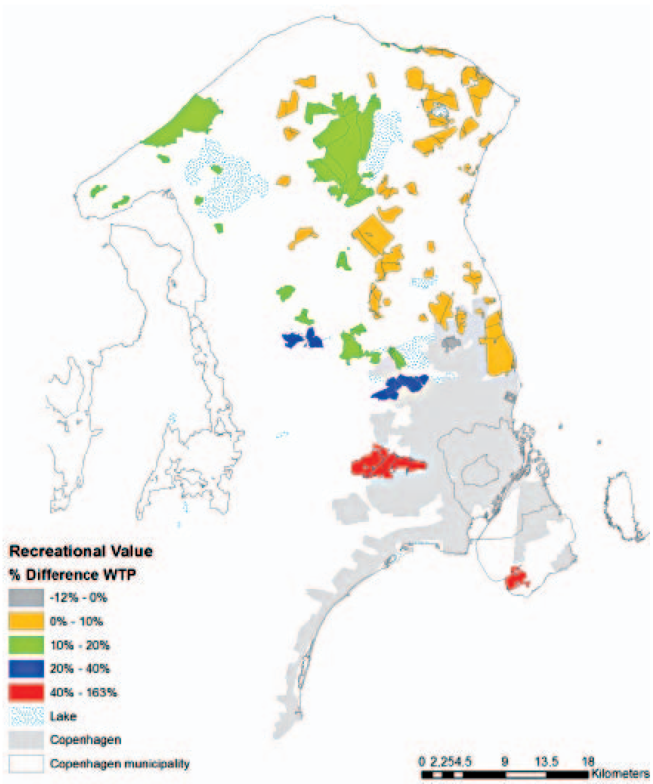


Figure 9.40. Differences in value of car access under scenario of population growth.

9.6 Summary and conclusions

The present study, though still to some extent fragmented in the approaches, shows the complexity of the analysis of recreation as ecosystem service.

The main effort that has been carried out is to base as much as possible the analysis on visitor surveys, so to approximate as best as possible people's behaviour and choices when they recreate. Findings that could be drawn from surveys that approximate people's behaviour in general terms have been applied to the EU-wide methodology, while detailed analyses have been applied to national/regional study cases.

The development of the overall approach was made according to the following steps: the estimate of visitors number and patterns of recreation trips; the mapping of the recreation potential as potential provision of the service to the citizens; the valuation of the service. Each of these steps is characterised by its own research needs since no common methodology has been developed to provide a consistent frame to address this ecosystem service. Furthermore, data availability poses constraints and need for adaptation of conceptual frames.

The EU-wide exercise is based on findings reported in Maes et al., 2011, with some improvements. What is most interesting, though, is the confirmation of some methodological steps that can be derived from surveys. One concerns the types of environments where people like to recreate, linked to nature quality and presence of water. In particular the Danish approach concludes that in general, forests receiving more than 500 000 visits are categorised with predominantly high recreation provision, i.e. forests close to Copenhagen or large attractive forests far from Copenhagen, while forests categorised as medium recreation provision correspond predominantly to forests with less than 500 000 visitors. Another important confirmation is coming from the analysis of travelled distance. A main assumption that was taken in the EU-wide exercise was in fact that all ecosystem types had to be analysed as potential sources for recreation, and not only the most valuable ones in terms of nature quality and biodiversity. In fact, if someone wants to recreate in nature shortly after work, or bring the children for a stroll, he does not have an unlimited selection of ecosystems available and can choose where to go in a limited surrounding from his home. It is therefore important to understand what the characteristics of current provision are, and then eventually plan how to improve it. Results show that in the 23 analysed EU Countries, on the average 35% of the population can easily reach sites with a high potential for recreation. This means that the remaining 65% is not in this situation. In order to understand what this means, a trade-off analysis has to be carried out with other ecosystem service, though preliminary analysis (see Maes at al, 2011 EUR report) show that areas characterised by a higher degree of naturalness (i.e. forests) have a multiple provision of ecosystem services, some of which directly impact human health (i.e. air quality regulation). Though the issue is not yet addressed in literature under the umbrella of ecosystem services, the restorative and stress reduction capacity of ecosystems would be a major theme for research. It is in fact reported that wilderness and the natural environment in general do have restorative capacities on humans. Accessibility to these areas is therefore important also from this point of view. The analysis made at country level provides some ideas on how accessibility can be granted: some countries have an inherent high provision of recreation potential because i.e. in Sweden/Finland the boreal environment is characterised by a high degree of naturalness. In Countries where this provision is lower because intensive agriculture covers large areas (i.e. Germany, United Kingdom, France, Italy), the network of protected areas is a major element in ensuring potential recreation provision. In fact intensive agriculture takes place mostly in lowlands, where some major European cities are located, and where millions of people live. The case of Italy is a good example of this situation: a high recreation potential is mostly provided by areas in the hills and mountains, which are further away from millions of citizens than the average distance of close-to-home trips. On the contrary, countries like Germany shows a more evenly distributed network of protected areas on the national territory.

The fact that in the case of recreation the surrounding environment is extremely important is demonstrated by the data of the Finnish survey, which show the outstanding importance of the everyman's right, or the right to have public access to the land, about 80% (even more in some regions) of close-to-home trips are in fact made to this type of environment. The total number of close-to-home trips accounts for over 500 million trips/year. The Danish survey also provides high estimates for trips to forests, estimated in over 26 million/year in the Copenhagen and Frederiksborg regions only.

The fact that the surroundings are important in recreation analysis highlights the role of urban green areas. As shown by chapter 9.3.3 also in this case spatial distribution matters, and has the double effect of providing a higher number of residents with recreation potential, and of diminishing visitors pressure on each area. Statistics on Dutch provinces show that availability of green urban areas to people living in a 500 m surrounding range from 14 to 56 m2 , with an average around 30 m2. Further research should compare the share of population that has easy access to such areas to the share that does not have easy access, in order to draw conclusions valuable also for town planning processes.

The valuation exercise provides interesting results. For example, in the case of Finland, the analysis of consumer surplus estimates per trip show that leisure homes and northern Finland stand out from the others. Furthermore, per trip value of a trip to State land in northern Finland is almost twice as big as value of a trip to state land in other parts of the country. Trips to everyman's right area in northern Finland provide a consumer surplus that is about 45 percent higher than trips to the same type of site elsewhere in Finland. This shows that people are willing to travel further away and recreation visits have a higher value in areas characterised by outstanding nature with a high potential for recreation. On the other hand, close-to-home trips to areas used by everyman's right reach the value of 107000 to 436000 euros/km2 in the capital region where most of the Finnish population is living. The total value of the recreation service is estimated in several hundreds of M€ for the capital city.

The Danish study on forests in the Copenhagen and Frederiksborg regions concludes that the willingness to pay for car access ranges from 1 to 12 M€ per site. The analysed forests are 52 so the total value is exceeding 50 M€ for just one type of ecosystem.

The scenario analysis is a pioneer study linking land use modelling, a population growth scenario and recreation provision. The scenario applied on Finland is a Business as Usual scenario, so no major changes were expected in recreation provision in 2030. In fact results show that under current conditions changes are very small. The procedure applied in order to reach the result, though, is complex and can be applied under many different conditions without any the need to be changed.

The procedure applied on the Danish study case is different and focuses on the increase in the urban population and the effect that this could have on the demand for forest recreation services. Results indicate that with an increase of 240 000 of the population living in the municipality of Copenhagen over a 20-year period, forests closest to Copenhagen would receive between 106 000 and 1 million additional trips (equivalent of 10-32% increase). Changes in the value of car access show in some locations a reduction of €134 000 per year while in other locations recreation services would yield as much as €2.8 million more if compared to the baseline.

It is premature to draw EU-wide conclusions from this study on the value of recreation as ecosystem service. Nevertheless the magnitude of estimates provided by the case study areas proves that such value may easily be in a range of billions of euros, and may increase if the avoided cost for health care due to recreation restorative and stress reduction capacity is included.

10. Mapping and stakeholder assessment of pollination services at different spatial scales

10.1 Introduction

In Europe, farmland biodiversity has drastically declined over the past few decades due to agricultural intensification, which has led to the loss and fragmentation of semi-natural grasslands (Öckinger & Smith 2007) and other non-crop habitats (Hietala-Koivu et al. 2004). Specialized and least mobile grassland insects have suffered from habitat fragmentation the most (Ekroos et al. 2010) and declines in the populations of pollinating grassland insects have been widely reported (Biesmeijer et al. 2006, Potts et al. 2010).

At the same time, along with the Millennium Ecosystem Assessment (2005), the availability of ecosystem services provided by ecosystems has become a topical issue (Kremen et al. 2002). Ecosystem services, such as crop pollination, are fundamental for human well-being and their economic value is considerable. Concerns have therefore arisen, whether such services can be maintained at a sustainable level in degraded agroecoystems (Kremen & Ostfeld, 2005). In addition, the worldwide demand for pollination services is increasing, as an increasing share of agricultural land is being devoted to the production of insect-pollinated crops (Aizen et al. 2008). In Finland for instance, the call for the self-sufficiency of plant protein sources may lead to increasing cultivation areas of legume crops, which are often pollinated by insects (Peltonen-Sainio et al. 2009).

Pollination is an ecosystem process which indirectly affects many other ecosystem services. Pollination is connected to food production and recreation services. The loss of pollinators has received a lot of concern globally due to its consequential meaning for human well-being. The loss of pollination can result for example in depletion of biodiversity, various climate risks and social and economic risks, such as threats to food security, rural development and industry (IRGC, 2009).

Crop pollination by bees and other insects is an ecosystem service with high economic value. The productivity of many agricultural crops depends on the presence of pollinating insects and the ecosystems that support insect populations. Insect pollination is necessary for 75% of the crops that are used directly as human food worldwide (Klein et al., 2007), and cultivation of pollinator-dependent crops has steadily increased between 1961 and 2006 (Aizen et al., 2008). Attempts have been made to estimate the economic value of pollination (Byrne and Fitzpatrick, 2009). According to Pimentel et al. (1997) the value of (animal) pollination in food production is estimated to be $65–75 billion globally and honeybee pollination alone in the United States was evaluated at $14.6 billion in 2000 by Morse and Calderone (2000). According to the TEEB report (2010), the total economic value of insect pollination globally is estimated to be €153 billion, which equates to 9.5% of agricultural production. According to Gallai et al. (2009) an estimated 10% of the total economic value of European food production, amounting to €22 billion in 2005, and €14.2 billion for the European Union, is dependent upon insect pollination. A complete pollinator loss would translate into a production deficit over current consumption levels of 40% for fruits and 16% for vegetables (Gallai et al., 2009). These estimates are uncertain since the dependency of crops on insect pollination is not completely understood. Also, current studies have estimated the value of pollinators only in terms of biomass produced and the particular value of the micronutrients contributing to the human diet has not been considered (Potts et al., 2011).

In Europe, crop production is argued to be highly dependent on insect pollination with about 84% of all crops that have been studied depending on or benefiting from insect pollination (William, 1994, 2002). The dependence of European crops on pollination and the high monetary value associated with crop pollination makes it important to delineate places where nature has the potential to provide pollination services in Europe. Here we present a first tier approach to map the relative importance of pollination to European agricultural crops. We frame our mapping approach in the ecosystem services cascade model which connects ecosystem structure and functioning to human well-being through the flow of ecosystem services (Figure 10.1). Different habitats, but in particular forest edges, grasslands rich in flowers and riparian areas, offer suitable sites for pollinator insects such as solitary or honey bees, bumblebees or hoverflies. As soon as these insects start foraging, ecosystems that host these insect populations have the potential to increase the yield of adjacent crops that are dependent on insect mediated pollination (e.g. fruit trees, rape seed, or water melon). This service delivers economic value which can be measured by assessing the contribution of pollination to total crop yield or by estimating the costs that are saved.

The abundance of insect populations that effectively contribute to crop pollination constitutes a primary indicator to measure the service flow (Figure 10.1). This requires field data of the abundance of solitary species as well as of nest density and colony size of social insects. Such data are not readily available at EU scale. Instead, we used a model to derive a secondary indicator which estimates the relative abundance of wild pollinators across the landscape. Based on land cover data, we mapped the pollination potential of ecosystems and we compared this with the demand for pollination using agricultural production data. In addition to these mapping studies the Finnish case study is accompanied by a local level policy analysis based on stakeholder interviews.

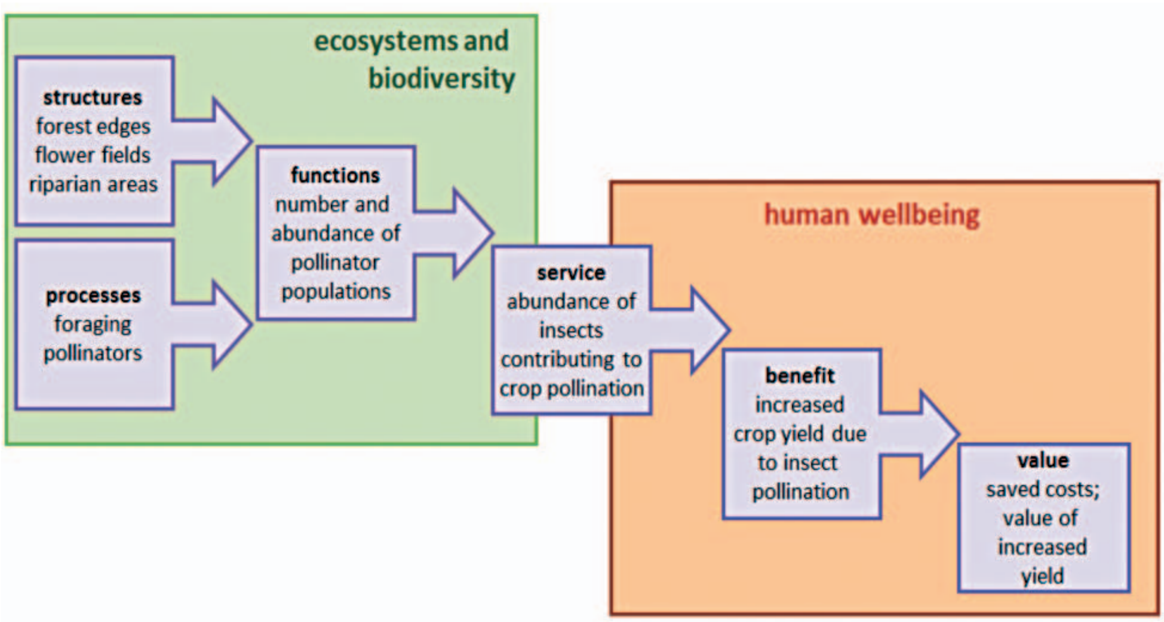


Figure 10.1. Application of the ecosystem services cascade model to frame indicators for mapping pollination services

Although managed pollination is a common practice in Europe, it was not considered here due, since we assumed that collecting data to map domesticated honey bees was not realistic. The Finnish policy analysis makes an exception on this since at the local level it is only natural to talk about domesticated and wild pollinators together. Bumblebees are the most important native pollinators of several crop varieties in the agricultural landscapes of northern Europe. It has been shown that mass-flowering crops, such as the oilseed rape, can enhance bumblebee populations at a landscape scale (Westphal et al., 2003). Also Winfree et al. (2007, 2008) have measured pollination provided by different species on farms in the US and concluded that wild bee pollinators provided the majority of crop pollination. However, fields with insect-pollinated crops only provide nectar and pollen during a limited period of time and therefore they cannot sustain bumblebee communities throughout their whole active season. Instead, the sufficient provision of floral resources requires a mosaic of different habitats in the landscape. Semi-natural grasslands and other non-crop habitats can provide a flow of nectar and pollen throughout the summer. Bumblebee nesting sites too are mostly located in non-crop habitats, such as forest edges, field margins and gardens (Osborne et al., 2008, Svensson, 2002). Evidence points out that the role of wild bee pollinators in crop pollination is important.

10.2 Drivers and pressures behind ecosystem services provided by pollinators in different land cover types

As described in the introduction, pollinators are dependent both on agricultural land and natural areas. Also domestic areas, such as gardens provide good nesting and foraging sites for pollinators. In the Figure 10.2 and Table 10.1 the interrelations between pollinators, the services they provide and the land cover type are explained. The arrows in the Figure 10.2 reflect the overall causes and effects that exist in the ecosystem and the interaction to society as described in the Table 10.1.

The different elements in the Figure 10.2 are defined as follows:

Society covers human social and welfare/wellbeing factors. This includes factors where pollination influence the human social and welfare/wellbeing properties and factors relevant for the livelihood of pollinators that are influenced by human activities. *Pollinators* cover all species of pollinating animals, mostly insects. Relations to this element include all factors that may influence the abundance and species composition of pollinators. *Agricultural* areas cover all cropping areas for commercial purposes. This covers all factors that may influence the farming practices, including pesticide application and the crop type distributions and factors related to pollination that are influenced by farming and crop distribution. *Domestic areas* cover all areas of housing, gardens, parks and other types of anthropogenic based land use. This includes all factors that may influence the ecosystem, including the abundance and composition of the pollinator and wild plant species and factors related to pollination that are influenced by the human activity in the domesticated areas. *Nature areas* cover all areas defined as "nature", including smaller semi-natural areas close to agricultural fields and domestic areas. This covers all factors that may influence the cropping praxis, including pesticide application and the crop type distributions and factors related to pollination that are influenced by the biodiversity and species abundance in the nature area.

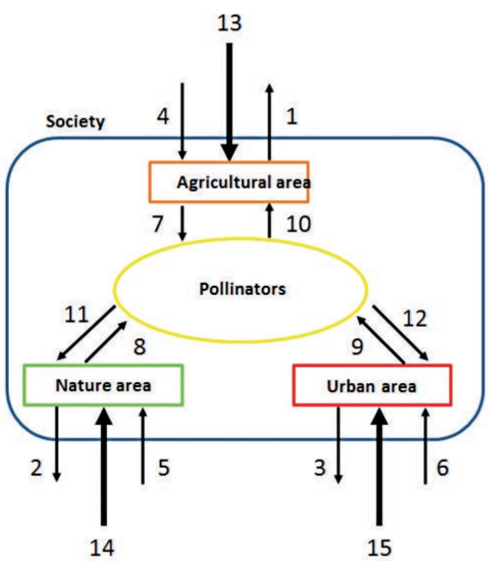


Figure 10.2. The interrelations between pollinators, land cover type and services.

Table 10.1. Explanations for the relationships in Figure 10.2.

Type of relation	Arrow number	Content
Ecosystem services/goods	1	Delivery of goods to society from agriculture, where pollination is considered to facilitate either quality or quantity. This is primarily food and biomass production
	2	Delivery of services and goods to society from nature areas, where pollination is considered to facilitate the quality and quantity. This is primarily welfare related to the presence of nature areas available to the public and genetic diversity for potential utilization.
	3	Delivery of services to society from domestic areas, where pollination is considered to facilitate the quality and quantity. This is primarily welfare related to the presence of nature close to residential areas.
Anthropogenic drivers for pollination	4	The demand of food in a world having an increased population is a driver for increasing agriculture production and thus intensification of agriculture practices.
	5	There are political drivers for securing natural areas
	6	Increased single family housing is a driver for increased domesticated areas
Anthropogenic pressure	7	*Direct pressures*: Activities in agricultural areas, such as pesticide application and ploughing, will add negatively to the livelihood of pollinators (nesting, survival, feeding), while growing of attractive flowering plants will add positively (feeding). *Indirect pressures*: Activities in agricultural areas, such as herbicide application, mechanical weed control and ploughing, will add negatively to the livelihood of wild plants in the agricultural areas and thus the feeding for pollinators.
	8	*Direct pressure:* The natural areas can support the livelihood of the pollinators directly by having nesting and wintering sites, so any change in the conditions of nature areas that limits the condition for this is a pressure. Reduction of nature areas will often be a result of a substitution of nature areas by either domesticated areas of agricultural areas that are less likely to support pollination so this is also a pressure. *Indirect* pressure: Reductions in the diversity and abundance of wild plants in natural areas will reduce feeding resources
	9	*Direct pressure*: Activities in domestic areas, such as pesticide application and mechanical weed control, will add negatively to the livelihood of pollinators, while growing of attractive flowering plants will add positively for feeding (larvae and adults). *Indirect pressures*: Activities in domestic areas, such as herbicide application and mechanical weed control, will add negatively to the livelihood of wild plants and thus the feeding of pollinators (larvae and adults).
Supporting ecosystem services	10	*Direct support*: Increasing yield for the cropping system due to the pollinating activity of the pollinators. Furthermore, the larvae for some pollinators (hoverflies), are carnivores eating herbivores and, thus, beneficial to the crops. There may be some negative effects due to some pollinators that also act as herbivores, especially the larvae of the butterflies. *Indirect support*: The abundance of wild plants may increase as a result of increased pollination which may lead to a decrease in yield for the cropping system due to: (1) Competition between the crops and the wild plants (weeds) for nutrition and/or light; (2) Increased abundance of herbivores that will attack the crops surveying in the wild plants. However, increased abundance of wild plants may lead to an increase in yield for the cropping system due to two factors: (1) Herbivores may tend to attack the wild plants instead of the crop; (2) Carnivores for the herbivores may benefit from the wild plants and, thus, increase in abundance and reduce the abundance of the herbivores.

Supporting ecosystem services	11	*Direct support*: Pollinators themselves add to insect biodiversity in natural areas and, thus, contribute positively to the ecosystem services delivered by natural areas. *Indirect support*: Pollinators will support a high diversity of wild plants that will add positively to the ecosystem services delivered by natural areas.
	12	*Direct support:* Positive influence on plant biodiversity in the domestic area from the pollinating activity. The pollinating insects will also add to insect biodiversity. *Indirect* support: Pollination will support the abundance of wild plant in domestic areas, and there is a benefit of wild plants adding to biodiversity in domestic areas. There may be some negative effects on wild plants, as weeds competing with cultural plants.
Mitigation and pressure reduction	13	*Mitigation:* Society can directly increase pollinator abundance by increasing the number of domesticated bees and other pollinators. The agricultural mitigation, in form of e.g. sowing of flowering plant and establishment of nesting sites, will add to pollinator livelihood. Other mitigation means could be a reduced application of pesticides. *Pressure reduction:* Reduction in insecticide usage will have a direct effect on the pollinator abundance but also a reduction in herbicide usage can be important if this increase to flowing intensity and abundance of wild plants on the field areas and along the edges. Reduced application of nutrients may increase the plant biodiversity for the nature close to field and thus increase feeding resources. Mechanical weed control can have negative effects on the pollinator livelihood.
	14	*Mitigation:* Society can directly increase pollinator abundance by increasing the number of domesticated bees and other pollinators. The management of nature areas should take into account improvement of pollinator livelihood by securing good conditions for high wild plant biodiversity and nesting sites. *Pressure reduction:* The dominating pressure in relation to natural areas is that the status of the area as “natural” is replaced by some kind of anthropogenic application. The status of natural areas as “natural” needs therefore to be preserved in order to reduce this pressure.
	15	*Mitigation:* Society can directly increase pollinator abundance by increasing the number of domesticated bees and other pollinators. The management of domestic areas should take into account improvement of pollinator livelihood by securing high plant biodiversity and nesting sites. *Pressure reduction:* Reduction in insecticide usage will have a direct effect on the pollinator abundance but also a reduction in herbicide usage can be important if this increase to flowing intensity and abundance of wild plants on the field areas and along the edges. Reduced application of nutrients may increase the plant biodiversity for the nature close to field and thus increase feeding resources. Mechanical weed control can have negative effects on the pollinator livelihood.

10.3. Mapping pollination services at European scale

10.3.1 Introduction

Pollination by insects helps to sustain and potentially increase the production of the majority of the global leading crops. While cereals do not profit from pollination, important fruit, vegetable, nut, spice, oil and stimulant crops profit from pollination (Klein et al., 2007). The pollination supply depends on the amount of honey bees, wild bees and other pollinators which visit crops. Pollinator abundance is in turn dependent on the availability of nesting sites and forage. The demand for the pollination service is generated by the decision of the farmer to plant crops which depend on or profit from pollination (Lautenbach et al., 2011). To meet supply and demand for pollination we compare the spatial configuration of nesting habitats, floral resources and pollination dependent crops. A key variable is the flight distance of pollinating insects which connects the demand with the supply. Note that flowering crops are suppliers of floral resources for pollinators while at the same time they may benefit from pollination as well. This is the case for fruit trees such as apple orchards. Other crops, for instance potato, carry flowers which attract foraging insects but the production of the eatable parts of the plant is situated in its root zone and hence, not dependent on pollination. Other crops, such as cereals, are not dependent on pollination and provide little floral resources for pollinators.

10.3.2 General outline of the pollination supply model

The applied methodology is derived from the InVEST model which was developed for mapping ecosystem services at local scale (InVEST, Lonsdorf et al., 2009) but adapted to fit a continental scaled mapping approach. The InVEST pollination model focuses on wild bees as a key animal pollinator. The model can be used to score land cover parcels for their potential contribution to crop pollination. Crops on farms that are surrounded by land parcels that support pollinator populations are expected to experience higher abundances of pollinating visitors. At European scale the model was adapted at three stages: (1) different input data and modeling strategies were used to map for floral availability and nesting suitability (Figure 3 and 4 and Table 1), (2) a different modeling strategy was adopted to assess the activity of pollinators, and (3) we excluded areas where pollinators can physically not occur.

The underlying rationale is explained in Figure 10.3. The model uses estimates of the availability of floral resources (A), bee flight ranges (B) and the availability of nesting sites (C) to derive an index of bee abundance (D) on each cell on a landscape. Flight range information is used a second time to estimate an index of bee abundance visiting agricultural cells (G). A first adaptation to the InVEST model was to set up two composite indicators to estimate floral availability (A) and nesting suitability (C). A second adaptation was to account for differences in activity (E) as a result of climatic variation in temperature and solar irradiance. Insects become inactive when a combination of temperature and irradiance falls below a certain threshold (Corbet et al., 1993). Including temperature dependent activity resulted in an updated pollination abundance index (F). A final alteration of the model was to mask out areas where insects cannot find nesting sites (H). This model requires four key input variables and parameters: (1) a map of nesting suitability, (2) a map of floral resource availability, (3) species specific parameters describing the flight range, (4) species specific parameters that relate temperature and solar irradiance to activity.

Maps can be produced for each pollinator species provided that parameters about flight distance and activity are available. Most information in the literature is, however, limited to bee and bumblebee species (Lonsdorf et al., 2009). Therefore, we generated two pollinator supply maps showing the relative pollinator abundance which were produced for two distinct ecological guilds of pollinators: pollinators with a relatively short flight distance using solitary bees as model species and pollinators with a relatively long flight distance using bumblebees as model species.

10.3.2.1 Nesting sites and floral availability

Two composite indicators were used to map nesting suitability (NS) and floral availability (FA). Both maps were constructed using similar spatial datasets but different weights were given to each spatial attribute with respect to their capacity to host nests or their availability of floral resources. Assigning weights to the various spatial attributes was based on the opinion of experts after discussions on a workshop. The result was a set of scores per land use class or spatial attribute on a scale between 0 and 1. Consider coniferous forest. Experts assigned high relative value to this type of land cover for nesting suitability with relative scores of 0.7 for forest core and 0.9 for forest edge, respectively, on a scale from 0 to 1. However, coniferous species do not produce flowers. Therefore, this land cover class received a lower score for relative floral availability (0.3 and 0.4 for core and edge, respectively). Table 10.2 lists the data that was used to construct both composite indicators.

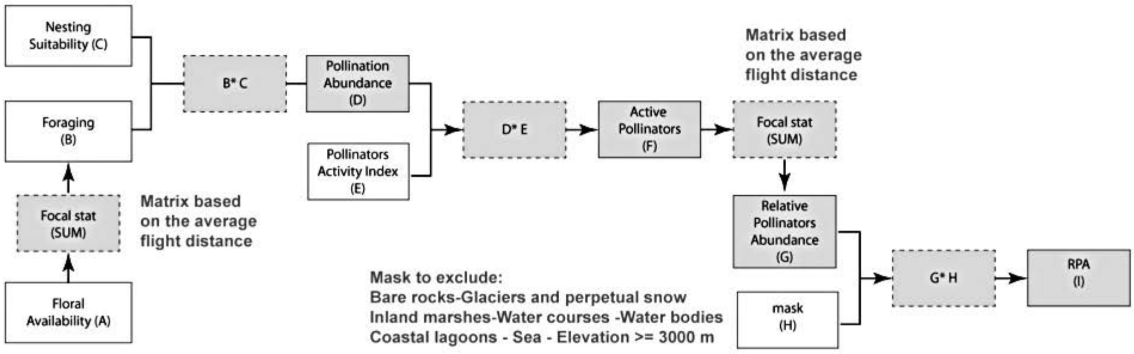


Figure 10.3. Flow diagram showing the sequence of GIS operations to derive a map of Relative Pollinator Abundance (RPA). Focal stat (Focal Statistics) calculates for each input cell a statistic of the values within a specified neighborhood around it, defined by the flight distance of bees or bumblebees. Details on the creation of maps for floral availability (A) and nesting suitability (C) are provided in Table 1 and Figure 3.

In a next step, the different datasets were combined in order to derive spatially explicit habitat suitability and floral availability (Figure 10.4). Both indicators were constituted using four components: forest, agriculture, water and roadsides. Firstly, two different forest datasets were combined with four agricultural land use datasets using a set of conditional operators. This first map was overlaid with spatial information of where riparian areas and roadsides, following observations that these habitats, in particular in agricultural areas, increase the potential for nesting sites and floral resources (Table 10.2). Again, conditional operators were used to make a composite map. Finally, we masked out water bodies (lakes) where pollinators cannot make nests. All calculations were made in ArcMap 10 using Python scripts at 25 m resolution, which corresponds to the resolution of the forest data. Final maps of the composite indicators were scaled up to the resolution of 100 m.

Table 10.2. Input data to map nesting suitability and floral availability to pollinators.

Land cover data (CLC) Corine Land Cover 2000 raster data - version 13 (02/2010) (CLC2000) Source: EEA Resolution 100 m	Every CLC class was given a score of 0 or 1 for the availability of nesting sites in the ground of in cavities. Every CLC class was given a score between 0 and 1 to value NS and FA using expert judgment. Two experts were invited to score land cover classes. Forest classes were treated differently and given an initial score of 0.
Crop share data (CAPRI) CAPRI model resulting in crop share statistics for homogeneous clusters of 1 km^2 pixels (HSMU), identified on the basis of the Farm Structure Survey regions (NUTS 2 or 3, depending on the Member State, EUROSTAT 2003), land cover (CLC2000), soil mapping units (European Soil Database V2.0, European Commission, 2004) and slope. Source: JRC Resolution 1 km	For each HSMU crop share is calculated and intersected with the CLC label 1 agricultural area. Crops were assigned to CLC classes of arable land. Crop types were assigned a value between 0 and 1 for NS and FA. Scoring is based on Westphal et al. (2003), Westphal et al. (2009), Gallai et al. (2009),

Olive farming data (Olive) Weissteiner et al. (2011) Source: JRC Resolution 1 km	Intensive olive cultivations receive lower scores for NS and FA in the CLC base map. The rationale for including lower scores in intensive olive plantations is based on expert judgment and is justified by the use of pesticides which inhibit strongly wild pollinators.
High Nature Value Farmland data (HNV) HNV is defined as areas in Europe where agriculture is a major (usually the dominant) land use and where that agriculture supports, or is associated with, either a high species and habitat diversity or the presence of species of European conservation concern, or both. Source: JRC Resolution 100 m	The presence of HNV increases the scores given to CLC classes based on expert judgment.
Riparian zones and river network data (Water) Riparian zones are defined as transitional areas occurring along land and freshwater ecosystems, characterized by unique soil, hydrology and biotic conditions strongly influenced by the stream water Clerici et al. (2011) CCM2 data CLC2000 data Source: JRC/EEA Resolution 25 m	Riparian zones, lakes boundaries, rivers and ditches in semi natural zones and levee have a positive impact on nesting (Lonsdorf et al. 2009). Buffers were created around maps of riparian areas, rivers and lake borders. NS and FA of these buffered areas were scored between 0.5 and 0.8 and these data were added to the CLC based map
Forest data (Forest) CLC2000 data Pan-European Forest/Non-Forest Map 2006 Source: JRC, EEA Resolution 25 m	Core forest and forest edges are suitable habitats for pollinators (Farwig et al. 2009; Lonsdorf et al. 2009; Hagen et al. 2010). The high resolution map allows detecting patches of forest that are not covered by the CLC2000 data. In addition, CLC2000 forest data were overlaid with the forest/non-forest map to avoid or repair spatial mismatches. NS values were 0.7 for core forest and 0.9 for edge forest. FA varied from 0.3 for coniferous core forest to maximum score of 1 for broad leaved edge forest.
Roadside (Roads) Source TeleAtlas Resolution 25 m	Road sides are used by bee and bumblebee species for nesting. Buffers were created around roads depending on road importance and scored between 0.1 and 0.8. Hopwood (2008); Lonsdorf et al. 2009

NS: Nesting Suitability
FA: Floral availability

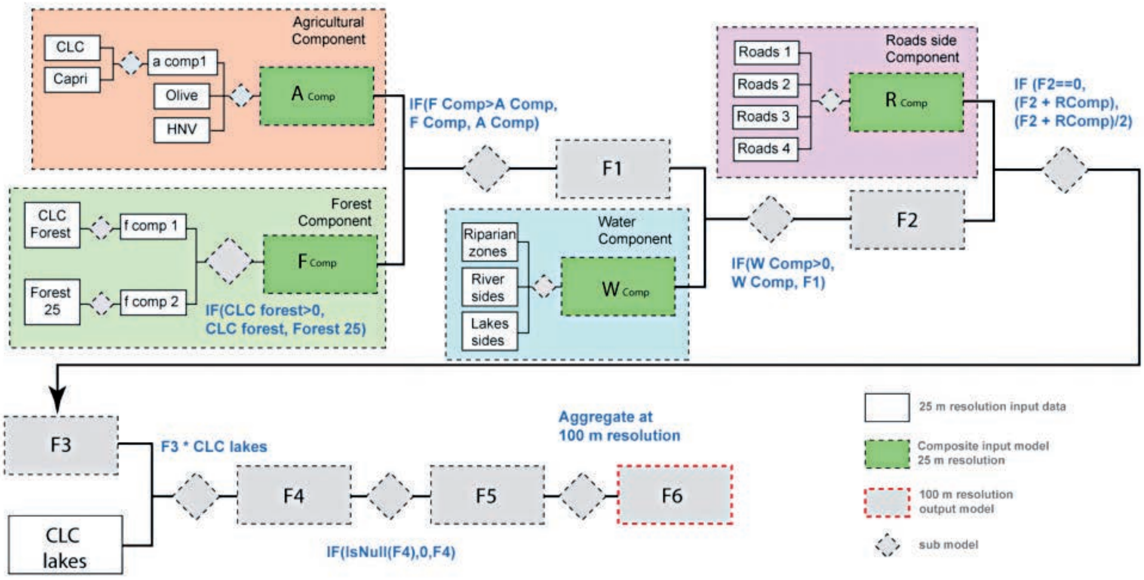


Figure 10.4. Flow diagram illustrating how spatial information is combined to derive maps of habitat suitability and floral availability.

10.3.2.2. Flight distances

Land parcels which are suitable to support nesting are connected to crops that need to be pollinated by the flight distance of pollinating insects. Wild bees and bumblebees can pollinate crops insofar as the distance between their nests and the crops that provide foraging resources does not exceed the maximum flight distance. Average foraging distances are species specific and vary between a few meters to several kilometers (Lonsdorf et al., 2009). Based on data of expected foraging distance of different bee and bumblebee species (Lonsdorf et al., 2009), we selected two distances, 250 m and 1000m, to represent short and long flight distance species. These two parameters were used to calculate focal statistics of land cover cells in order to assess the relative pollinator abundance.

10.3.2.3. Activity

Insects are cold-blooded animals and their metabolism is strongly linked to temperature. Habitats may be suitable to provide nesting sites or forage to pollinators but if the ambient temperature is below a certain threshold, the potential to pollinate approaches zero as bees or bumblebees will not leave the nest in order to forage. Corbet et al. (1993) developed a model to express pollination activities using proportion of active bees and bumblebees. This proportion was measured by counting in the field the numbers of workers that leave the nest for foraging relative to the peak number of nest leavers that was observed during daily counting. We adapted the relative pollination abundance to account for climatic variation in temperature and solar irradiance by calculating an annually averaged activity coefficient between 0 and 100% representing the pollination activity of bees and bumblebees. This assessment was performed at 50 km resolution using the MARS climate database (Van der Goot, 1998).

10.3.2.4. Demand for pollination

We assessed the biophysical demand for pollination using a methodology based on Gallai et al. (2008). Their work is based on the hypothesis that the economic impact of pollinators on agricultural output is measurable through the use of dependence ratios quantifying the impact of a lack of insect pollinators on crop production value. We multiplied CAPRI based statistics on crop production and the dependence ratios of Gallai et al. (2008) to estimate what share of the total crop yield in metric ton can be attributed to insect pollination. This value corresponds to a production deficit which is the reduction in crop production in absence of animal pollination (Aizen et al., 2009).

10.3.3. Relative pollinator abundance (RPA) as indicator for supply

An EU-wide map of relative pollinator abundance (RPA) is presented in Figure 10.5. This map depicts the potential of land cover cells to provide crop pollination by wild bee species. It is based on the input information that is presented in Figure 10.6 including the relative suitability of land cover cells to host pollinator populations, the availability of floral resources and the average activity of bees as a result of climatic variation. A similar map for bumblebees is available but not presented here. While maps of RPA for bees and bumblebees are largely holding similar information, there are subtle differences caused by the higher activity rate and the longer flight distances of bumblebees relative to bees. Bumblebees are active at lower temperatures than bees and their larger body size allows them to make longer flights.

The general pattern of the RPA is an increase of pollination potential along a north-south gradient in southern direction following the temperature gradient in Europe, corresponding to the modeled activity rate of bees and bumblebees (Figure 10.6). For a given temperature, pollination potential is low in areas where the dominant land use is arable land used for the production of cereals. This is the case for the east of the United Kingdom, areas in France surrounding the capital, areas in central Spain, the Po plain in Italy, areas in northern Germany, Poland and Slovakia and the along the borders of the Danube in Bulgaria and Romania. These areas are assumed to have low nesting suitability (Figure 10.6) and to offer limited resources for foraging due to an absence of plants with flowers carrying nectar (Figure 10.6). Though complemented with data from the JRC forest map at 25 m, the model lacks information on presence of semi-natural vegetation and landscape elements in agricultural land (i.e. hedges, ponds, ditches etc.). Some agri-environmental measures such as flower strips and stream buffer zones may increase the presence of bees as well. Such shortcomings cause an underestimation of pollination potential in arable land.

Zooming into particular areas also allows examining in more depth the effects that different spatial variables had on the construction of the RPA. Figures 10.7 and 10.8 show how forest structure and riparian areas along water bodies, respectively, have been weighed in order to assign relative values to land parcels for nesting suitability. Both pictures refer to an area in north Italy at the southern end of Lake Maggiore which drains into River Ticino. The CORINE land cover map of Figure 10.7 shows a varied landscape consisting of a mixture of forest, arable land, urban fabric. A major airport serving the greater Milan area is situated at the eastern side of the map. A detailed zoom area, based on the CORINE map, shows the forest patches situated west from the Ticino river. The maps show also how different scores were given to land parcels to assess the contribution of forest habitat to nest suitability. Non forested areas are scored zero; forest core received a value of 0.7 while the highest score went to forest edge (0.9), acknowledging that edge habitats contribute more to nest suitability than other land parcels. A second map covers the same area but is based on the forest/non forest map at 25 m resolution. Both datasets were combined to set relative values for the contribution of forests to nesting suitability of land parcels at 25 m resolution. Evidently, working at higher resolution allows giving additional value to land parcels that are classified differently in the CORINE map (see also chapter 10.4, the Finnish case study). Many patches of forest are situated in arable land or in urban fabric and increase locally the pollination potential of these land parcels. The resulting pollination potential is mapped in the upper right corner. This map combines the data on nesting suitability and relative floral abundance connecting nesting sites with floral resources using information on the flight distance of bees and bumblebees. This results to a smoothed map of pollination potential with high values in forested areas and low values in urban areas.

Figure 10.8 shows how riparian areas are assumed to contribute to pollination potential. Consider the same area as for the forest example. The CLC land cover information was first updated with a map of rivers and a map of riparian areas. Two tributaries to the Ticino are added on the CLC map. Furthermore, riparian areas in dark blue color are added to the map. These areas coincide with natural vegetation along rivers. These two types of spatial information were used to attribute higher values to land parcels close to rivers (0.5) or coinciding with riparian areas (0.8). The resulting map of relative pollination abundance is depicted in the right upper corner.

The map of European relative pollination abundance is largely based on expert knowledge. The model is in essence based on field evidence that the visitation rate of crops by pollinators is a function of the distance to natural areas (Rickets et al., 2008; Garibaldi et al., 2011). The basic assumption of the model is that natural areas and in particular edge habitats offer suitable nesting sites and floral resources. It therefore represents a first tier approach that needs to be validated further using statistics on population abundance of different pollinator species.

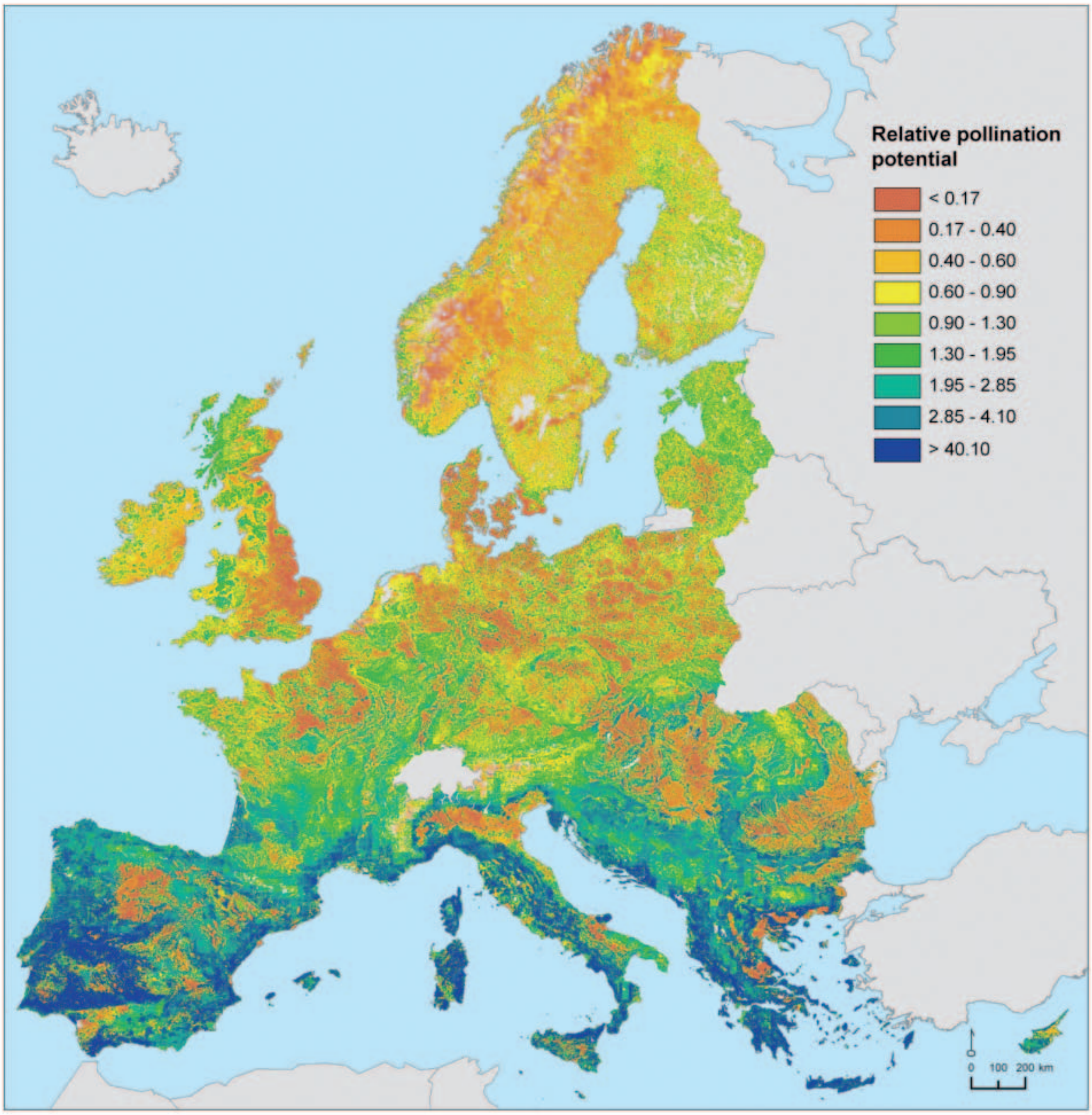


Figure 10.5. Relative pollination potential across Europe (dimensionless units).

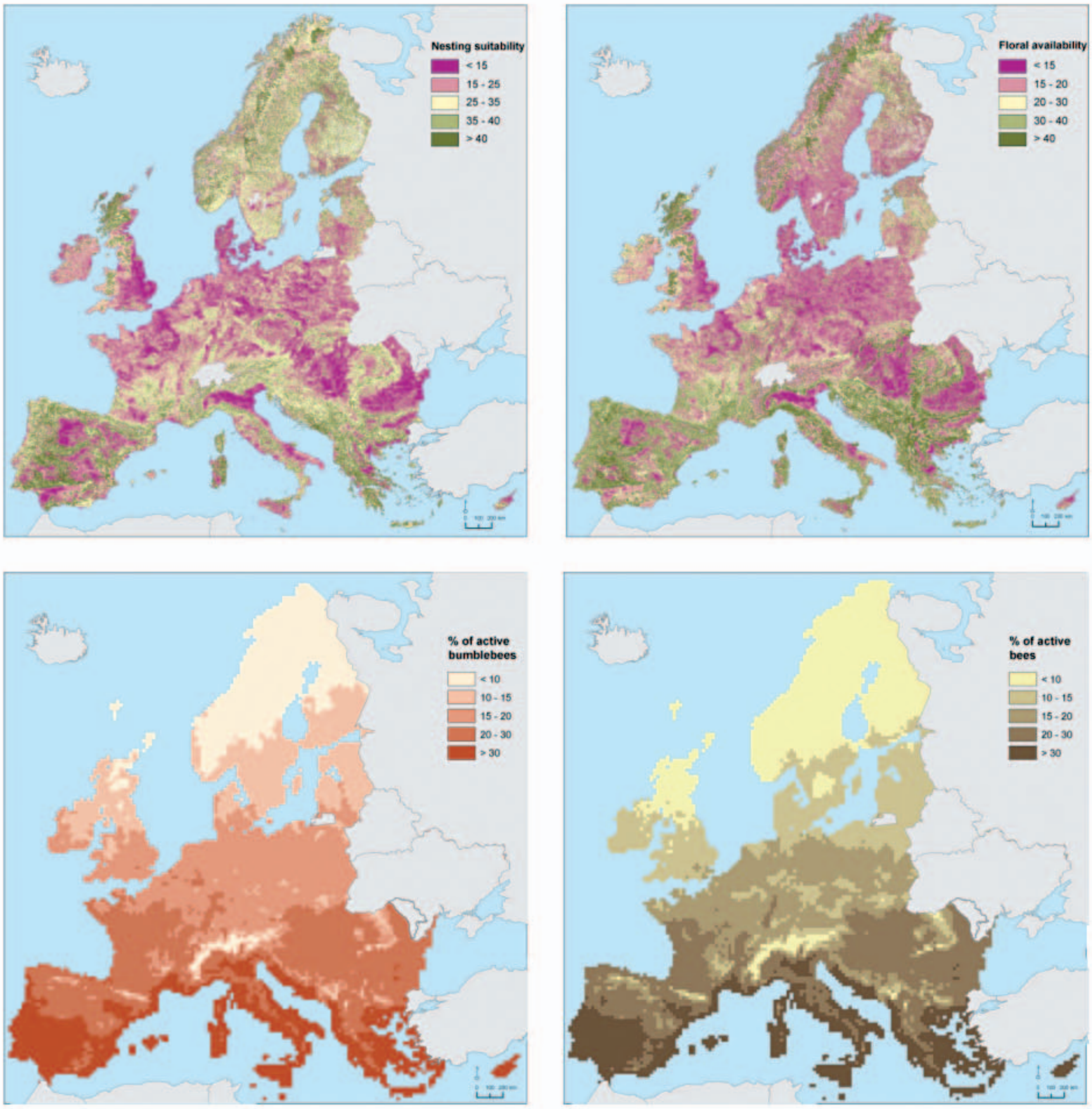


Figure 10.6. Nesting suitability (NS), floral availability (FA) and climatic dependency. Both NS and FA are dimensionless indicators. Activity rates are representing the % of active individuals of a colony (in case of social species) or in a population (solitary species).

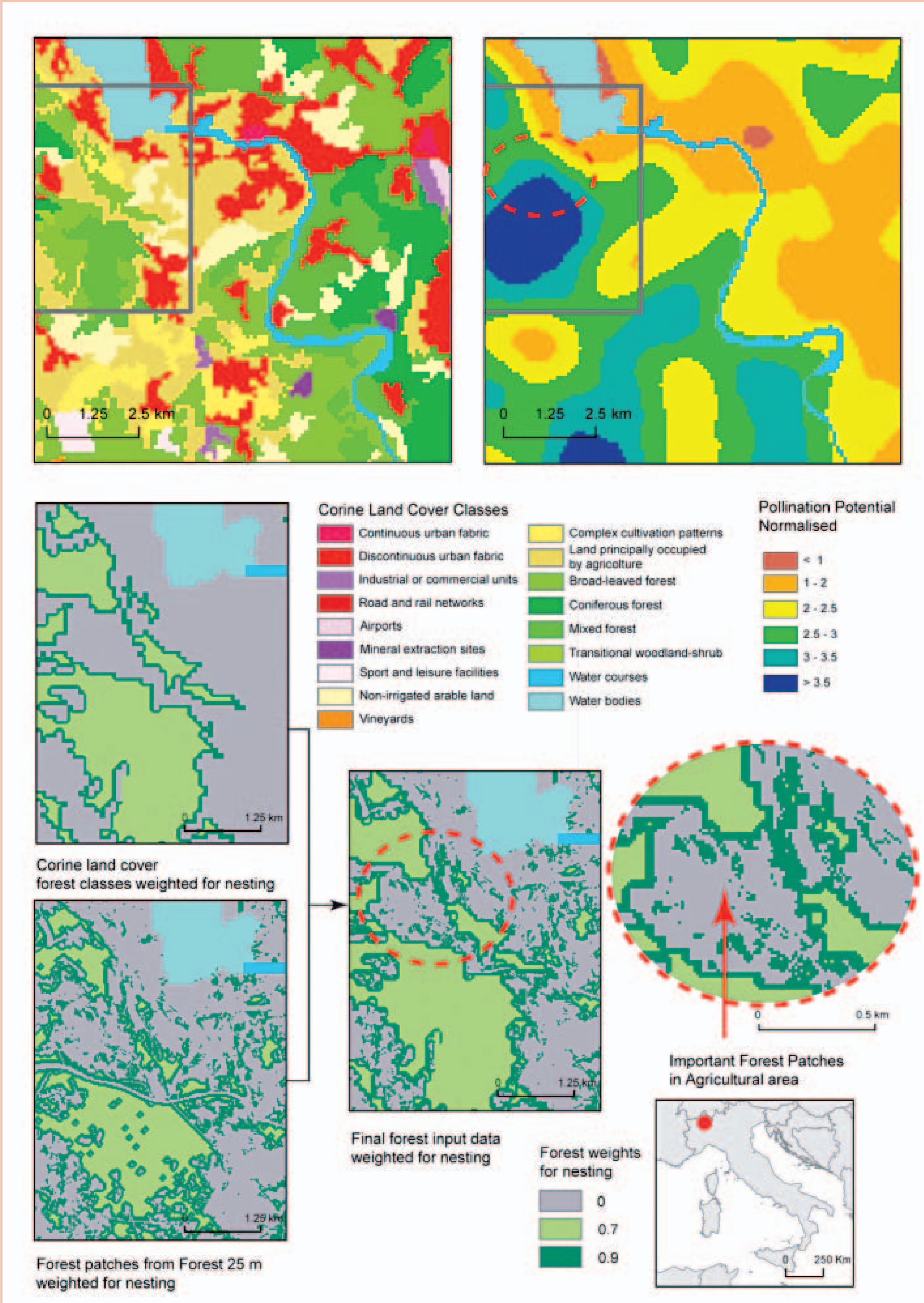


Figure 10.7. Relative pollination potential of a landscape south of Lago Maggiore along the borders of River Ticino, north Italy. The picture shows how two types of information on forests (CLC2000 maps and the JRC forest/non-forest map at 25m resolution) are combined to score land parcels for nesting suitability.

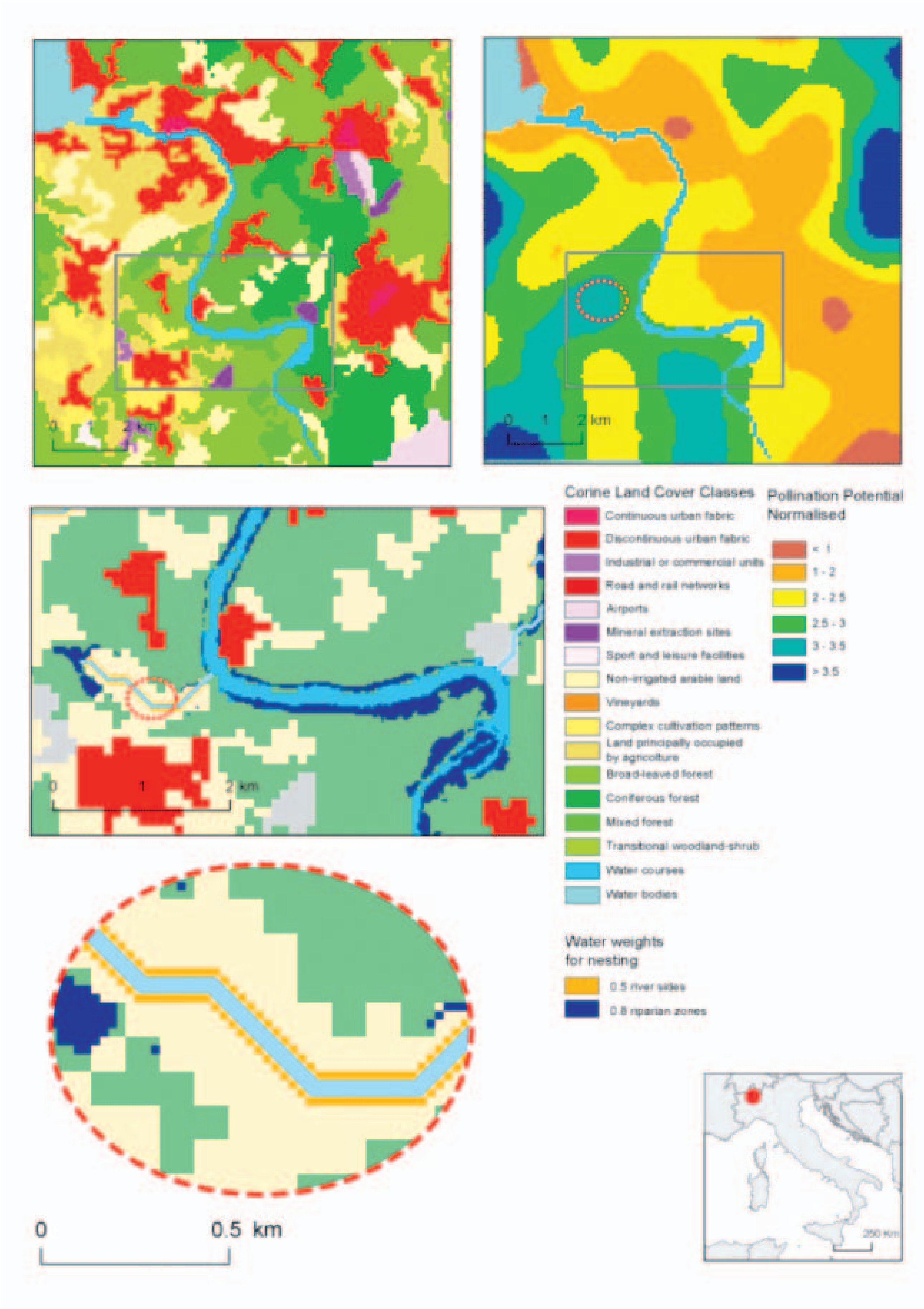


Figure 10.8. Relative pollination potential of a landscape south of Lago Maggiore along the borders of River Ticino, north Italy. The picture shows how two types of information on river sides (river network data and maps of riparian areas) are combined to score land parcels for nesting suitability.

10.3.2. Demand for pollination

Among the main crops that contribute to human food, some, such as most cereals, do not depend on insects for their pollination, while others can be highly or totally dependent on insect pollination, such as many fruits and vegetables (Klein et al., 2007). Several statistics have been reported to express the contribution of pollination to crop production. The production of 84% of crop species cultivated in Europe depends directly on insect pollinators, especially bees (Williams, 1994). And Klein et al. (2007) found that 87 crops, that is 70% of the 124 main crops used directly for human consumption in the world, are dependent on pollinators. However, if production statistics are used, the contribution of pollination to agriculture decreases, mainly due to the large share of non-dependent crops in total yield. Gallai et al (2008) estimated that 9.5% of the economic value of global crop production can be attributed to insect pollination. They pointed out that the production value of a ton of the crop categories that do not depend on insect pollination – namely cereals, sugar crops, and roots and tubers – averaged 151 € while that of those that are pollinator-dependent averaged 761 €, or five times more, and these values were significantly different. Finally, Aizen et al (2009) calculated the production deficit in agricultural production in absence of animal pollination between 2 and 4% for the developed world.

Table 10.3 estimates the contribution of insect pollination to crop production for 27 Member States of the EU27. A first assessment calculated the contribution of pollination to the total production of crops that are dependent on pollination while a second assessment estimated the contribution to the total crop production.

At aggregated EU level, 23.6% of the total production of crops dependent on pollination can be assigned to insect pollination. This figure can be interpreted as a production deficit if no pollination services were offered by insects. This value decreases to 1% if all crop production is considered, including crops that are not dependent on pollination. There are important differences between countries, in particular for the first indicator which is leveled off by the large production volumes of non-dependent cereals in the second indicator. If only dependent crops are considered, the share of insect pollination in crop production was particularly high in Austria and Slovenia which both have important fruit production which benefits from insect pollination explaining the high share in Table 10.3. In part, these results are biased by tomato production which in several of these countries will be in green houses and thus dependent on managed pollination.

A second important conclusion derives from comparing pollination dependent production against total crop production. The share of non-dependent crops such as cereals, maize and potatoes decreases the importance of insect pollination. Importantly however is that crop production of countries with a high pollination potential resulting from high average temperatures are more dependent on pollination. In particular Mediterranean countries as Italy, Cyprus, Greece and Spain show higher contributions than the EU average.

Pollination supply versus demand was mapped in a semi-quantitative way in Figure 10.9. The map intersects 2 classes of pollination potential (low and high separated by the average) with 2 classes of crop demand for pollination services which was estimated as the crop dependence multiplied by the crop production of crops dependent on pollination (low and high separated by the average). Areas in dark green correspond to agricultural land with a high pollination potential and high demand for pollination services. Areas in light green have a high potential but crops that do not require insect pollination. These areas are mainly situated south of the 50° latitude. North of this latitude agricultural area with relatively low pollination potential with still large portions of agricultural crops that require pollination is found.

Similar to our attempt to map pollination potential, the assessment of demand is a first approximation that needs further refinements. Our approach is conservative in the sense that we grouped crops into a few categories only (derived from the CAPRI model). This may result in a low overall statistic for the EU27 (1%) which is lower than the 3% of production deficit estimated by Aizen et al. (2008).

Table 10.3. The contribution of insect pollination to crop production (metric tonnes) based on production deficit in absence of animal pollination.

	Contribution to production of crops dependent on pollination	Contribution to total production
Austria	43.9%	1.0%
Belgium	29.6%	0.8%
Bulgaria	22.2%	1.1%
Cyprus	13.3%	3.3%
Czech Republic	27.9%	1.0%
Denmark	14.4%	0.3%
Estonia	22.4%	0.3%
Finland	19.7%	0.2%
France	24.7%	0.8%
Germany	27.6%	0.6%
Greece	21.5%	3.4%
Hungary	33.7%	1.9%
Ireland	2.9%	0.0%
Italy	23.6%	2.9%
Latvia	20.8%	0.3%
Lithuania	10.6%	0.3%
Malta	11.8%	1.2%
Netherlands	31.2%	0.5%
Poland	31.5%	1.7%
Portugal	21.1%	1.5%
Romania	27.5%	1.1%
Slovak Republic	24.8%	0.9%
Slovenia	40.5%	1.4%
Spain	20.2%	2.2%
Sweden	21.2%	0.2%
United Kingdom	11.2%	0.2%
EU27	23.6%	1.0%

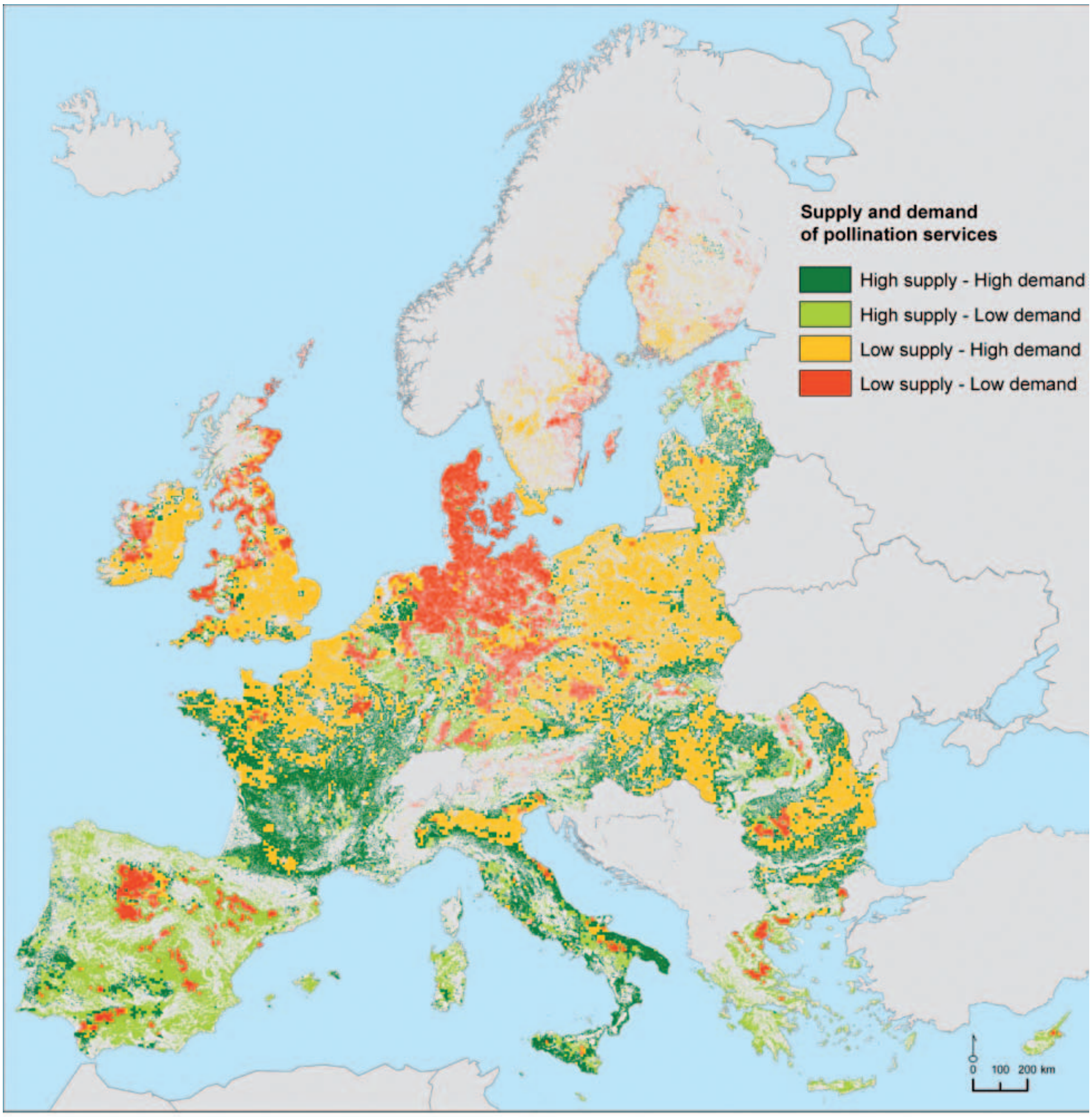


Figure 10.9. Relative pollination supply versus demand for pollination services based on production deficit statistics for agricultural land use in the EU-27.

10.4 Mapping pollination services at multiple scales in southwestern Finland

10.4.1 Introduction and study aims

Finland's location in the northern Europe restricts the range of crops that can be successfully cultivated. As a consequence cultivation of insect-pollinated crops is not as extensive in Finland as in more southern parts of Europe and the contribution of insect-pollinated crops to the total agricultural production is only ca. 0.2 %. The most important insect-pollinated crops in Finland include oilseed rape, red clover, apple, red- and blackcurrant as well as strawberry and raspberry. Finland also differs from most European countries in its primary land use patterns: only 7% of the land area is used for agriculture, whereas 78% of the land is covered by forestry.

The aim of the Finnish case study was to complement the European level mapping of pollination services by applying largely the same methodology based on the InVEST model (Lonsdorf et al. 2009) to Finland as was used in chapter 10.3 at the European level. The purpose was to produce maps of the relative pollinator abundance at different spatial scales and compare these to maps of pollination demand indicated by the distribution of insect-pollinated crops. The focus on a more restricted area in Finland also enabled the use of more detailed land use information than what was available for the whole Europe, including e.g. detailed information on the occurrence of semi-natural grasslands and field level information on the cultivated crops. One specific aim was to evaluate the usability of the mapping method at local scale planning of the implementation of agri-environment scheme measures and other environmentally friendly practices that can be recommended to farmers.

10.4.2 GIS datasets

We used six different GIS datasets in the project, available at the Finnish Environment Institute (SYKE):

I. *Corine Land Cover 2006*; This dataset is based on a supervised interpretation of Landsat Enhanced Thematic Mapper Plus images completed with digital databases using a grid size of 25 m (Härmä et al. 2004). The first Finnish Corine Land Cover database was published in year 2000 (CLC2000) and an updated version in year 2006 (CLC2006).

II. *National field plot register 2008 and 2010*; These datasets were obtained from the Information Centre of the Ministry of Agriculture and Forestry. In the actual pollination service mapping we used data of 2008, but the map on the distribution of insect-pollinated crops was produced using data of 2010.

III. *National inventory of traditional rural biotopes during 1992-1998* (Vainio et al. 2001); This dataset includes information on locally, regionally and nationally important traditional rural biotopes, including species-rich semi-natural grasslands. The biotopes are further classified as open or forested.

IV. *Agri-environment scheme (AES) contract areas;* This dataset was obtained from the Ministry of Agriculture and Forestry and it includes (a) contract areas for the management of semi-natural grasslands, (b) contract areas for the enhancement of biodiversity, (c) buffer zones along waterways and (d) organic production contracts (Aakkula et al. 2010). Contract areas (a) and (b) are further classified as open or forested and they involve support for grazing (and more rarely for mowing) of semi-natural grasslands, wooded pastures and forests. Circa 30 % of these contract areas were also identified as valuable traditional rural biotopes in the National inventory of 1992-1998 (dataset III) (Puurunen 2004).

V. *Occurrence of grasslands*; This dataset was recently compiled as a part of a PhD project carried out in SYKE (Kivinen 2007). It includes information on all grassland-like habitats in Finland and is based on combining different remote sensing datasets and maps. It was largely derived from the SLICES (Separated Land Use/Land Cover Information System) database in 10 m x 10 m resolution (Mikkola et al. 1999) and the validity of the grassland interpretation was verified by field checks in 2004. The data complements the two above-mentioned datasets by its better coverage, but it does not include any information on the ecological quality or management of the grassland areas.

VI. *Natural pastures*; This dataset was obtained from the Ministry of Agriculture and Forestry. However, the current management status of the natural pasture areas is unknown.

10.4.3 Case study area

The case study area is situated in southwestern Finland in the provinces of Varsinais-Suomi and Satakunta (Figure 10.10). A grid of 10 km x 10 km was first overlaid with the map of Finland and the case study area was then defined based on the following criteria:

1. Those 10 km x 10 km grid cells that completely fitted within the provinces of Varsinais-Suomi and Satakunta
2. Those 10 km x 10 km grid cells that were completely covered by all the GIS datasets III-VI (all the other datasets covered the entire country)
3. Those 10 km x 10 km grid cells that did not overlap with the Baltic sea

The case study area, especially its southern part, is rather intensively cultivated from the Finnish perspective. Agriculture is dominated by monocultures of spring cereal production. The northern part of the area is more forested than the southern part, as shown by the land use map in Figure 10.11. Cultivation of oilseed rape is widely practiced and in the Finnish scale, there are a high number of berry and fruit farms. The distribution of insect-pollinated crops within the case study area is shown in Figure 10.12 and the total cultivation areas of these crops are summarized in Table 10.4.

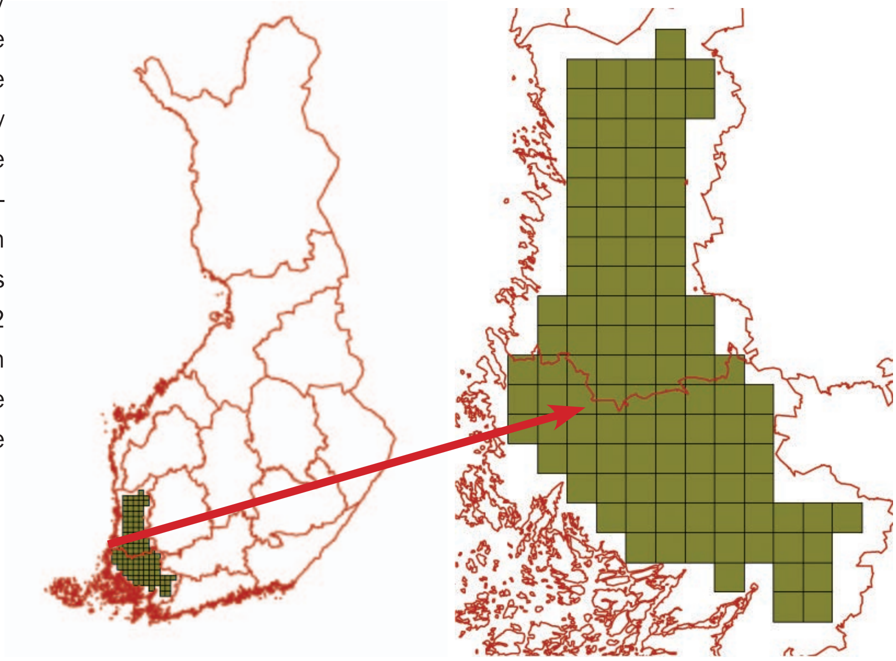


Figure 10.10. Case study area in southwestern Finland with the 10 km x 10 km grid cells.

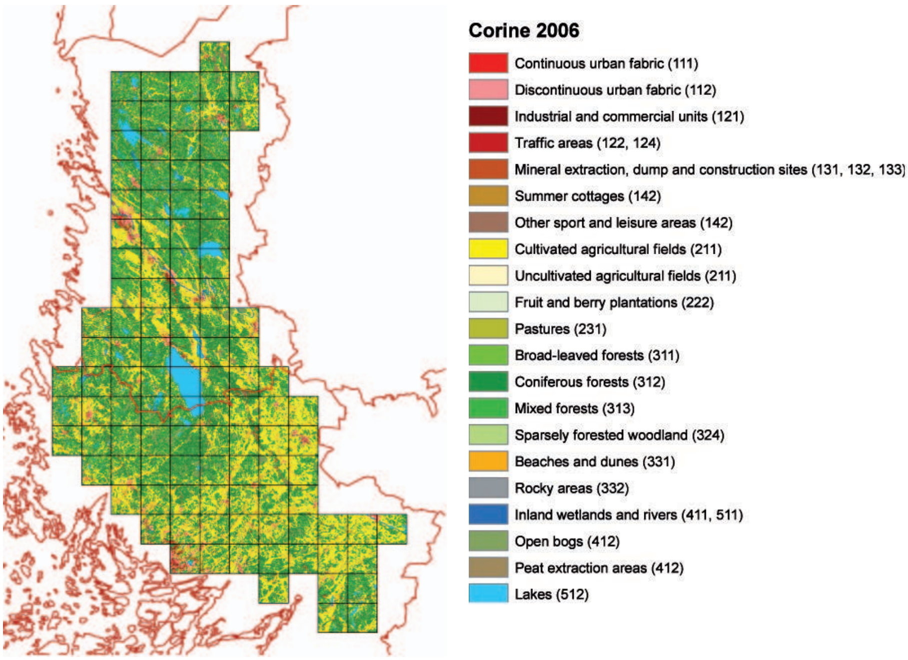


Figure 10.11. Corine 2006 land use map of the case study area (level3 in Corine 2006 land use classes in parenthesis). Shades of green are mostly forests, yellow areas are cultivated fields, shades of red are urban areas and blue areas are lakes. Other land use classes cover only small areas.

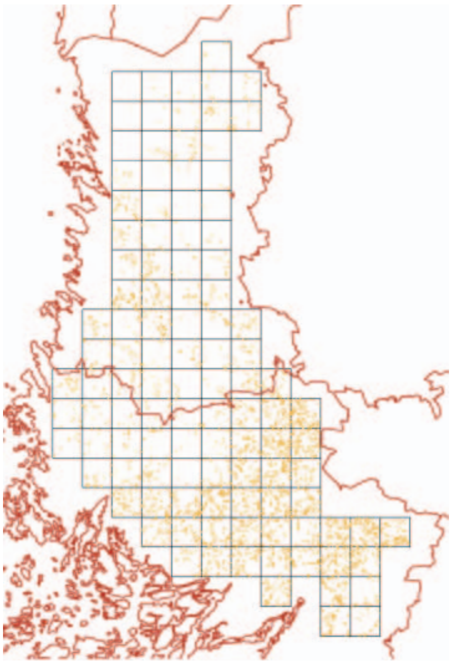


Figure 10.12. The distribution of agricultural fields with insect-pollinated crops (National field plot register 2010) within the Finnish case study area.

Table 10.4. Total cultivated areas of insect-pollinated crops in the case study area in summer 2010.

Crop variety	Cultivated area (ha)
Apple (*Malus x domestica*)	24
Black currant (*Ribes nigrum*)	16
Buckwheat (*Fagopyrum esculentum*)	30
Caraway (*Carum carvi*)	2060
Certified seed production of red clover (*Trifolium pratense**)	105
Cucumber (*Cucumis sativus*)	32
Field bean (*Vicia faba*)	2733
Flax (*Linum usitatissimum*)	641
Gooseberry (*Ribes uva-crispa*)	1
Highbush blueberry (*Vaccinium corymbosum*)	3
Honey production field (e.g. *Phacelia tanacetifolia, Trifolium pratense**)	17
Mustard (*Brassica sp.*)	6
Plum (*Prunus x domestica*)	1
Pumpkin (*Cucurbita sp.*)	1
Raspberry (*Rubus idaeus*)	30
Red currant (*Ribes rubrum*)	1
Spring oilseed rape (*Brassica napus subsp. oleifera*)	3702
Spring oilseed rape (*Brassica rapa subsp. oleifera*)	28322
Strawberry (*Fragaria × ananassa*)	333
Sunflower (*Helianthus annuus*)	2
Winter oilseed rape (*Brassica napus subsp. oleifera*)	24
Winter oilseed rape (*Brassica rapa subsp. oleifera*)	94
Total	38178

* In addition red clover (*Trifolium pratense*) is usually included in the most commonly used seed mixture in the establishment of environmental fallows. In 2010 the area of such environmental fallows in Finland was ca 130 000 ha.

10.4.4 Pollination service mapping

The pollination service mapping was based on the estimated suitability of different habitats for bumblebee nesting and foraging (Lonsdorf et al. 2009). We assumed that bumblebees are the most important native pollinators occurring in the case study area and treated the hypothetical bumblebee community as it was a single species with certain specific characteristics.

We assigned a nesting and foraging score for each of the 182 land use types occurring in the GIS datasets I-VI. The scores ranged from 0 to 1, 0 being the least and 1 being the most favorable for bumblebees. The scoring was carried out based on literature (e.g. Alanen 2009, Goulson 2003, Svensson 2002, Teräs 1985) and our own estimates. As regards to the nesting scores, bumblebees are known to nest both below and above ground and we estimated the suitability of habitats based on this information. As regards to the foraging scores, we took into account that bumblebees are active throughout the summer, as opposed to many solitary bees which have specific and limited flight periods. We therefore estimated floral availability in each of the habitats during the entire summer.

The detailed list of nesting and foraging score is presented in the Appendix 1. As regards to grassland habitats, for instance, we assigned a higher value to a permanent pasture when its management status was known (agri-environment scheme special contract area in dataset IV) than when it was not known (dataset VI). Different kinds of set-asides were considered less valuable than semi-natural grasslands and grassland fields used as pasture were considered less valuable than natural pastures. Higher values were assigned for open than forested traditional rural biotopes. As regards to forest edges, those 25 m x 25 m cells in the Corine 2006 data that were situated at the edges of forests (land use classes 311, 312, 313) were assigned a higher value than for the forest interior cells both for foraging (0.5) and nesting (0.5), because forest edges as more open habitats offer more nectar and pollen resources as well as better nesting opportunities (Banaszak & Cierzniak 2000, Calabuig 2000, Svensson 2002).

In case of overlapping data, the maximum available value was assigned for each 25 m x 25 m grid cell. For instance, if the grid cell was classified as pasture in Corine 2006 (yielding nesting and foraging scores of 0.6 and 0.6) and as a permanent pasture agri-environmental special contract area in field plot register 2008 (yielding nesting and foraging scores of 1 and 1), we used the larger values of the field plot register.

Three different grid sizes were used in producing the result maps:

- 25 m x 25 m; this is the resolution in the Finnish Corine 2006 data
- 500 m x 500 m; this corresponds to the average foraging range of bumblebees (Darvill et al. 2004, Knight et al. 2005, Walther-Hellwig & Frankl 2000)
- 10 km x 10 km; this corresponds to the grid size commonly used in different species distribution atlases in Finland

10.4.5 Results

The mapping results on pollination services are illustrated in Figures 10.13 and 10.14. Values for each grid cell are the mean values of nesting and foraging scores at each particular presentation scale.

Pollination service maps of the entire case study area at three different grid sizes are presented in Figure 10.13. In the 25 m x 25 m map it can be seen that there is a lot of small scale variation in the landscapes. Lakes appear on the maps as areas with the lowest values. In the 500 m x 500 m map regional patterns start emerging, but these are best seen in the 10 km x 10 km map. 10 m x 10 km grid is thus the most appropriate scale when discussing regional patterns in the availability of pollination services. The availability of pollination services was generally highest in the northern parts and lowest in the southeastern parts of the case study area.

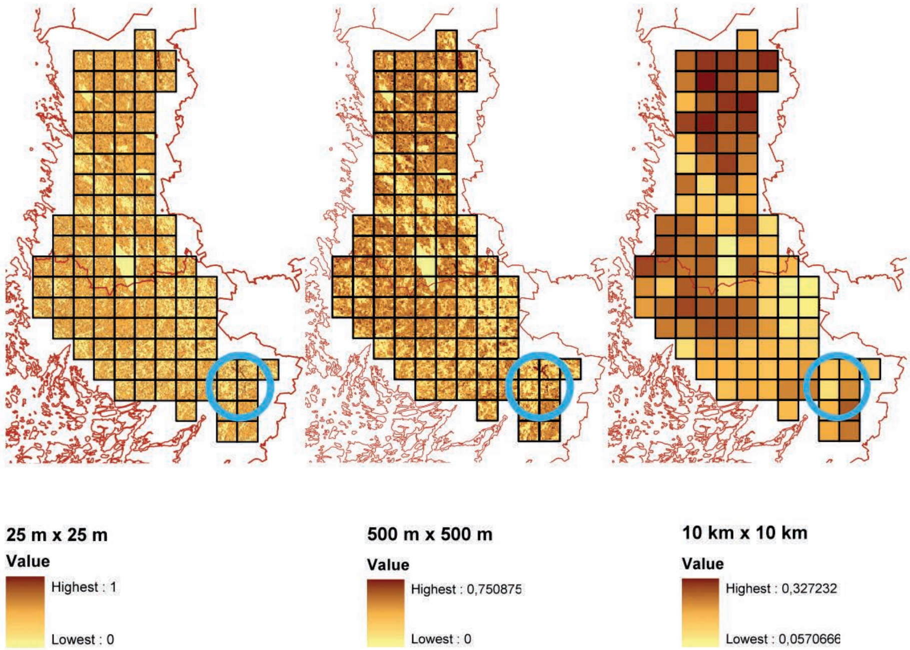


Figure 10.13. Estimated availability of pollination services in the Finnish case study area. In order to better illustrate spatial variation at more local scale, the six 10 km x 10 km grid cells indicated with the blue circle are presented in larger size in Figure 10.14.

In the following three sections we further present the mapping results on pollination services. In the first section we focus on the Rekijoki river valley area, indicated by the blue circle in each map of Figures 10.13 and 10.14. In the second section, we examine the distribution of pollination services in relation to pollination demand, defined by the distribution of insect-pollinated crops. In the third section, we concentrate on the spatial variation in estimated nesting and foraging values in an agricultural landscape surrounding a berry farm.

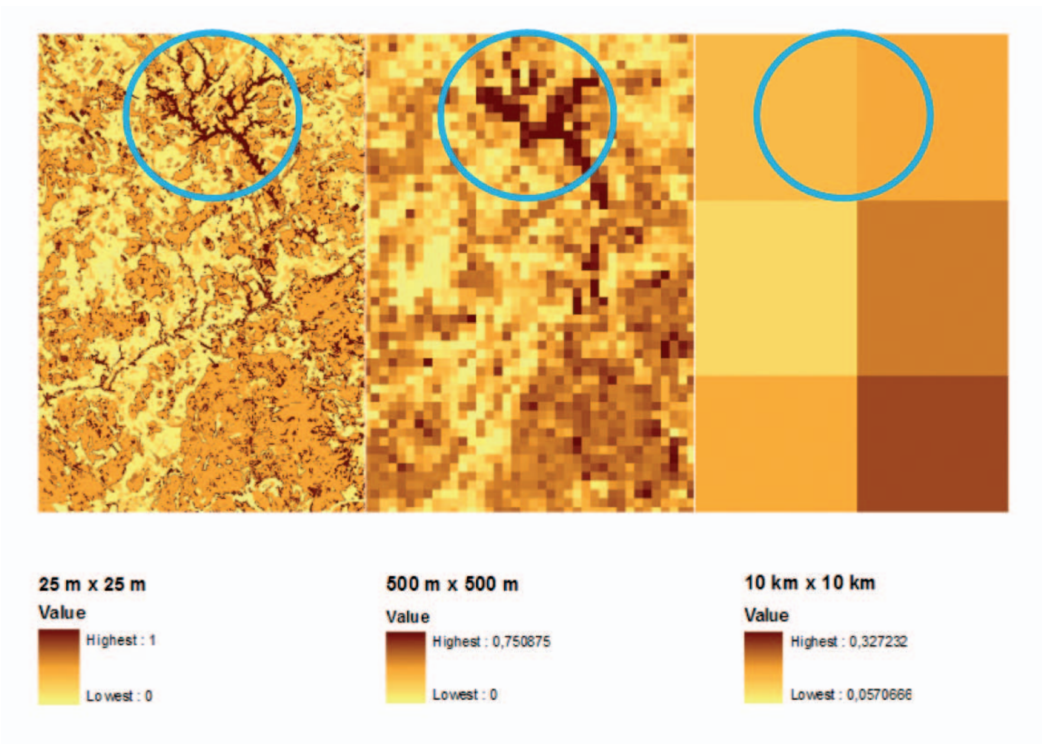


Figure 10.14. Estimated availability of pollination services at a local scale, in the Rekijoki river valley area, shown at three different grid sizes. The blue circle indicates the location of the largest remaining aggregation of mesic semi-natural grasslands existing in Finland.

10.4.5.1 Pollination services in the Rekijoki river valley

Rekijoki river valley is a nationally unique area and has a high conservation priority, as it is the largest still existing aggregation of species-rich semi-natural grasslands in Finland. The river valley has been more or less continuously grazed by cattle for hundreds of years (Luoto et al. 2003) and it supports viable populations of several endangered species, such as the Clouded Apollo (*Parnassius mnemosyne*) butterfly (Luoto et al. 2001). The continued management and maintenance of this and other similar areas elsewhere in Finland is crucial for the flora and fauna of semi-natural grasslands.

The high pollination service value of the river valley area can be seen at the grid sizes 25 m x 25 m and 500 m x 500 m. However, when using the grid size of 10 km x 10 km, this area of prime importance in the conservation of pollinators and other species of semi-natural grasslands, shows only a modest pollination service value (Figure 10.14). This pattern is due to the fact that the river valley is surrounded by rather monotonous and large agricultural fields. The low pollination value of these fields cancels out the high value of the aggregation of the traditional rural biotopes at the 10 km scale.

As regards to pollination services for cultivated crops, the relatively even distribution of forest edges and other important bumblebee nesting habitats in agricultural landscapes is therefore crucial. The availability of pollination services is very high in the semi-natural grasslands of the Rekijoki river valley, but this does not necessarily benefit the surrounding fields of the wider farmland landscape with insect-pollinated crops, as the flight range of pollinators is usually limited to distances less than 1000 m (Darvill et al. 2004, Knight et al. 2005).

10.4.5.2 Pollination demand and pollination services

Pollination demand, defined by the distribution of insect-pollinated crops within the case study area, is compared to the estimated availability of pollination services in Figure 10.15. The demand for insect pollination is highest in the southeastern parts of the case study area, whereas the availability of pollination services is highest in the northern parts. The pollination demand and pollination service maps are thus almost mirror images. This pattern results from the fact that the distribution of insect-pollinated crops largely follows the distribution of cultivated fields, as can be seen from the pollination demand maps of the Rekijoki river valley area in Figure 10.16.

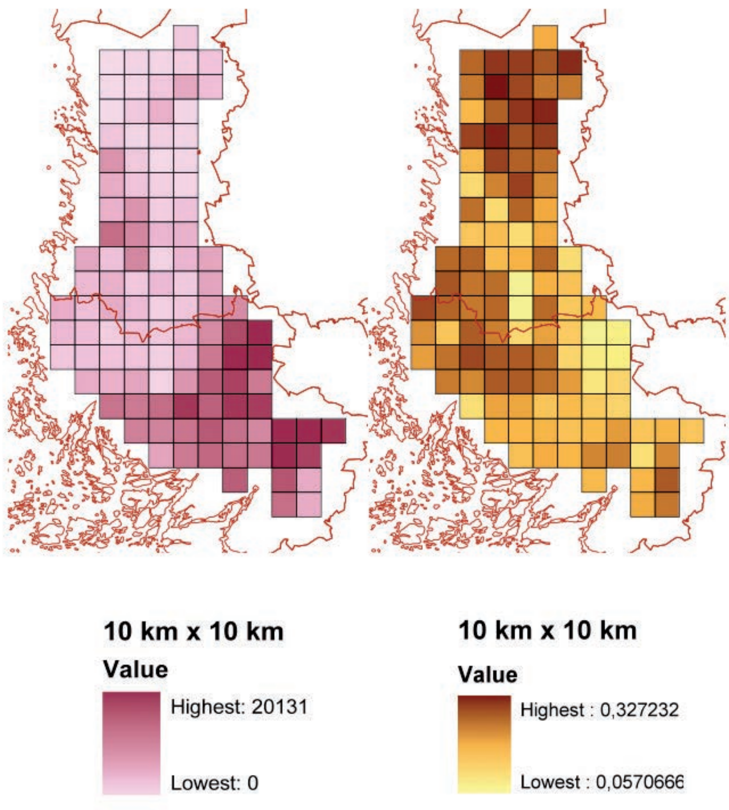


Figure 10.15. Pollination demand (in the left) and pollination service (in the right) maps of the case study area. In the pollination demand map, values of the grid cells are summed values of 25 m x 25 m grid cells.

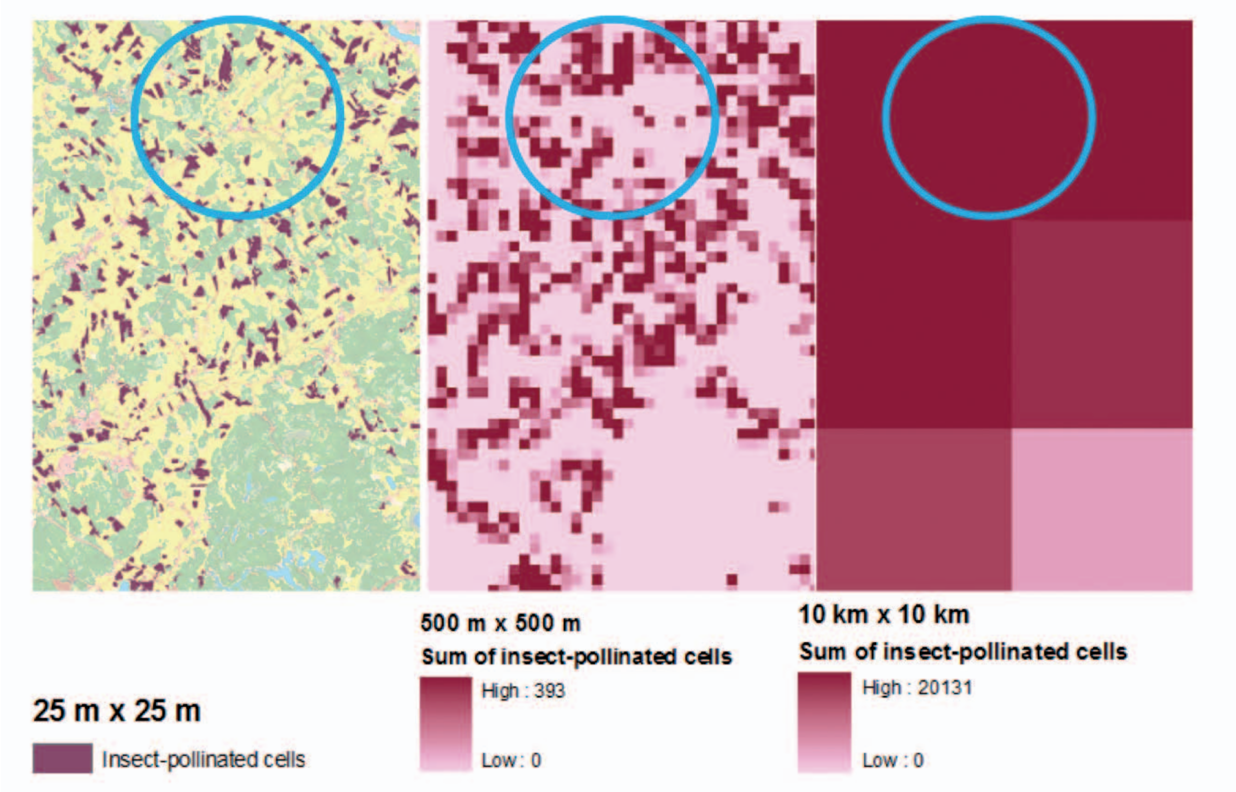


Figure 10.16. Pollination demand at a local scale, in the Rekijoki river valley area (blue circle), shown at three different grid sizes. In the 25 m x 25 m map, (transparent) Corine 2006 land use map is shown as background and the darkest colour indicates locations of fields with insect-pollinated crops (mainly oilseed-rape).

10.4.5.3 Local spatial variation of nesting and foraging values

An example of the spatial variation in the estimated nesting and foraging values in an agricultural landscape is shown in Figure 10.17. As can be seen by comparing them with the Corine 2006 land use map, agricultural fields show low nesting values, whereas fields with insect-pollinated crops show intermediate foraging values. The high value of forest edges and scattered patches of grassland can also be seen from the maps. Forests show intermediate values.

These types of maps could be used in the local planning of the implementation of agri-environmental measures, as they can help identifying localities where pollination demand is high but pollination services are scarce. Furthermore, these maps illustrate that even small patches of woodland in the middle of large field parcels, for instance, can potentially act as pollinator source habitats and thus their removal should be discouraged. Even more detailed data could provide insights into the importance of e.g. individual field margins or even single trees or shrubs that provide nectar and pollen resources for pollinators.

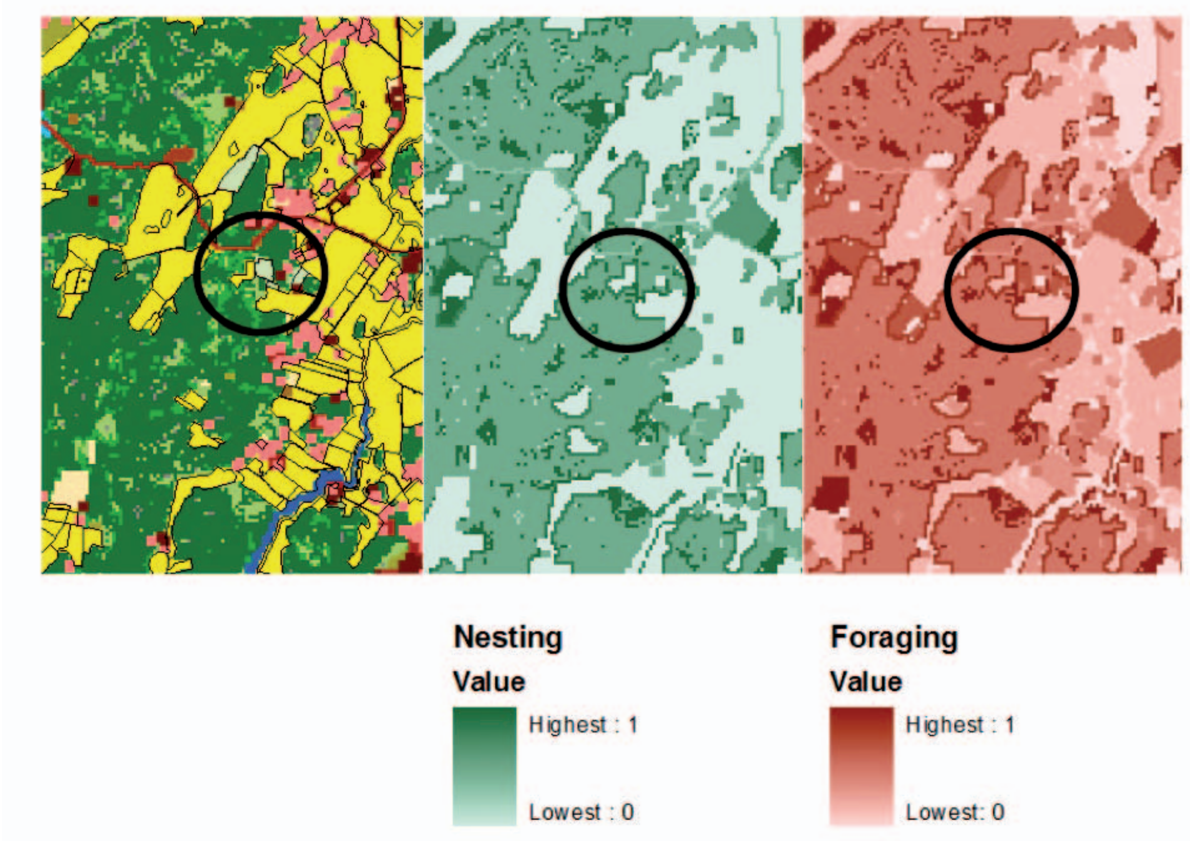


Figure 10.17. Example maps showing variation in the estimated nesting and foraging values within an agricultural landscape, together with the Corine 2006 land use map (in the left). Colour codes for the land use types are as in Figure 10.11. Field parcels are outlined with black, yellow parcels are cultivated agricultural fields (level 211) and pale turquoise parcels are fruit and berry plantations (level 222). One of the interviews for the policy analysis section (10.6) was carried out on a berry farm (location marked with the black circle), where raspberry, currants, highbush blueberry and gooseberry are produced.

10.4.6 Discussion

In this case study we applied the InVEST model for mapping pollination services provided by native bumblebees in Finnish agricultural landscapes based on GIS data on the occurrence of different kinds of habitats varying in their estimated value for foraging and nesting of bumblebees. We visualized the availability of pollination services as opposed to the location of agricultural fields with insect-pollinated crops both at a local and regional scale in SW Finland and examined the importance of scale in visualizing pollination services.

The availability of pollination services was generally highest in the northern parts of our case study area, whereas the pollination demand indicated by the distribution of insect-pollinated crops was highest in its southern parts. At the moment farmers in our case study area rely mainly on the domesticated honey bee for pollination. This is especially true in areas, where the extensive cultivation of oilseed rape has forced farmers to think about the pollination needs of their crops. However, should there be any problems with beekeeping, the role of native pollinators could become more evident. Already now bee colonies are struggling with diseases and the varroa mite (Varroa destructor) problem is widely spread also in Finland. Furthermore most of the beekeepers at the moment are past middle-age, which poses a challenge for the continuation of beekeeping in the future.

As climate changes, new crops are likely to become relevant in the case study area and some of these may require insect pollination. Furthermore the call for the national self-sufficiency of plant protein sources may lead to increasing cultivation areas of such plants as the field bean (*Vicia faba*), which is most efficiently pollinated by bumblebees (Peltonen-Sainio et al. 2009). Such trends may lead to more interest on native pollinators and to measures by which their populations can be enhanced in agricultural landscapes. Within agri-environmental schemes set-asides (Alanen et al. 2011) and different kinds of sown wildflower strips (Haaland et al. 2011) are effective in enhancing bumblebees, assuming nectar and pollen sources are made available. Suitable plant species include *Phacelia tanacetifolia*, *Vicia villosa* and *Centaurea jacea* (Alanen et al. 2011).

As a methodological question we noticed that there is need for even more detailed data. For example, information on field margins was missing in our datasets, although they can be important pollinator habitats. The availability of pollination services in this case study could therefore have been underestimated. In addition, we lacked information on open areas in field-forest ecotones and instead assigned higher values to all of those 25 m x 25 cells that were situated at the edges of forests. This could have in turn overestimated the availability of pollination services.

10.5 Modelling pollinator resources, crop pollinator richness and crop pollination across the British landscape

10.5.1. Introduction

In the UK the area of insect pollinated crops is increasing and its economic value was up to £1057 million during 2007 (Breeze et al., 2011). Wild pollinators provide a large proportion of the pollination service to agriculture in the U.K in field settings (Breeze et al., 2011). These wild species will still have a role in delivering pollination services to partially enclosed (poly-tunnel) or orchard cropping systems where managed bees (honey bees, bumblebee *Bombus terrestris,* red mason bee *Osmia rufa*) are also employed (Lye et al., 2011). Enclosed (glasshouse) crops will be solely reliant on managed pollinators and hence are not included in this analysis. The nesting and floral resources of pollinators are threatened, in the British landscape as elsewhere, by multiple factors but particularly by land-use change and intensification (Potts et al., 2010). In the UK, declines in pollinator forage plants are linked with the concomitant decline in wild bees (Carvell et al., 2006; Biesmeijer et al., 2006).

In the British case study, focused on wild insect pollinators we set out to achieve two objectives:

1. Model the density of pollinator (bumblebee) wild flower resources at a fine resolution across the British landscape
2. Model the distribution of insect-pollinated crops and crop pollinator richness across the British landscape and the extent of any spatial mismatch.

10.5.2 Methods

10.5.2.1 Objective 1: Model the density of pollinator (bumblebee) wild flower resources at a fine resolution across the British landscape

Data was recorded on the species richness of nectar producing plants for both bees and butterflies as part of the Countryside Survey (CS) of Great Britain, carried out in 2007 (see www.countrysidesurvey.org.uk). Species counts were recorded in 4m^2 quadrats nested within a stratified (by vegetation type) random sample of 588 1 km squares over Great Britain. The plots provide good spatial coverage over Great Britain and can therefore be seen as spatially representative and can be used to build up a model relating to pollinator species richness throughout GB. Further variables that were recorded in the CS2007, either at the 4m^2 quadrat level or at the larger scale 1 km square level, that were thought to affect pollinator species richness were considered for use as explanatory variables. Additional long-term average climate variables were available via the UK Met Office at 5km² resolution and were considered for inclusion. Table 10.5 shows a full list of variables that were available for inclusion in the models.

Table 10.5. List of explanatory variables thought ecologically justifiable to include in the GAMM model of both wild bees and butterflies.

Driver of spatial diversity patterns	Potential Explanatory variables	Source
Environmental factor	Altitude	UK Ordnance Survey Map
Environmental factor	Slope of plot	Measured in plot in CS2007
Environmental factor	Aspect of plot	Measured in plot in CS2007
Land use	Shade class of plot	Measured in plot in CS2007
Land use	Canopy height of plot	Measured in plot in CS2007
Climate	Mean annual temperature	UKCIP long term averages (1969 to 2000) (5km²)
Climate	Annual rainfall	UKCIP long term averages (1969 to 2000) (5km²)
Climate	Long term mean daily sunshine hours	UKCIP long term averages (1969 to 2000) (5km²)
Climate	Mean daily % cloud cover	UKCIP long term averages (1969 to 2000) (5km²)
Land use	Broad habitat type of plot	Mapped in CS2007
Land use	% of woody cover	Calculated from species abundance data
Land use	Coincidence with agri-environment scheme	Polygon-level assignment of each plot for England only in 2007 (source Natural England)
Atmospheric pollution	Total nitrogen deposition	CBED averages for 2004,'05 and '06 (5km²)
Land use	Total length of linear features in 1km square	Mapped in each CS 1km square in 2007
Land use/ environmental factor	Total area of polygon containing plot[1]	Mapped in each CS 1km square in 2007

[1]Where polygons were bisected by the edge of each 1km square, the complete area of the polygon was estimated using Bayesian inference given the known distribution of areas of polygons falling entirely within the 1km squares.

Generalised additive mixed models (GAMM) (Lin and Zhang, 1999) were used to model the spatial relationship between nectar plant density and available explanatory variables. The GAMM model framework allows both fixed and random affects to be present in the model. The random components included are to account for unobserved affects that could influence the outcome of the response variable. If dependency is present between observations, this would lead to under or over dispersion in our model and hence any variation and standard errors of parameters would be incorrectly estimated. Allowing for extra variation using the random components in the model accounts for this and therefore enables us to include observations with a dependency structure. The standard errors on our estimates are then more accurate and any inference is more reliable.

We fitted a GAMM of the following form;

$$g\{\mathrm{E}[y_i \mid \mathbf{x},\mathbf{b}]\} = \alpha + \sum_{j=1}^{k} f_j(x_{ji}) + \mathbf{Z}_i\mathbf{b}$$

where **Z** represents different grouping levels and **b** ~ *N*(**0** , **σ**) represents the differing variation assigned to each of the groups in **Z**.

Regression parameters were estimated by using a penalised quasi likelihood based approach in the statistical software program R. Standard likelihood based techniques can often not be used for GAMMs because of an intractable numerical integration required for maximisation of the likelihood. Penalised quasi likelihood uses a Laplace approximation to the true likelihood that enables the complex multi-dimensional model to be integrated over the random effects and the parameters estimated by maximising the quasi-likelihood.

Along with terms for each of the variables selected for inclusion in the model, we also included a term to account for any underlying spatial trend. Inclusion of a spatial trend surface accounts for any residual spatial autocorrelation present in the data that cannot be explained by the set of explanatory variables. Hence, any spatial autocorrelation present is "mopped-up" by the purely spatial term in the model and does not affect parameter estimation, selection and uncertainty for the other terms. In the model, a spatial trend was included via a first order interaction for the spatial location of the survey square, with no restrictions on the number of degrees of freedom imposed.

Parameter selection in the model was dictated firstly by ecological experience and theory. Having identified the population of variables to consider, variable selection in the model composed several different aspects. All combinations of variables were considered together with a number of interaction terms. Only the first order interactions thought ecologically justifiable were considered. The best fitting model was deemed by consideration of both the AIC and the generalised cross validation (GCV) score. Having fitted each model, plots of residuals were checked together with quantile-quantile plots of the observed and predicted values to ensure the goodness of fit was sufficient to use the model for prediction.

In addition, we mapped the distribution of floral resources (nectar and pollen) for insect pollinators provided by agri-environment schemes (AES). These data were obtained for AES uptake from DEFRA (England only).

10.5.2.2 Objective 2: Model the distribution of insect-pollinated crops and crop pollinator richness across the British landscape and the extent of any spatial mismatch.

Data on the occurrence of pollinator species (solitary and social bees) recorded per 10km x 10km square was provided by the Bees, Wasps and Ants Recording Society (BWARS, http://www.bwars.com). Subsequently our analysis was restricted to those bee species known to be associated with pollination of crops. The area of insect pollinated crops (hectares per 2km grid) was obtained from agricultural census statistics from UK government departments (e.g. DEFRA) downloaded from EDINA (http://edina.ac.uk/). We focussed on key insect-pollinated crops namely: oilseed rape (*Brassica napus*), field bean (*Vicia fabia*) and broad crop groups: soft fruits (strawberry, blackcurrant, redcurrant, gooseberry, blackberry and raspberry) and top fruits (apple, pear, plum and cherry). The pollinator species occurrence data were then standardised for variable recording effort (Hill, 2011) and the number of pollinator species adjusted based on neighbourhood predictions modelled from agricultural data (EDINA 2010 England and Wales 5km resolution, soft fruit data 2004 data; 2010 Scotland 2km resolution).

The degree of correlation between pollinator and crop abundance was investigated to identify places within the UK that grew high proportions of a given crop but had an apparent deficit in that crops respective pollinators. Potential mismatches between the distributions of crops and their pollinators were visualised by plotting the standardised residuals from linear regression of each crop's area (hectares of oilseed rape, field bean, soft fruits, top fruits, respectively) against the adjusted richness of its associated pollinators. Autocovariate models were used to address spatial autocorrelation in the data by estimating how much the response variable at any given site reflected response values at surrounding locations. This is achieved by fitting a distance-weighted function of neighbouring response values to the model's explanatory variables to capture autocorrelation arising from processes such as limited dispersal and movement of censused individual pollinators between sampling sites (Dormann et al., 2007).

10.5.3. Results

10.5.3.1 Objective 1: Model the density of pollinator (bumblebee) wild flower resources at a fine resolution across the British landscape

Overall, the density of wild flower resources across the British landscape for pollinators was greater in lowland areas and in the south and west of Britain (Figure 10.18). That the south-west of England was relatively high in floral resources probably reflected the wetter, milder climate and lower land-use intensity compared with the more intensively farmed east of England (e.g. Lincolnshire and east Anglia). The uptake of AES was similarly heterogeneous across the British landscape and tended to follow the same southwesterly distribution pattern as wild plant resources (Figure 10.19).

The best fitting model (GAMM) comprised mean annual temperature, mean monthly accumulated rainfall, a first order interaction between mean annual temperature and mean monthly accumulated rainfall, nitrogen deposition, broad habitat type, altitude, woody cover in each plot and geometry (habitat patch size and total length of linear features in each 1km square). Models also included a spatial trend surface in the form of an interaction term for the spatial location of each 1km square and the random effect of survey square on between plot variance.

To map the response variable of interest across Great Britain, we require the covariate information to be available at the same resolution and at the same locations as we wish to map. Some of the variables chosen in our best fitting model were, however, not available over the whole of Great Britain. Therefore, in order to demonstrate the mapping capabilities of the method we modeled the data once again, but only using covariates that we have information on over the whole of Great Britain. This shows that mapping is possible with the GAMM-based approach even when data for more finely resolved predictors is unavailable. The model was then used to predict the nectar producing plant species richness for bees over Great Britain at a 1km square resolution (Figure 10.18). This model is therefore capable of up-scaling to national estimates and demonstrates the usefulness of such an approach. As the model used was based only on covariates that were available at a national scale, estimates will not be as accurate as would be if the best fitting model could be applied.

Nevertheless, though the results from these maps may not be considered as being truly reflective or entirely accurate because of issues with model fitting, these results show the method works well and can produce informative national coverage maps. Any shortfall here does not come from the modeling approach but simply through a lack of data.

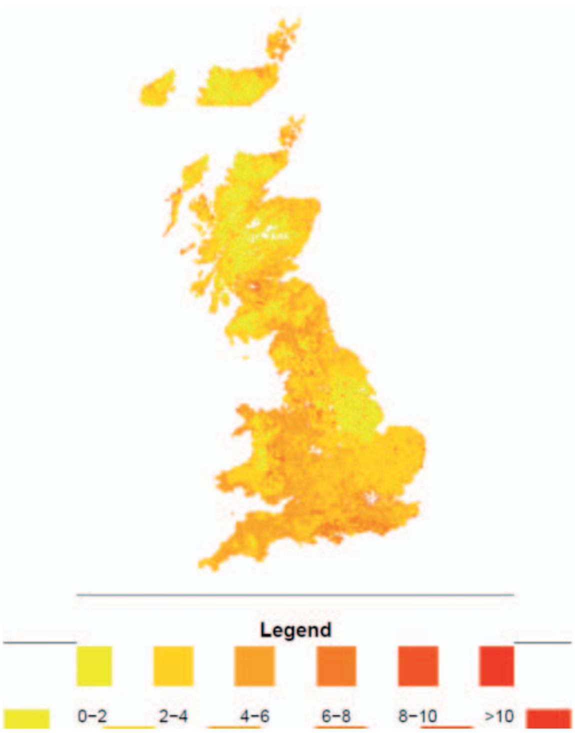


Figure 5.18. Predicted mean bee nectar plant richness per 4m2 in 2007 averaged over the Broad Habitats in each 1km square. Predictions generated from a Generalised Additive Mixed Model that included Broad Habitat class, climate, patch size, length of linear features in each 1km square and agri-environment scheme (ELS) status in 2007 as explanatory variables.

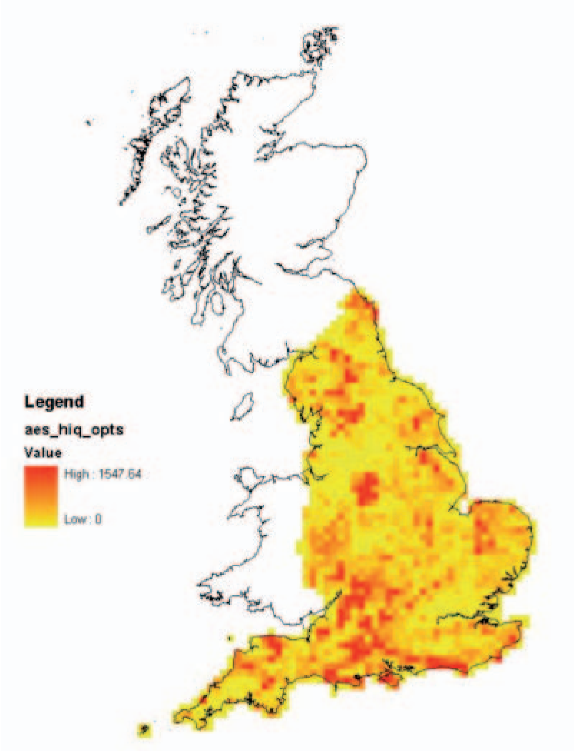


Figure 5.19. Provision of pollen and nectar resources from the agri-environment schemes (based on analysis of AES uptake data for England)

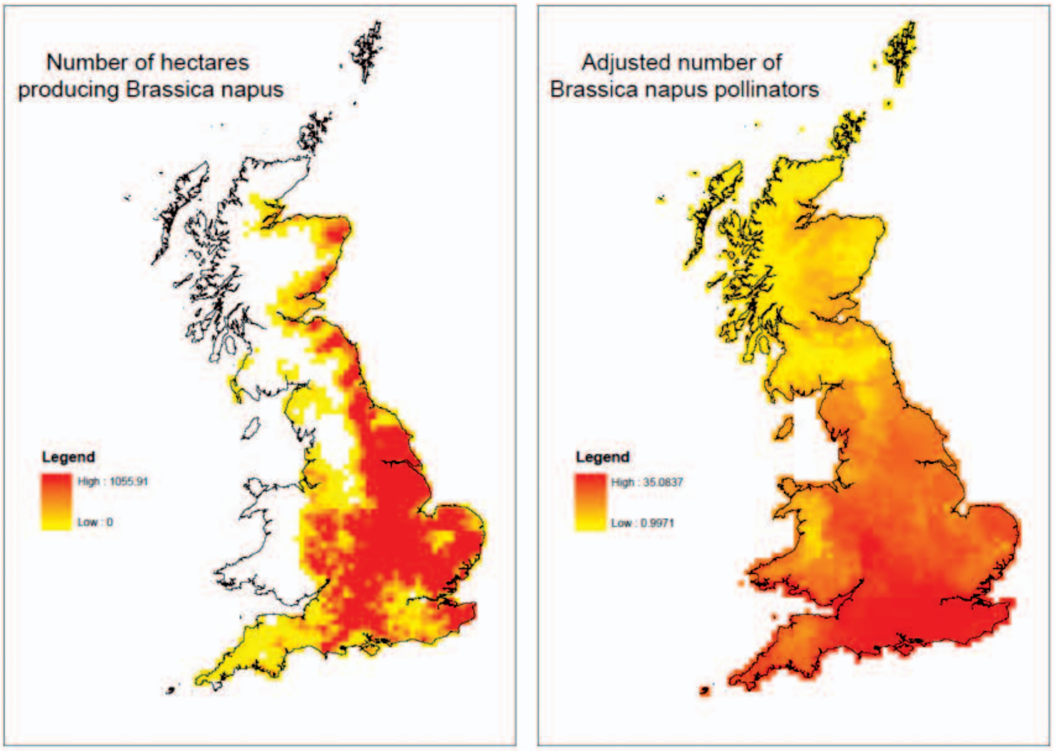
10.5.3.2 Objective 2: Model the distribution of insect-pollinated crops and crop pollinator richness across the British landscape and the extent of any spatial mismatch.

The modeling of the spatial overlap between crop area and crop pollinator richness showed that in some areas of Britain there is a potential for a spatial mismatch between insect-pollinated crops and the species richness of wild pollinators. For example, there is a high potential mismatch (shades of light blue) in the east of the country for field bean and its pollinators (Figure 10.21), where there is a high crop cover but lower pollinator resource. Similarly, Scotland supports an economically important soft-fruits industry in the south-east, and area that supports relatively low wild pollinator richness (Figure 10.23). Similar patterns for the other crops suggest that while in certain areas of the country there are sufficient pollinator resources to meet crop pollination needs, elsewhere the same crop may suffer from a deficit of wild pollination services (Figures 10.20-10.23). However, the available data only allowed an assessment of pollinator species richness. The abundance of individual pollinator species may be more important than species richness in the successful delivery of pollination services to crops. Such data on the abundance of wild pollinators are simply not available due to a lack of systematic monitoring in the UK and worldwide.

This approach of modeling crop areas and bee richness (from species occurrence records) produces maps of spatial pattern that are easy to interpret visually. These maps must, however, be treated with appropriate caution. The probability of each grid cell in the map having a certain value is strongly influenced by the values of surrounding cells (spatial autocorrelation). To quantify accurately the relationship between crop and associated pollinator distributions this spatial autocorrelation in the data was quantified and accounted for in a regression analysis (Dormann et al., 2007). For all four crops, spatial autocorrelation proved a highly significant variable in the regression analysis of crop area with pollinator species richness. Nonetheless, once this autocorrelation had been accounted for a highly significant relationship remained between crop area and crop pollinator richness (Table 10.6).

Table 10.6. Accounting for spatial autocorrelation, the results of linear regression of crop pollinator richness with four crop types.

Crop type	AIC	Crop ha		Spatial autocorrelation	
		F	P	F	P
Vicia faba	7853.93	11062.77	<0.001	42676.72	<0.001
Brassica napus	9137.66	13545.45	<0.001	60237.54	<0.001
Top Fruit	8702.69	2435.799	<0.001	65552.04	<0.001
Soft Fruit	8966.97	793.5909	<0.001	54337.39	<0.001



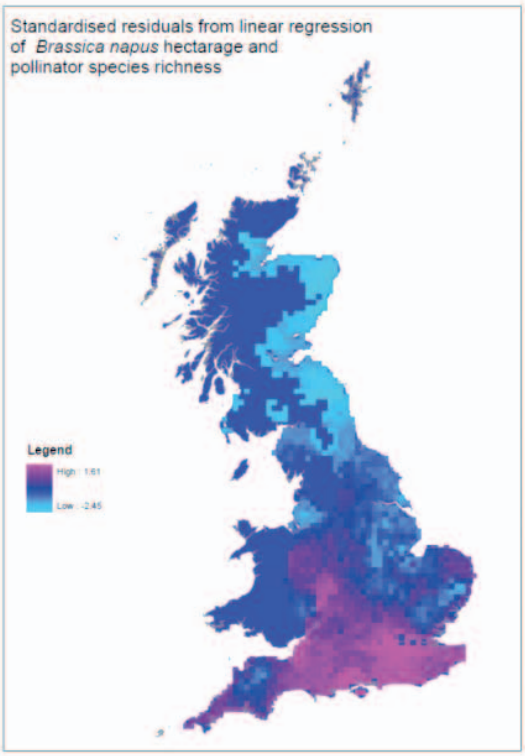
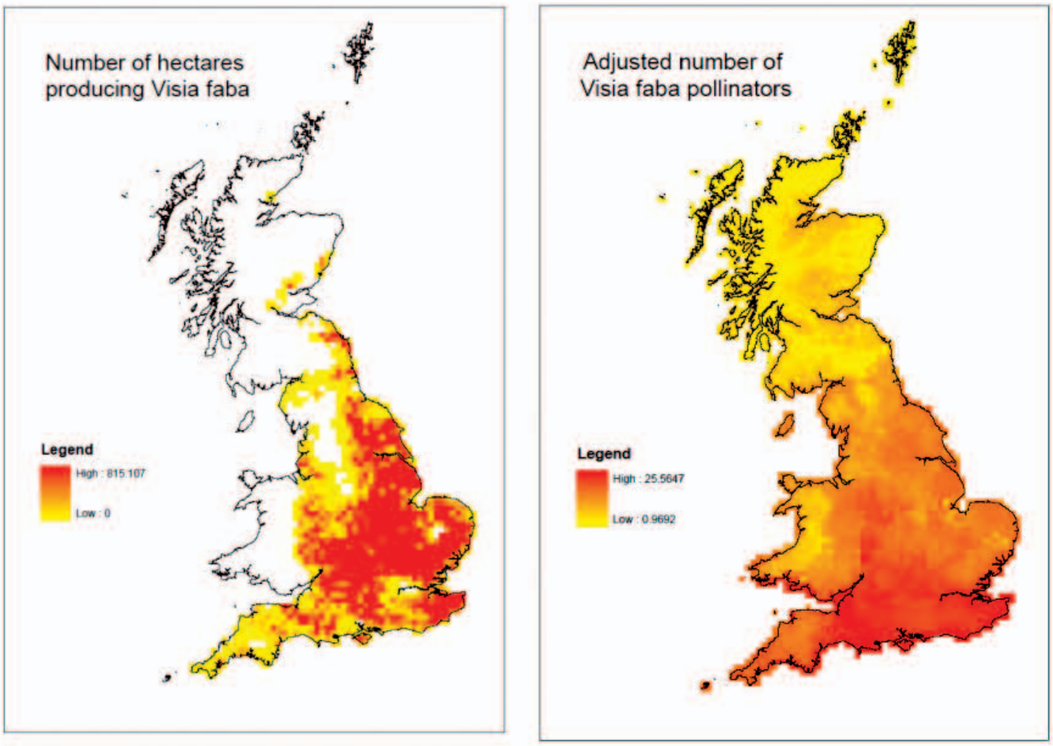


Figure 5.20. Oilseed rape (Brassica napus).

Distribution of oilseed rape (*Brassica napus*) crops, the species richness of its wild pollinators, and the potential for pollination mismatches. Pink shades indicate high overlap between crops and pollinator richness and light blue shades show low overlap. Dark blue indicates no crop grown.



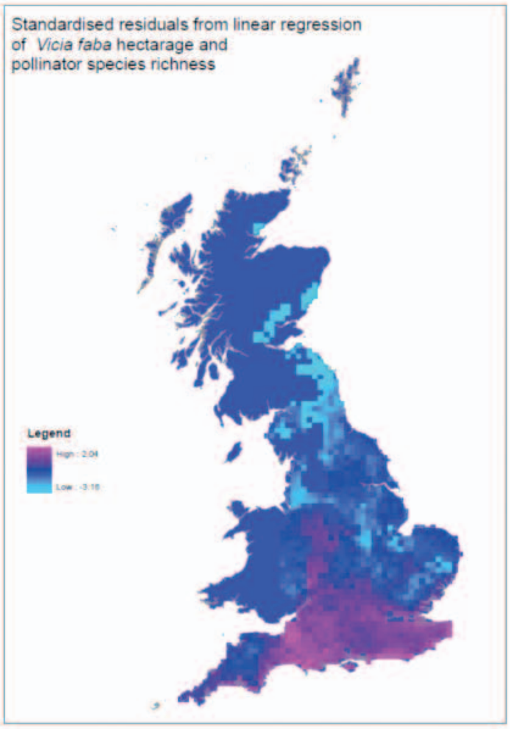
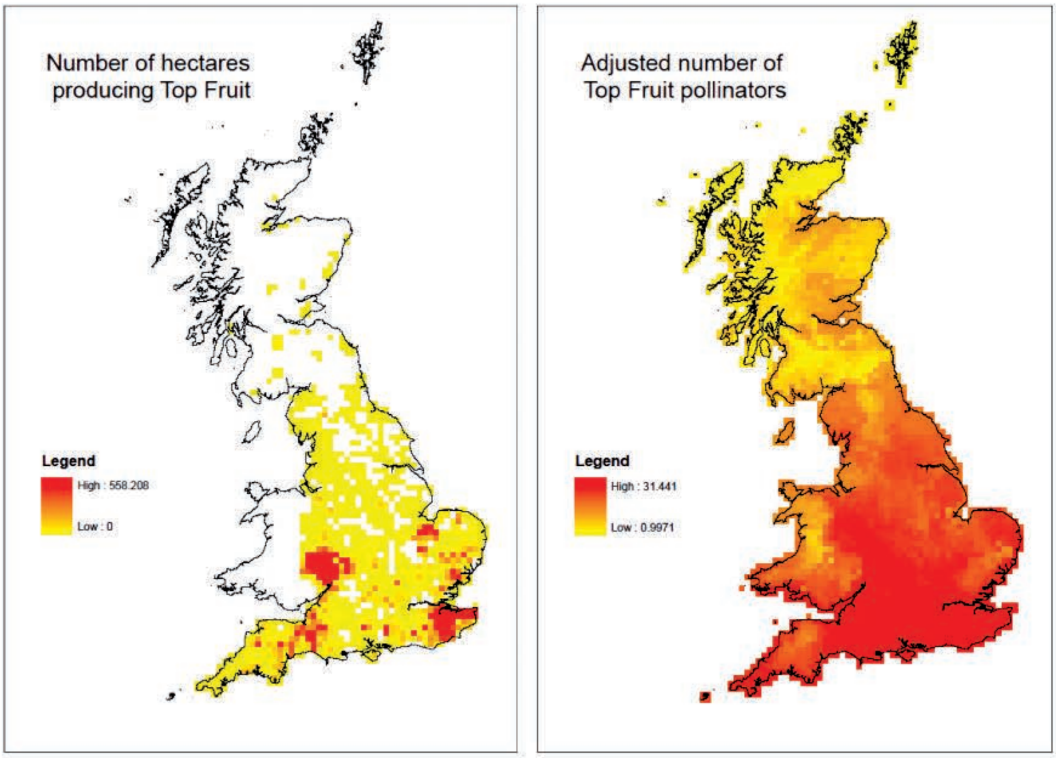


Figure 5.21. Field bean (Vicia fabia)

Distribution of Field bean (*Vicia fabia*) crop, the species richness of its wild pollinators, and the potential for pollination mismatches. Pink shades indicate high overlap between crops and pollinator richness and light blue shades low overlap. Dark blue indicates no crop grown.



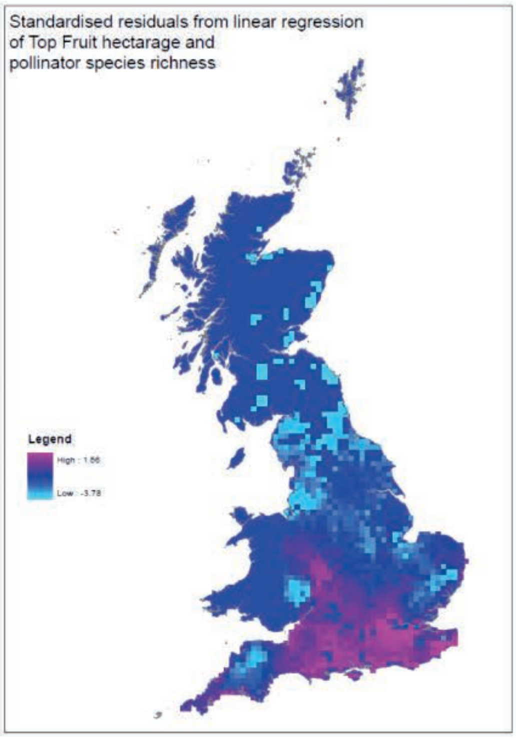


Figure 5.22. Top fruit (orchard crops e.g. apples)

Distribution of top fruit (apples, pears, plums, cherries) crops, the species richness of its wild pollinators, and the potential for pollination mismatches. Pink shades indicate high overlap between crops and pollinator richness and light blue shades show low overlap. Dark blue indicates no crop grown.

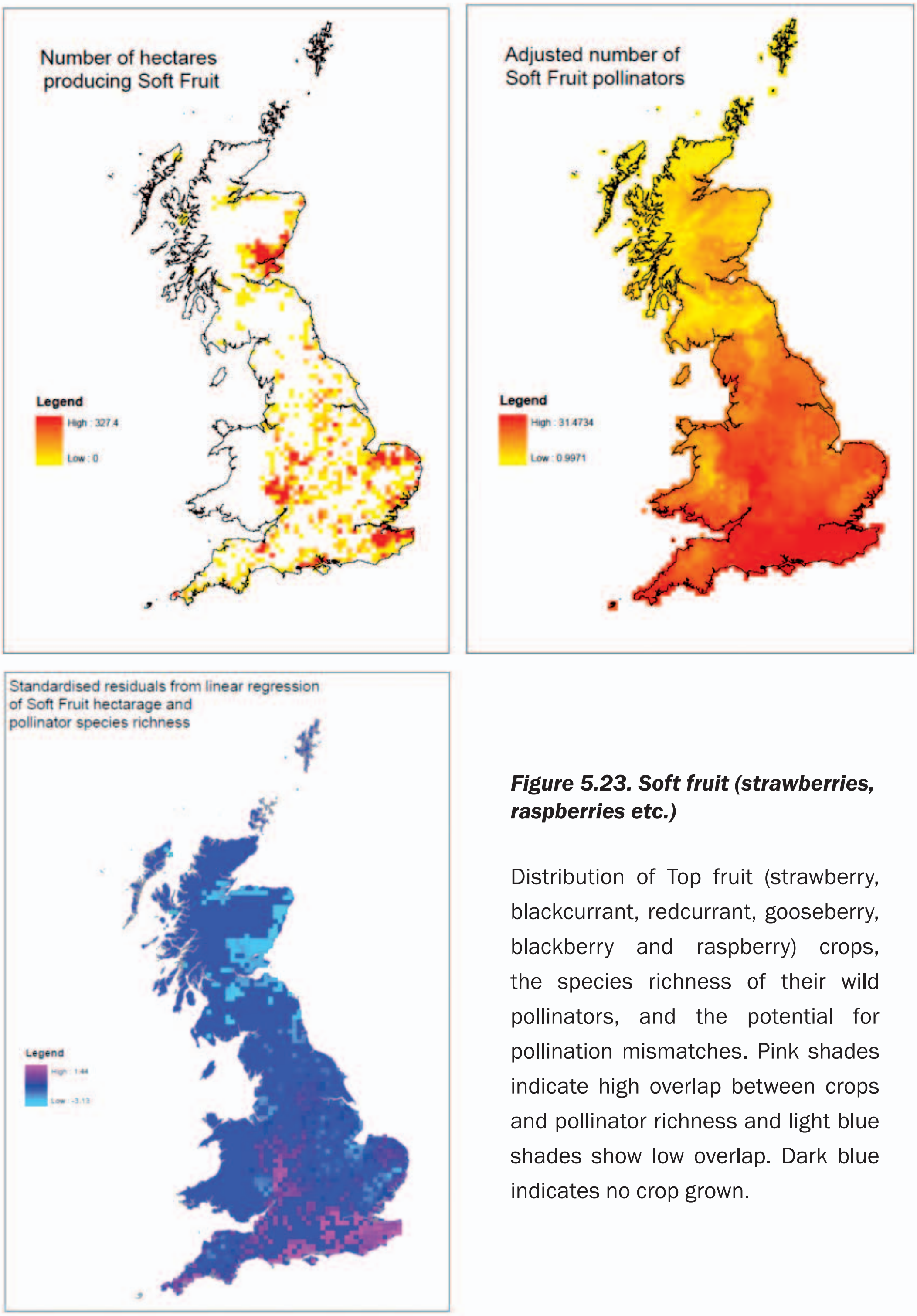


Figure 5.23. Soft fruit (strawberries, raspberries etc.)

Distribution of Top fruit (strawberry, blackcurrant, redcurrant, gooseberry, blackberry and raspberry) crops, the species richness of their wild pollinators, and the potential for pollination mismatches. Pink shades indicate high overlap between crops and pollinator richness and light blue shades show low overlap. Dark blue indicates no crop grown.

10.5.4. Conclusions

It is notable that much of the insect-pollinated crops grown in Great Britain are planted in the south and east of Britain whereas the wild flower resources follow a tendency towards the south and west. Moreover, the modeling approaches tried here suggest that there is potential for spatial mismatches between crops and their wild pollinators at least in certain regions of the country. In part, some of this mismatch may be due to historic land-use intensification in the eastern regions of the country leading to loss of wild pollinator resources. Land-use type is itself partly driven by natural environmental gradients (e.g.

precipitation, topography, soils) but these gradients may also have a fundamental role in the distribution of the flowering plants and insect themselves.

It is arguable that wild pollinator abundance is more important than species richness for the supply of effective pollination services i.e. pollen transfer. Diverse pollinator communities may, however, provide a degree of redundancy or functional complementarity in the pollination system (Hoehn et al., 2998). Such diversity may therefore underpin service resilience in the face of environmental changes that extirpate species. Pollinator abundances were not modeled in this case study simply because such data are generally lacking in the absence of systematic large-scale and long-term monitoring programmes. Without such pollinator density there will always remain a degree of uncertainty in real-world accuracy of the modeling undertaken.

Another caveat is that the modeling presented here only accounts for coarse patterns in space. This ignores the fine-spatial scales at which pollination processes actually occur (i.e. generally metres to 100s of metres) and the temporal dynamics of pollination as floral resources and flowering crops boom and bust across the growing season. This should be borne in mind when considering the application of large-scale maps of pollination services.

These conditions aside the models produced here represent a useful start to the quantification of gaps in pollination service provision. This will help the targeting of interventions to build towards a more sustainable agriculture.

10.6 Policy analysis on pollination services – A Finnish case study

10.6.1 Introduction

This section offers a policy analysis on pollination at a regional level in Finland. The case study area is the same as in the mapping study presented in chapter 10.4. The purpose of this study was to learn from an interdisciplinary work by combining a mapping methodology with qualitative methods such as literature review and interviews. Based on this work it was possible to 1) explore how the stakeholders perceive mapping of ecosystem services as a method and 2) also ask the stakeholders about their opinions about policies related to pollination. Given these two goals, this case study can be read either together with the mapping case study of Finland (chapter 10.4) or with the EU-level policy analysis presented in the chapter 2.

10.6.2 Data and methods

The data consists mainly of stakeholder interviews conducted in the south-west Finland in the same case area as in the Finnish pollination services mapping case study (section 5.4). Previous research publications and policy documents are used to back up the analysis. In all of the interviews, maps were used as a tool for discussion. The interviewed stakeholders were shown land use maps at different scales from the case study area. Also the method which was used in scoring the different elements in the landscape according to their value as foraging areas and nesting sites for pollinators was briefly explained to them. This enabled us to discuss the land use and farming practices from the perspective of pollinator conservation and management.

This study included six interviews. The stakeholders were selected from the south-west Finland case study area and they represented regional environmental administration, conservation and beekeeper NGOs, beekeepers, farmers and research. Since these data represent a selective and small case study, it is not possible to make any national or EU level generalization of the results. Instead, the used method is appropriate for bringing up topics, identifying concerns and enhancement of understanding on the local and regional level perceptions.

The following six stakeholder interviews were carried out:

- MTT, Agrifood Research Finland (Professor, Dr. Sc. Agr. & For., Plant Production Research, Horticulture)
- South-west Finland Centre for Economic Development (Transport and the Environment, The environment and natural resources) & Association for Traditional Rural Landscapes in south-west Finland (NGO)
- Regional Council of south-west Finland (Environmental Planner, natural environment)
- Finnish Association for Beekeepers (pollination services)
- Beekeeper (honey production)
- Berry farm (raspberry, blackcurrant, redcurrant, highbush blueberry, gooseberry)

10.6.3 Results from the stakeholder interviews

10.6.3.1 Opinions about the 'mapping exercise'

All of the interviewees reacted positively to the maps which were shown during the discussions. The method of valuing the landscape from the perspective of pollinators seemed to raise the stakeholders' interest. Yet they were also critical and suspicious about the application of these kinds of maps. This criticism was particularly a concern over geographical scales. For example the beekeepers saw that many of their everyday practices and decisions are dependent on micro-level factors in the landscape and thus the map would not be a useful tool in their work. For example, the microclimate of any potential hive site in a landscape is controlled by e.g. windiness and air temperature. Concerns were also raised that maps could be a new bureaucratic tool to control farmers.

When discussing pollination in the context of land use planning in administration, the results were not optimistic. Pollination as an ecosystem service takes place at lower scales than current land use planning processes. Furthermore, it was stated that at the moment pollination is not used as a criterion in land use planning. Using land use planning as a tool in pollinator conservation would require changes in the administration.

Some of the interviewees listed several possibilities for using maps in pollination related policies:

- A tool for visualising and comparing stakeholder opinions
- Usage as a tool in stakeholder negotiations
- Mainstreaming scientific information to stakeholders
- A tool for using power (trust issue is important)
- A working tool for the managers and administration
- Usage as a legal document (administrative land use planning but potentially also in contracts between stakeholders)
- Studying and identifying the connectivity of different regions and environments
- Visualising and comparing the environment from different pollinator species' perspectives
- A useful "beginner's" tool if designing practices to an unknown location
- Locating and identifying potential places and areas for development measures
- Putting the existing data into use, instead of collecting new data

The best feature of maps is that they can visualise things. One concern is the power issue. Maps do not only present pure facts, they can also leave out information and be biased. On the other hand, this can be used in good goals; e.g. different values can be mapped and compared. Another concern in using maps is that they could set strict boundaries for management. Marking voluntary conservation areas or other flexible agreements on a map may not be motivating for stakeholders or land owners. It is considered a too concrete or binding tool and thus an obstacle for flexible and adaptive planning.

10.6.3.2 Pollination as an ecosystem service and its connection to other ecosystem services

The importance of pollination and its relevance for agriculture was well realised by the interviewed stakeholders. CAP was easily identified as the most important policy sector which has an effect on pollination. The connection is multifaceted. First, agriculture is dependent on pollination (Gallai et al., 2009; Aizen et al., 2008; Klein et al., 2007). Thus the conservation of pollinators should evidently fall into the interests of CAP. Second, the pollinators may also benefit from agriculture. In this sense this can be seen as a win-win situation. However, as studies have shown, some agricultural practices are harmful to pollinators (IRGC, 2009; Klein et al., 2007). These negative impacts were not discussed by most of the interviewees and the topic was considered to be sensitive.

It became evident in the interviews that in discussing pollination, attention was easily targeted at managed bees instead of wild pollinators. The concept of "pollination services" equalled honeybees in the stakeholders´ perceptions. There were, however, a few exceptions. Wild berries are important for Finnish people. They are a reason to go out in the forest on every-man rights bases and a meaningful part of recreational services throughout Finland. Reduced amount of berries was seen as a problem for recreation but also for a healthy lifestyle in general. It was also discussed whether managed bees could be used to pollinate wild berries. It is also to be noted that not only humans are interested in the wild berries. For example, bad berry yield has caused brown bears to wander into gardens and house yards. This has caused human-wildlife conflicts and threatening situations. This is one example of how ecosystem services are never an isolated phenomenon, but an ecological process intertwined with other processes.

Bumblebees were mentioned by the berry farmers as they told that they appear sometimes but not always. Bumblebees were considered especially important in the spring time and for the high-bush blueberry. However, the farmers had not analysed or planned the local environment from the perspective of bumblebees as carefully as they had from the domesticated honey bees' perspective. In their opinion they were dependent on the honey bees since there was so much to pollinate. In addition, the honeybees were considered to be more cooperative and manageable than the wild pollinators. Some of the wild insects were seen unhelpful and aggressive.

In addition to CAP, also nature conservation and forestry policies were mentioned. These gained marginal attention in the interviews since they are not the most relevant policy frames in the everyday practices of the interviewees.

Pollinator friendly landscapes are typically considered beautiful at the same time, as they are e.g. rich in flowers. The interviews showed that this is well known also by the stakeholders and this cultural ecosystem service is highly valued. In this respect, berry farming was considered a better practice compared to intensive cereal farming. All the interviewees had the opinion that small field plots created a more beautiful landscape than large plots. In the Finnish MYTVAS project, researchers have used photography as a method in a follow-up study of landscape change (Kuussaari et al., 2008). Photographing the landscape in different seasons and years provides data on the changes in the landscape. This data can be analysed by qualitative but also quantitative methods, especially since the quality of the photographs has improved due to technological development. This kind of study is most suitable for long-term follow-ups.

Another way to identify connections between ecosystem services, besides looking from the ecological perspective, is to look at the policy implementation and farming practices at the field level. Some practices, e.g. buffer strips, may have positive effects for water purification, erosion control, pollination and landscape at the same time. Looking at the connection from the policy perspective could be a way to identify most efficient and cost-effective measures for nature conservation.

By comparing these results to the policy analysis at the EU level (chapter 2) it can be said that the interviewees' perceptions on the connections between different policies and pollination is somewhat narrow. Also the connection between pollination and other ecosystem services was mostly limited to the most obvious and direct connections; food production and landscape.

10.6.3.3 Economic valuation and policy instruments

Most of the stakeholders, when asked about the drivers behind pollinator loss, stated the market economy as a key driver. None of them started to look for ecological reasons, but their perceptions were targeted at the socio-economic arena. On the other hand the economic instruments, e.g. the agri-environment support, were seen as a suitable tool for steering the situation. These two, demand on the market and economic instruments, together largely determine which crops are cultivated and which measures and practices are used. On the other hand, one of the interviewees held the opinion that agri-environment schemes had no relevance for pollinators. Of the current measures, only long-term set-asides were seen as potentially beneficial to pollinators.

Discussion about economic instruments combined with the analyses of ecosystem services approach raised a question of economic responsibility. One stakeholder pointed out that the financial base could be broadened. The private sector has a strong interest in the agricultural business and therefore their participation and liability should be re-considered in the environmental issues. Tax revenues are not the only possible source of income when designing policies. Enterprises and companies could provide support for farmers to produce and maintain ecosystem services. Benefits of environmentally friendly practices have a marketing value.

In addition to farmers and enterprises, the role of consumers was also discussed. There is a lot of regulation as well as voluntary agreements in farming and other industries related to agriculture business, but less attention is paid towards the consumers. What steers consumer choices? Who holds the power over consumers? What are the procedures and relations between farmers, subcontractors, retailers and consumers? These processes and power relations within them should be opened up and studied. This is concordant with the notion of the ecosystem services approach. The concept helps to identify the services. Thus also the beneficiaries should be identified.

The concept of ecosystem services was highly attached to economic evaluation by the stakeholders. This was justified by the belief that in some cases economic reasoning might work better in motivating stakeholders compared to ecological reasoning. It was also found relieving that talking about values has been legitimized through the concept. Furthermore, as one interviewee pointed out: "One euro does not always equal one euro. Economic values have different mentalities. An euro with a good spirit may result in good deeds, without the request of full compensation".

On the other hand, economic instruments, such as compensations or financial aid, were seen only as one option and not sufficient if used alone. There are some ecosystem services or practices related to them which are not motivated by money. Therefore some other motivating instruments need to be developed on the side. These instruments need to be practical and functional at the farm level, since the farmers motivation is a key issue in creating good practices. What makes this especially difficult is the fact that different farmers are motivated by different things. One might be interested in protecting birds while another might be interested in saving other wildlife or maintaining a beautiful landscape. This means that the practices and measures need to be tailored at a farm level. General regional or national guidelines are not the lowest scale of policy-making (Aakkula et al., 2006).

This challenge was also reflected against the concept of ecosystem services. While it was generally considered as a good term for motivation, it still lacks a lot of operationalization into practical knowledge. One interviewee stated: “The value of mitigation efforts must be reasoned from the farmer’s perspective, not from the ecosystem’s perspective”.

10.6.3.4 Pollination and payments for ecosystem services

The industry around selling and buying pollination services is only starting to surface in Finland and the topic gained many contradictory comments in the interviews. The following options were identified:

- Mutual and equal benefit, no economic payments for ecosystem services
    - When the farmer needs pollinators and the beekeeper a good location for his/her beehives, the co-operation may be based on exchange of services.
- The beekeeper pays
    - When a beekeeper wants to specialize in the production of unifloral honeys it might be difficult to find a suitable location (e.g. raspberry fields). This, in theory, could lead to a motivation to pay for a good location. However, at the moment this is not affordable since the low market price of honey.
- The farmer pays
    - When the farmer needs pollinators but the beekeeper does not have an interest in honey production or finds it unprofitable the farmer might end up in paying for the pollination service.
    - In honey production, this option might help solve the unprofitability problem for specialization.
    - It was told by the interviewees that the number of beekeepers whose main interest is to offer pollination services is growing. In this case honey might be just a side product.

There are several challenges but also possibilities related to this phenomenon:

- Not all crops are interesting to beekeepers (e.g. turnip rape). What happens to these crops as regards to pollination?
- Would the increasing price of pollination services motivate farmers to pay more attention to wild pollinators and eventually decrease the market (economic benefit vs. ecological benefit)?
- Would the development of markets also enhance further research and mitigation actions (R&D)?
- Market value is difficult to determine since the benefits of pollinators are unknown and they vary.
- Many old customs and cultural issues are not concordant with the idea of ecosystem payments, such as:
    - People are ashamed to ask for money.
    - Farmers expect to get the services for free (or by exchange).
    - Old trust relations might be broken and this might have negative consequences instead of improving the situation (downsizing mutual cooperation and trust among beekeepers and farmers).

One example of the latter point is that the interviewed berry farmers knew that there were hives for sale but they found this a bit strange. They themselves had had beehives in their farm for 30 years. They had a reciprocal agreement with a local beekeeper and they had also agreed about common practices with him (about spraying herbicides etc.) and thus they had a good and tailored cooperation. The benefit between them and the beekeeper was valued to be equal and they thought that pollination turning into merchandise was not very welcome.

10.6.3.5 Knowledge and knowledge gaps experienced by the stakeholders

One striking, but very evident, point experienced by the stakeholders was that they don't lack any relevant information. Instead they rushed to explain how they see a lot of information which is not usable or relevant for their concerns. The problem with all information is its transformability into practices. The stakeholders' illustrations of the problem are listed below:

- There is no one to interpret the research findings to farmers (a challenge of popularizing science)
- How to turn the scientific/ecologic information into reasonable practices at the local level
- There is too much irrelevant information compared to the farmers everyday practices and reality
- The farmers may not be aware of the good outcomes of some mitigation strategies or environmental measures
- Too many good practices are dependent on coincidence or hearsay instead of systematic development
- The process of transforming the knowledge from one level to another has not been taken care of

Several ideas, but perhaps not so many new ones, were discussed as a way to solve these challenges:

- Popularizing articles in the media which farmers already read/follow; newspapers and their "scientific" pull-outs;
- Increasing multiple consultation services at farm level;
- Internet and the "ask from the expert"-sites;
- Public seminars and smaller discussion groups;
- One-to-one discussions at the farm/field level between stakeholders, e.g. administration + farmers or scientist + farmers.

However, if looked at carefully there were also some knowledge gaps which can be identified directly or indirectly from the data:

Related to management we need to know:

- How to motivate the farmers?
- How to build reasonable administrative processes in complex and multidimensional circumstances?
- What is the economic value of pollination at landscape scale? How to set the market value for contracts?

Related to bees we need to know:

- What causes diseases in honeybees and how can this problem be avoided/managed?

Related to pollination we need to know:

- What is the relation between different berries/crops and different pollinators?
- How should the different berries/crop fields be situated to ensure even pollination to all of them?
- How many bee hives per hectare?
- Are the pollinators loyal to certain flowers (àelimination of competitive wild plants)?
- What is the difference between bumblebees and honeybees as pollinators
- What is the significance of smaller not so well-known insects?
- Why do some varieties of a certain plant species work better than others in honey production (especially varieties of turnip rape)?
- How do new plants work, e.g. broad bean in honey production or in pollination in general?

10.6.3.6 Management issues and power relations

After discussing pollination, farming practices and mapping, also mitigation measures and management issues were discussed with the stakeholders. Some of the stakeholders hold the opinion that agricultural land use and the measures which affect the landscape are under-monitored. There is not enough control over land-owners or managers. They should at least have the obligation to notify any future changes, as currently there is no way to control land use changes at local scales. It is to be noted that this does not mean stricter regulation as such, only more efficient monitoring. In addition to monitoring, management of specific areas, e.g. traditional rural biotopes, was mentioned as one poorly utilized mitigation measure for pollinator loss.

The stakeholders identified a general lack of connectivity as a problem in creating effective mitigation. This includes the connectivity of policies, different ecosystem services, of local practices and of different stakeholders. This calls for more collective action, which may be a cultural challenge. Two interviewees stated that this is particularly difficult for Finnish mentality. Even so, farmers should be encouraged to build networks, work together and join efforts. For example one beekeeper with several hundreds of hives is highly significant for the surrounding region. If this beekeeper decides to end his business, what is the outcome for farmers? These kinds of analyses could be motivated through visualizations. Visualization could also be made on how different land uses and crop types in particular can be combined in an ecologically sensible way so that pollination services are maintained.

While acknowledging these challenges, the stakeholders also identified many simple and affordable environmental measures which are under-utilized for 'no good reason'. The status of pollinators could be enhanced by some simple measures, e.g. leaving a tree, a hedgerow, a woody island among fields, a sandy or rocky area, or decaying wood untouched. Sometimes the low popularity of these simple measures is not because of lack of knowledge or understanding, but lack of motivation. Motivation seems like a key factor in many respects.

First, there is information; secondly comes the understanding; and thirdly the motivation. Things which may weaken the motivation are: unwillingness to break up social structures (such as old networks, old habits and customs), social distance from the administration or other stakeholders, costs, fear of new work load, bureaucracy, unreasonably long procedures, impractical suggestions, un-relatedness to personal interests or everyday practices.

10.6.5 Conclusions: Practical, institutional and administrative gaps and discontinuities

Pollination as an ecosystem service has shown to be very well acknowledged by many of the stakeholders based on this study. However, it is evident that the realization of pollination as an ecological phenomenon is strong but the realization of its practical connections to socio-economic phenomena is only staring to surface. Economic value of pollination is well known but there are other relevant discussions around the socio-economic sphere. The term ecosystem service helps to conceptualize pollination as a "service" but the ideas about the beneficiaries or liabilities related to this service are not yet clear. However, identifying these responsibilities and beneficiaries is important for future policy-making, planning, and for avoiding stakeholder conflicts. On the other hand, this identification may bring new stakeholders to the play. This analysis shows that identifying and conceptualizing responsibilities and entitlements is a social construction which changes over time. The concept of ecosystem service is a tool to go through these discussions.

Agricultural practices should be investigated as a multi-layered socio-economic phenomenon in order to provide sufficient contextual information for sound and effective decision-making. This means that in addition to ecological research many social, cultural, institutional and economic drivers should be studied. More attention should be paid to the concrete agricultural practices at the local and regional level. The Good Farming Practices should put more focus on pollination. It is worthy to realize that the stakeholders identified many voluntary and practical measures to be more effective than the existing measures provided by legal or administrative regulation. Pollinators are supported not only by the formal but also many informal institutions. The meaning of both of these spheres should be analysed.

Stakeholder interviews have shown that pollination as a governing question is not linear and that the biggest problems do not lie in the lack of knowledge. Rather the most important problems, when looked from the stakeholders' perspectives, lie in the gaps and discontinuities between administrative scales (see also Aakkula et al., 2006). Scientific knowledge does not meet the practicalities at the farm level. Nor do they match with the social or cultural institutions embedded in rural life-modes. Højrup (2003, pp. 5) states this governing problem nicely:

> "The logic of a life-mode lies in the structural problematique by which subjects perceive 'the environment' in the activities of praxis; when subjects disagree about what the world looks like, it is because they operate with different conceptual systems which blind them to each other's ways of seeing"

At the moment it seems that there are no governance procedures to overcome these obstacles. On the other hand processes which integrate different life-modes and practices can be developed and investigated. Therefore the processes of integrating scientific information to practices at the farm level should be a target for future research and development. Trust, spirit and motivation are key factors in governance processes. They require long-term processes in which information and development of practices go hand in hand. Passing on or creating information is not a procedure or a measure, but it is an interactive social process.

10.7 Quality assessment of the study

The problem of pollination deficit is complex, both in relation to ecological interactions and consequences and the multi-layered socio-economic system behind actions and strategies to enhance and secure pollination. The increased availability of large geographical reference data sets makes mapping a promising method for decision support. It has been shown possible to make mapping at a detailed scale of the entire Europe to rank both the pollination potential and needs based on landscape and agricultural information data bases.

However, mapping of pollination and deficits in crop pollination will always be limited to simple conditions and the results need an effort to be interpreted. How it should be interpreted, depends on the stakeholders involved. Mapping is a very relative method and cannot be used to quantify the problems behind lack of pollination. Our study here does not include domesticated pollinators and this fact raises the uncertainty in applying the results. The main uncertainty comes from the fact that the landscape attributes as reported in the databases are assumed to be unique descriptors for the abundance of pollinating insects. This is not valid to some degree, where local ecological conditions and socio-cultural history is driving the abundance of pollinators. It is also not the case that the landscape attributes are sufficient to characterize the ecological conditions in detail to capture all important ecological information that governs the abundance of pollinators.

The ranking result can be considered more valid within a single region, e.g. a rank between a location in Norway and a location in Spain is more uncertain than a ranking between two Spanish locations. The need for details in mapping was further displayed in the Finish case study, where a scale of 25 m was tested and even at that scale some local landscape factors can be hidden. However, the scaling issue is not simple to assess directly as it also depends on how the mean values of the attributes are found. E.g. a 10 m wide flower-strip may not be directly visible in the mapping, but the existence of flower strips can be used when the mean value for more aggregated attributes are calculated. It will obviously be a good idea to perform mapping as an input to planning of activities to investigate pollination and the service it delivers. However, the mapping will first be really strong when domesticated bees are included also.

The applications of the maps for stakeholder needs are not simple and depend obviously on the type of a stakeholder. There can even be resistance against the mapping results to be public. It is therefore important to involve the stakeholders closely and early before maps for stakeholder usage are developed.

10.8. Summary and conclusions

Pollination as an ecosystem service was studied in four case studies that complemented each other in several ways.

Two of the studies used the InVEST model approach to map the availability of pollination services as well as their demand, first at the European scale (10.3) and secondly in more detail within a case study are in southwestern Finland (10.4). This approach was based on the estimated value of different kind of habitats as foraging and nesting areas for wild pollinators (the managed pollinators such as the honey bee were not considered) and the various available habitat and land use maps. The UK case study (10.5) was based more strictly on available empirical data on the occurrence of wild flowers, insect-pollinated crops and wild pollinator insects. Modelled distribution maps of the density of pollinator wild flower resources and pollinator species richness across the British landscape were then produced based on statistical models fitted with the available empirical flower and pollinator data. The fourth case study (10.6) focused on a policy analysis on pollination services in Finland based on stakeholder interviews in southwestern Finland.

Below we summarize the main findings and conclusions of the four case studies:

1. The first general finding was that mapping of the availability of pollination services can be done even at the European scale based on the availability of habitats suitable for foraging and nesting of pollinator insects. However, the maps presented in this report should only be considered as the first attempt to map pollination potential and its demand which can be useful as the first approximation but which would certainly benefit from further refinements.

2. The mapping method based on the InVEST model produced useful maps that can be helpful in assessing large-scale patterns of the availability of pollination services and its potential mismatches with the pollination demand of agricultural crops. Such information may be helpful in planning both European Union's and its Member State's policies related to both to sustainable agriculture and maintenance of biodiversity. The maps can also be used to assess needs for practical mitigation measures to promote insect pollinators for example in national agri-environment schemes in much smaller local scales.

3. The European level mapping revealed that the pollination potential (measured as the relative pollinator abundance) generally increases from north towards southern Europe which corresponds to the modeled temperature-dependent activity rate of bees and bumblebees.

4. Another main finding was that in a given temperature, pollination potential is low in large areas where the dominant land use is arable land used for the production of cereals. This is the case for the east of the United Kingdom, areas in France surrounding the capital, areas in central Spain, the Po plain in Italy, areas in northern Germany, Poland and Slovakia and the along the borders of the Danube in Bulgaria and Romania. These areas are assumed to have low pollinator nesting suitability and to offer limited resources for foraging due to an absence of plants with flowers carrying nectar.

5. At aggregated EU level, 23.6% of the total production of crops dependent on pollination can be assigned to insect pollination. This figure can be interpreted as a production deficit if no pollination services were

offered by insects. This value decreases to 1% if all crop production is considered, including crops that are not dependent on pollination. However, there are significant differences between countries in these values. If only crops dependent on insect-pollination are considered, the share of insect pollination in crop production was particularly high in Austria and Slovenia which both have important fruit production.

6. There were important differences between countries in pollination dependent production compared against total crop production. The share of crops non-dependent of insect pollination such as cereals, maize and potatoes decreases the importance of insect pollination. Importantly however is that crop production of countries with a high pollination potential resulting from high average temperatures are more dependent on pollination. In particular Mediterranean countries as Italy, Cyprus, Greece and Spain show higher contributions than the EU average.

7. In the Finnish case study area the availability of pollination services was generally highest in the northern parts and lowest in the southeastern parts, whereas the demand for insect pollination had just the opposite pattern. These patterns were better seen in the scale of the 10 km grid than in the smaller grid sizes and they were largely due to the differences in cover of forest and arable land between the northern and southern parts. In the northern part cultivated fields tended to be smaller and thereby the distances to forest edges with high pollination availability tended to remain small, whereas in the southern part arable fields constituted much larger cultivated open areas with low availability of pollination services and the distribution of insect-pollinated crops followed the general distribution of arable areas.

8. The Finnish high resolution maps (grid size of 25 m) were found useful in the local planning of the implementation of agri-environmental measures, because they can help identifying localities where pollination demand is high but pollination services are scarce, and where practical mitigation measures are needed. These maps also illustrated that even small patches of woodland in the middle of large field parcels can potentially act as important pollinator source habitats in agricultural landscapes.

9. The Finnish pollination service maps based on different grid sizes (varying from 25 m to 10 km) illustrated that some phenomena associated with pollination are scale sensitive, in other words they may disappear from the maps when the scale becomes coarser. Scale sensitivity was seen in the case of the Rekijoki river valley which is the largest still existing aggregation of species-rich semi-natural grasslands in Finland and therefore a nationally unique area with a high conservation priority. This area represents a national pollinator insect hot-spot with several threatened species and it was well-visible in the 25 m and 500 m grid maps. However, in the 10 km grid map this area received a lower than average value in the availability of pollination services, because the areas surrounding the river valley were relatively intensively cultivated arable areas with generally a low pollination service level. This example highlights that, whereas the availability of pollination services for cultivated crops may be optimal in landscapes with relatively even distribution of suitable bumblebee habitat (in the northern areas of the Finnish case study area), this does not mean that these same landscapes would be best for conservation of pollinator insect diversity.

10. Despite the fact that the UK case study was based on essentially different methodology in producing the maps on pollination potential, it produced qualitatively very similar large-scale patterns and observations as the European level mapping for Britain. A main result of the UK study was that much of the insect-pollinated crops grown in Great Britain are planted in the south and east of Britain, whereas their wild flower resources follow a tendency towards the south and west.

11. More detailed analyses for single insect-pollinated crop species (oilseed rape and field bean) or groups of ecologically similar species (fruit trees and berries) suggested that there is potential for spatial mismatches between crops and their wild pollinators at least in certain regions of the country.

12. An important difference between the UK and European level case studies was that the UK study produced a map on pollinator species richness (based on real species distribution data), whereas the European mapping estimated wild pollinator abundance (based on suitable habitat availability). While it is assumable that pollinator abundance is more important than species richness for the supply of effective pollination services, diverse pollinator communities may, however, provide a degree of redundancy or functional complementarity in the pollination system. Such diversity may therefore underpin service resilience in the face of environmental changes that extirpate species.

13. From the policy analysis it became evident in the interviews that the stakeholders at regional and local levels easily targeted their attention at managed bees instead of wild pollinators. However, it remains to be seen if the commercialization of pollination services creates more interest towards wild pollinators.

14. Most of the stakeholders, when asked about the drivers behind pollinator loss, stated the market economy as a key driver. Perceptions were targeted at the socio-economic arena rather than ecologic drivers or pressures. On the other hand this is concordant with the fact that economic instruments, e.g. the agri-environment support, were seen as a suitable tool for steering the situation. Market economy and economic instruments were seen to be the two most important determinants behind of which crops are cultivated and which measures and practices are used.

15. The concept of ecosystem services was found to be useful by the stakeholders, but on the other hand it has opened up new questions about responsibilities and liabilities. Especially the relations between different policies and also the responsibilities of different stakeholders in the agricultural business need to be clarified and analysed.

16. The stakeholders hold the opinion that they don't lack any relevant information. Instead, the operationalization of the scientific information and development of good social practices were identified as key concerns.

17. Based on the stakeholder interviews it can be said that in addition to scientific knowledge and formal administrative tools also the informal practices and codes of conduct are an important aspect of pollinator conservation. More attention should be paid in investigating the role of informal institutions and practices.

18. All of the interviewees reacted positively to the maps which were shown during the discussions. The method of valuing the landscape from the perspective of pollinators seemed to raise the stakeholders' interest. Yet they were also critical and suspicious about the application of these kinds of maps (fear of bureaucracy or further control). Trust is a highly important issue when developing practices and measures at the local level.

19. When discussing pollination in the context of land use planning in administration, the results were not optimistic. Pollination as an ecosystem service takes place at lower scales than current land use planning processes.

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Appendix 1. Nesting and foraging scores for the different land use types in the GIS datasets. Source: 1 = Corine 2006 (dataset I), 2 = Field plot register 2008 (dataset II) and 3 = datasets III-VI.

Description	Nesting	Foraging	Source
Agri-environment scheme contract area (open). traditional rural biotope management	1	1	3
Open traditional rural biotope. locally important	1	1	3
Open traditional rural biotope. nationally important	1	1	3
Open traditional rural biotope. regionally important	1	1	3
Permanent pasture. agri-environment scheme special contract area	1	1	2
Agri-environment scheme contract area (open). promotion of biodiversity	1	1	3
Permanent pasture. open pasturage	0.8	0.7	2
Forested traditional rural bi otope. regionally important	0.8	0.7	3
Forested traditional rural biotope. locally important	0.8	0.7	3
Forested traditional rural biotope. nationally important	0.8	0.7	3
Agri-environment scheme contract area (forested). traditional rural biotope management	0.8	0.7	3
Field plot register forests. forested pasturage	0.8	0.7	2
Cultivated field. agri-environment scheme special contract area. perennial buffer strip with grasses	0.8	0.5	2
Natural pasture or meadow	0.7	0.7	3
Cultivated field. agri-environment scheme special contract area. promotion of biodiversity or set-aside	0.7	0.7	2
Abandoned agricultural field	0.7	0.7	1
Permanent pasture. natural pasture or meadow	0.7	0.7	2
Abandoned. forested agricultural field	0.7	0.7	1
Grassland	0.7	0.7	3
Field plot register forests. forested natural pasture or meadow	0.7	0.7	2
Agri-environment scheme contract area (forested). promotion of biodiversity	0.7	0.7	3
Permanent pasture	0.6	0.6	3
Field plot register. agri-environment scheme special contract area (20 years). other area	0.6	0.6	2
Transitional woodland-shrub (cc <10%)	0.6	0.6	1
Transitional woodland-shrub (cc 10-30%) on mineral soil	0.6	0.6	1
Transitional woodland-shrub (cc 10-30%) on peat soil	0.6	0.6	1
Transitional woodland-shrub (cc 10-30%) on rocky terrain	0.6	0.6	1
Pasture	0.6	0.6	1
Managed. uncultivated field	0.6	0.6	2
Built area. summer cottage	0.6	0.6	1
Field plot register. uncultivated field	0.6	0.6	2
Field plot register forests. reforested agricultural field	0.5	0.5	2
Buffer zone	0.5	0.5	3
Cultivated field. agri-environment scheme special contract area (5 or 10 years). buffer zone with grasses	0.5	0.5	2
Cultivated field. agri-environment scheme special contract area (20 years)	0.4	0.4	2
Cultivated field. agri-environment scheme special contract area (5 or 10 years). promotion of biodiversity	0.4	0.4	2
Set-aside	0.4	0.4	2
Field plot register forests. forest pasture	0.4	0.4	2
Cultivated field. special plants and uses. temporarily unCultivated field	0.4	0.4	2
Permanent pasture. grassland field for fodder or silage (5-10 years)	0.4	0.3	2
Permanent pasture. grassland field for pasture (5-10 years)	0.4	0.3	2
Cultivated field. special plants and uses. willows (Salix) for biomass production (duration ≤ 20 years)	0.3	0.5	2
Cultivated field. nursery garden (< 5 years) of berries. fruits and ornamental plants	0.3	0.4	2
Cultivated field. nursery garden (≥ 5 years) of berries. fruits and ornamental plants	0.3	0.4	2
Built area. discontinuous urban fabric	0.3	0.3	1
Forest. broad-leaved on mineral soil	0.3	0.3	1
Forest. broad-leaved on peat soil	0.3	0.3	1
Forest. coniferous on mineral soil	0.3	0.3	1
Forest. coniferous on peat soil	0.3	0.3	1
Forest. coniferous on rocky terrain	0.3	0.3	1
Forest. mixed forest on peat soil	0.3	0.3	1
Forest. mixed on mineral soil	0.3	0.3	1
Forest. mixed on rocky terrain	0.3	0.3	1
Cultivated field. grassland field. perennial (2-4 years or in crop rotation) for fodder or silage	0.3	0.2	2
Cultivated field. grassland field. perennial (2-4 years or in crop rotation) for pasture	0.3	0.2	2
Christmas tree plantation	0.3	0.1	2
Cultivated field. special plants and uses. greenery (trees and shrubs ≥ 5 years)	0.3	0.1	2

Crop rotation fallow in organic production	0.2	0.4	2
Cultivated field. fruits. berries and nursery gardens. raspberry (Rubus idaeus)	0.2	0.4	2
Fruit tree or berry plantation	0.2	0.4	1
Cultivated field. fruits. berries and nursery gardens. apple (Malus domestica)	0.2	0.4	2
Cultivated field. fruits. berries and nursery gardens. black currant (Ribes nigrum)	0.2	0.4	2
Cultivated field. fruits. berries and nursery gardens. highbush blueberry (Vaccinium corymbosum)	0.2	0.4	2
Cultivated field. fruits. berries and nursery gardens. lingonberry (Vaccinum vitis-idaea)	0.2	0.4	2
Cultivated field. fruits. berries and nursery gardens. other fruits	0.2	0.4	2
Cultivated field. fruits. berries and nursery gardens. plum (Prunus x domestica)	0.2	0.4	2
Cultivated field. fruits. berries and nursery gardens. red currant (Ribes rubrum)	0.2	0.4	2
Organic production	0.2	0.3	3
Cultivated field. special plants and uses. vegetable garden	0.2	0.3	2
Cultivated field. fruits. berries and nursery gardens. gooseberry (Ribes uva-crispa)	0.2	0.3	2
Cultivated field. fruits. berries and nursery gardens. rowan (Sorbus aucuparia) for berry production	0.2	0.3	2
Cultivated field. grassland field. for green manure	0.2	0.2	2
Cultivated field. grassland field. perennial (2-4 years or in crop rotation) for grass seed production	0.2	0.2	2
Built area. road and rail networks and associated land	0.2	0.2	1
Cultivated field. fruits. berries and nursery gardens. black chokeberry (Aronia melanocarpa var. grandifolia)	0.2	0.2	2
Cultivated field. fruits. berries and nursery gardens. sea-buckthorn (Hippophae rhamnoides)	0.2	0.1	2
Beach. dune or sandy area	0.2	0.1	1
Built area. continuous urban fabric	0.2	0.1	1
Cultivated field. legume crops. mixed cultivation of legume crops (> 50 %) and cereal	0.1	0.4	2
Cultivated field. legume crops. mixed cultivation of legume crops and cereal (≥ 50 %)	0.1	0.4	2
Cultivated field. fruits. berries and nursery gardens. other berries	0.1	0.4	2
Cultivated field. fruits. berries and nursery gardens. strawberry (Fragaria × ananassa)	0.1	0.3	2
Cultivated field. special plants and uses. ornamental plants (< 5 years)	0.1	0.3	2
Cultivated field. special plants and uses. ornamental plants (≥ 5 years)	0.1	0.3	2
Inland marsh on land	0.1	0.2	1
Bare rock	0.1	0.2	1
Cultivated field. grassland field. annual for fodder or silage	0.1	0.1	2
Cultivated field. grassland field. annual for grass seed production	0.1	0.1	2
Cultivated field. grassland field. annual for pasture	0.1	0.1	2
Built area. Airport	0.1	0.1	1
Cultivated field. special plants and uses. field for honey production (e.g. Phacelia tanacetifolia)	0	0.5	2
Cultivated field. grassland field. certified seed production of alsike clover (Trifolium hybridum)	0	0.4	2
Cultivated field. grassland field. certified seed production of red clover (Trifolium pratense)	0	0.4	2
Cultivated field. legume crops. vetches (Vicia sp.)	0	0.4	2
Cultivated field. oil crops. spring oilseed rape (Brassica napus subsp. oleifera)	0	0.4	2
Cultivated field. oil crops. spring oilseed rape (Brassica rapa subsp. oleifera)	0	0.4	2
Cultivated field. oil crops. winter oilseed rape (Brassica napus subsp. oleifera)	0	0.4	2
Cultivated field. oil crops. winter oilseed rape (Brassica rapa subsp. oleifera)	0	0.4	2
Cultivated field. fruits. berries and nursery gardens. muskmelon (Cucumis melo)	0	0.4	2
Cultivated field. legume crops. field bean (Vicia faba)	0	0.4	2
Cultivated field. oil crops. sunflower (Helianthus annuus)	0	0.4	2
Cultivated field. spices and medicinal plants. mustard (Brassica sp.)	0	0.4	2
Cultivated field. open field vegetables. common bean (Phaseolus vulgaris var. nanus)	0	0.3	2
Cultivated field. cereals. buckwheat (Fagopyrum esculentum)	0	0.3	2
Cultivated field. oil crops. camelina (Camelina sativa)	0	0.3	2
Cultivated field. oil crops. flax (Linum usitatissimum)	0	0.3	2
Cultivated field. open field vegetables. cucumber (Cucumis sativus)	0	0.3	2
Cultivated field. open field vegetables. pumpkin (Cucurbita sp.)	0	0.3	2
Cultivated field. spices and medicinal plants. caraway (Carum carvi)	0	0.3	2
Bog	0	0.2	1
Inland marsh in water	0	0.2	1
Cultivated field. cereals. barley (Hordeum vulgare) for fodder	0	0.1	2
Cultivated field. cereals. barley (Hordeum vulgare) for malt	0	0.1	2
Cultivated field. cereals. cereal for silage	0	0.1	2
Cultivated field. cereals. mixed cereal	0	0.1	2
Cultivated field. cereals. oat (Avena sativa)	0	0.1	2
Cultivated field. cereals. other cereals	0	0.1	2
Cultivated field. cereals. spring rye (Secale cereale)	0	0.1	2
Cultivated field. cereals. spring wheat (Triticum aestivum)	0	0.1	2

Cultivated field. cereals. triticale (× Triticosecale)	0	0.1	2
Cultivated field. cereals. winter rye (Secale cerealse)	0	0.1	2
Cultivated field. cereals. winter spelt (Triticum spelta)	0	0.1	2
Cultivated field. cereals. winter wheat (Triticum aestivum)	0	0.1	2
Cultivated field. legume crops. pea (Pisum sativum) for fodder	0	0.1	2
Cultivated field. legume crops. pea (Pisum sativum). edible variety	0	0.1	2
Cultivated field. open field vegetables. pea (Pisum sativum)	0	0.1	2
Cultivated field. potato (Solanum tuberosum). certified seed potato production	0	0.1	2
Cultivated field. potato (Solanum tuberosum). edible varieties for industrial use	0	0.1	2
Cultivated field. potato (Solanum tuberosum). other edible varieties	0	0.1	2
Cultivated field. potato (Solanum tuberosum). other use	0	0.1	2
Cultivated field. potato (Solanum tuberosum). seed potato production	0	0.1	2
Cultivated field. potato (Solanum tuberosum). seed potato production of starch potato	0	0.1	2
Cultivated field. potato (Solanum tuberosum). starch potato	0	0.1	2
Cultivated field. special plants and uses. sweet corn (Zea mays var. rugosa)	0	0.1	2
Cultivated field. special plants and uses. reed canary grass (Phalaris arundinacea) (< 5 years)	0	0.1	2
Field plot register. agri-environment scheme special contract area. other area	0	0	2
Cultivated field. grassland field. certified seed production of meadow fescue (Festuca pratensis)	0	0	2
Cultivated field. grassland field. certified seed production of perennial ryegrass (Lolium perenne)	0	0	2
Cultivated field. grassland field. certified seed production of tall fescue (Festuca arundinacea)	0	0	2
Cultivated field. grassland field. certified seed production of timothy-grass (Phleum pratense)	0	0	2
Cultivated field	0	0	1
Cultivated field. grassland field. for lawn production	0	0	2
Cultivated field. potato (Solanum tuberosum). early varieties grown under mulch	0	0	2
Bog used for peat extraction	0	0	1
Built area. construction site	0	0	1
Built area. golf course	0	0	1
Built area. Hippodrome	0	0	1
Built area. industrial or commercial unit	0	0	1
Built area. other sport and leisure facility	0	0	1
Dump site	0	0	1
Lake	0	0	1
Mineral extraction site	0	0	1
River	0	0	1
Cultivated field. open field vegetables. asparagus (Asparagus officinalis)	0	0	2
Cultivated field. open field vegetables. broccoli (Brassica oleracea var. italica)	0	0	2
Cultivated field. open field vegetables. brussels sprout (Brassica oleracea var. gemmifera)	0	0	2
Cultivated field. open field vegetables. carrot (Daucus carota)	0	0	2
Cultivated field. open field vegetables. cauliflower (Brassica oleracea var. botrytis)	0	0	2
Cultivated field. open field vegetables. celeriac (Apium graveolens var. rapaceum)	0	0	2
Cultivated field. open field vegetables. crispy variety of lettuce (Lactuca sativa)	0	0	2
Cultivated field. open field vegetables. dill (Anethum graveolens)	0	0	2
Cultivated field. open field vegetables. garlic (Allium sativum)	0	0	2
Cultivated field. open field vegetables. napa cabbage (Brassica rapa subsp. pekinensis)	0	0	2
Cultivated field. open field vegetables. onion (Allium cepa)	0	0	2
Cultivated field. open field vegetables. other vegetables	0	0	2
Cultivated field. open field vegetables. parsley (Petroselinum hortense)	0	0	2
Cultivated field. open field vegetables. parsnip (Pastinaca sativa)	0	0	2
Cultivated field. open field vegetables. red beet (Beta vulgaris var. rubra)	0	0	2
Cultivated field. open field vegetables. red cabbage (Brassica oleracea var. capitata f. rubra)	0	0	2
Cultivated field. open field vegetables. rhubarb (Rheum rhabarbarum)	0	0	2
Cultivated field. open field vegetables. savoy cabbage (Brassica oleracea var. sabauda)	0	0	2
Cultivated field. open field vegetables. soft-leaved variety of lettuce (Lactuca sativa)	0	0	2
Cultivated field. open field vegetables. spinach (Spinacia oleracea)	0	0	2
Cultivated field. open field vegetables. turnip (Brassica napus ssp. rapifera)	0	0	2
Cultivated field. open field vegetables. white cabbage (Brassica oleracea var. capitata)	0	0	2
Cultivated field. open field vegetables. white turnip (Brassica rapa var. rapa)	0	0	2
Cultivated field. open field vegetables. zucchini (Cucurbita pepo)	0	0	2
Cultivated field. special plants and uses. Greenhouse	0	0	2
Cultivated field. special plants and uses. other fodder crops (e.g. Brassica napus)	0	0	2
Cultivated field. special plants and uses. root crops and cabbage (Brassica oleracea) for fodder	0	0	2
Cultivated field. special plants and uses. sugar beet (Beta vulgaris var. altissima)	0	0	2

Ecosystems are critically important to our well-being and prosperity as they provide us with food, clean air or fresh water and they maintain a livable biosphere. Consequently, ecosystem services are increasingly considered as crucial argument to support decision making in policies that affect the use or the state of natural resources. In particular, new biodiversity policies, which have been adopted at global and EU scales, have set targets to safeguard biodiversity as well as to maintain the supply of ecosystem services. Achieving biodiversity targets requires demonstrating that changes in policies affecting natural resources are beneficial to human well-being through the enhanced flow of ecosystem services. It also requires prioritizing investments and making them cost-effective based on a sound knowledge base and assessment methods. This study has contributed case studies to help exploring how such assessments might be developed at multiple spatial scale, in particular for pollination, recreation and water purification. The spatial assessment of these ecosystem services included maps displaying the potential and actual supply of these services in both biophysical and monetary units. Scenarios were used to estimate changes in the flow of ecosystem services and to estimate benefits that arise from policy changes. Our approaches show that the inclusion of the ecosystem services concept into policies would allow a systematic review of the consequences of policy measures for services beyond conventional environmental assessments.

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