Benefits of increased data resolution for European conservation planning

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Preface

This study contributes to the EU project "Global Earth Observation – Benefit Estimation: Now, Next and Emerging" (GEOBENE). Its objective is to develop methodologies and analytical tools to assess societal benefits of global earth observation. The project encompasses the domains of disasters, health, energy, climate, water, weather, ecosystems, agriculture, and biodiversity.

The Group on Earth Observation assumes that global earth observations are instrumental to achieve sustainable development. However, there have been no integrated assessments of their economic, social and environmental benefits to date.

The vision is to develop a high quality, timely, and comprehensive Global Earth Observation System of Systems (GEOSS). This includes a global biodiversity observation system that fulfills the data needs of the multilateral environmental agreements, governments, natural resource planners, scientific researchers and civil society, and integrates with ecological, agriculture, health, disaster, and climate monitoring policy.
A GEOSS biodiversity observation system would create a mechanism to integrate biodiversity data with other observations more effectively, leverage investments in local and national research and observation projects and networks for global analysis and modelling. It will build on existing efforts in order to collectively provide essential data and models for monitoring and reporting in the framework of the biodiversity-related conventions, and provide new information and tools for biodiversity research (Group on Earth Observations 2005).

This study contributes to the societal benefit area biodiversity and consists of two sub-studies. Part A deals with the modelling of explicit wetland habitat area for the European Union 25 countries. Part B shows how the implementation of these habitat area data influences the results of a habitat allocation model.

A Estimation of spatially explicit wetland distribution

Introduction

In Europe, the spatial distribution of wetlands is not well known except for large wetland areas or for wetlands of special ecological interest. Even those wetland areas, which have been identified on the behalf of European Environment Agency (EEA), correspond to wetland areas of ecological interest and represent only a rather small part of all wetland areas. This study deals with the development of the GIS-based wetland distribution model “Swedi”. By considering the matrix characteristics the model evaluates the spatially explicit distribution of existing wetland habitats and potential restoration sites. It simultaneously distinguishes different wetland types. The aim of this study is to compile spatially consistent information on wetlands differentiated by wetland types and characteristics, but initially regardless of their conservation status or restoration costs.

Definition of wetlands

Often wetland terms and definitions are not standardized. The RAMSAR Convention (Article 1.1) defines wetlands as "areas of marsh, fen, peat land or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters". In addition, the Convention (Article 2.1) determines that wetlands "may incorporate riparian and coastal zones adjacent to the wetlands". In wetlands water is present at or near the surface of the land also if only for varying periods of the year. Wetlands vary widely in soil, topography, climate, hydrology, water chemistry, vegetation, and other factors, also because of human disturbance. In our study we concentrate on the natural freshwater or inland wetlands as defined in table 1.

The definition of inland wetlands also includes marshes and wet meadows dominated by herbaceous plants that are most often human made as well as shrub- or tree-dominated swamps. In Europe, inland wetlands are most common on floodplains along rivers and streams, along the margins of lakes and ponds, and in other low-lying areas where the groundwater intercepts the soil surface or where precipitation sufficiently saturates the soil (vernal pools and bogs). Many of these wetlands are seasonal and may be wet only periodically.

Table 1. Wetland terms and their definitions

Common Wetland Names	Definition
Peatland	generic term of any wetland that accumulates partially decayed plant matter.
Bog	peat-accumulating wetland that has no significant inflows or outflows. Water and nutrient input entirely through precipitation; characterized by acid water, low alkalinity, and low nutrients. Peat accumulation usually dominated by acidophilic mosses, particularly sphagnum.
Fen	peat-accumulating wetland that receives some drainage from surrounding mineral soil. Usually dominated by sedge, reed (→reedswamp), shrub or forest (→swampforest). Surface runoff and/or ground water have neutral pH and moderate to high nutrients.
Marsh/ natural wet grasslands	permanently or periodically inundated site characterized by nutrient-rich water and emergent herbaceous vegetation (grasses, sedges, reed) adapted to saturated soil conditions. In European terminology a marsh has a mineral soil substrate and does not accumulate peat.
Reedswamp	marsh or fen dominated by Phragmites (common reed);
Swampforest	wetland dominated by trees, most often forested fen. Depends on nutrient-rich ground water derived from mineral soils.
Alluvial forest	Periodically inundated forest areas next to river courses.

Methods

GIS and spatial modelling are assumed to provide an appropriate tool to locate potential existing wetland areas as well as to illustrate the most suitable areas for wetland regeneration measures. This GIS model aims to depict the distribution of wetland areas at regional level and at coarse geographic scale. This involves the integration of a variety of GIS datasets and multiple iterations of expert review and interpretation to delineate the potential wetland areas of Europe. We used the GIS tool ArcGIS9 for analysis. Figure 1 gives an overview of the Swedi (Spatial wetland distribution) model structure and its core input data.

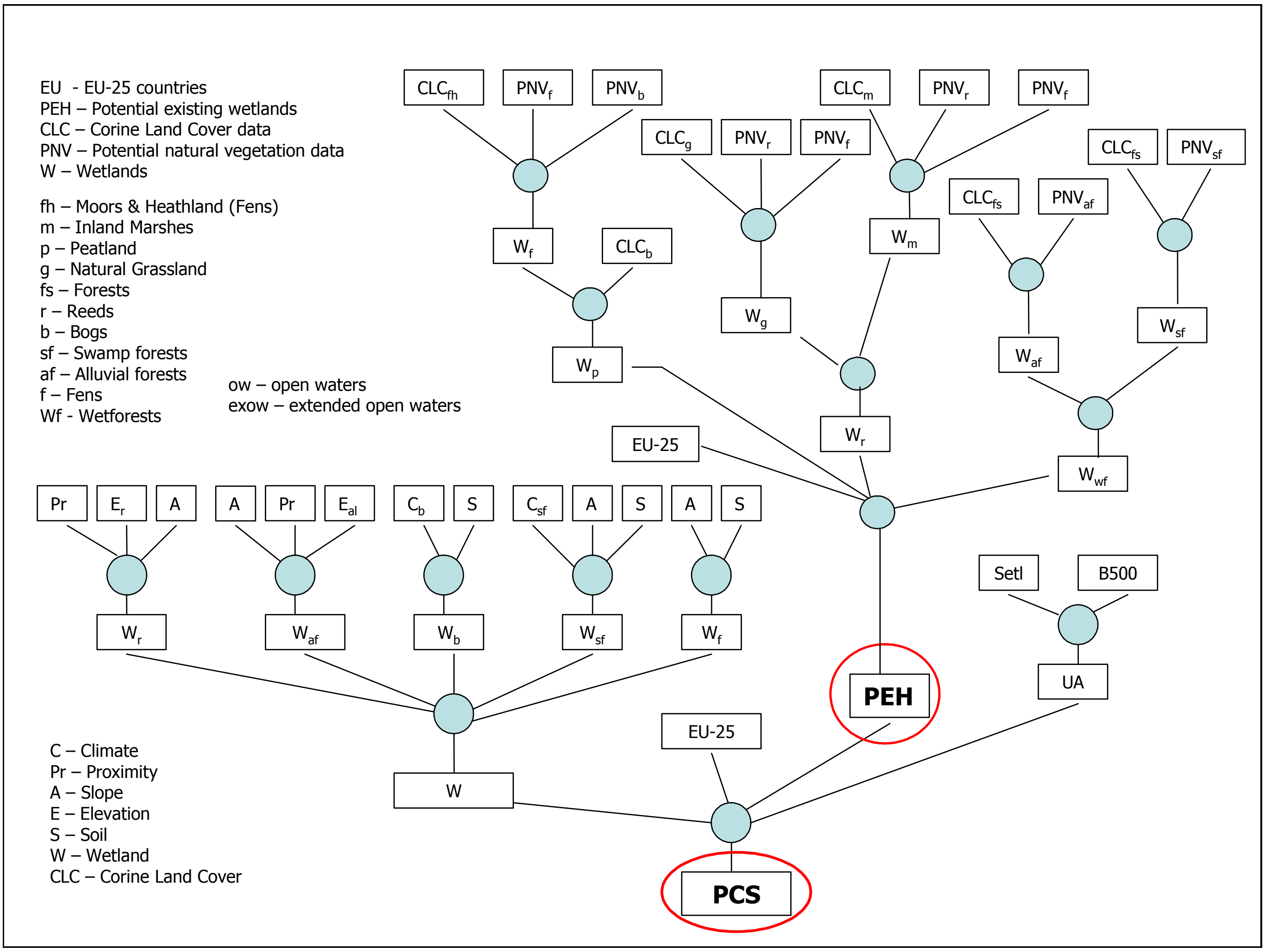

Fig. 1. The spatial wetland distribution model “Swedi”

Results

The results of the Swedi model are illustrated through wetland distribution maps. It is possible to produce the potential existing habitats at spatial resolution of one hectare and the potential convertible sites at 1 km² grid for the EU-25 states excluding the islands Malta and Cyprus. Figure 2 shows the spatial distribution of potential existing habitats and potential convertible sites.

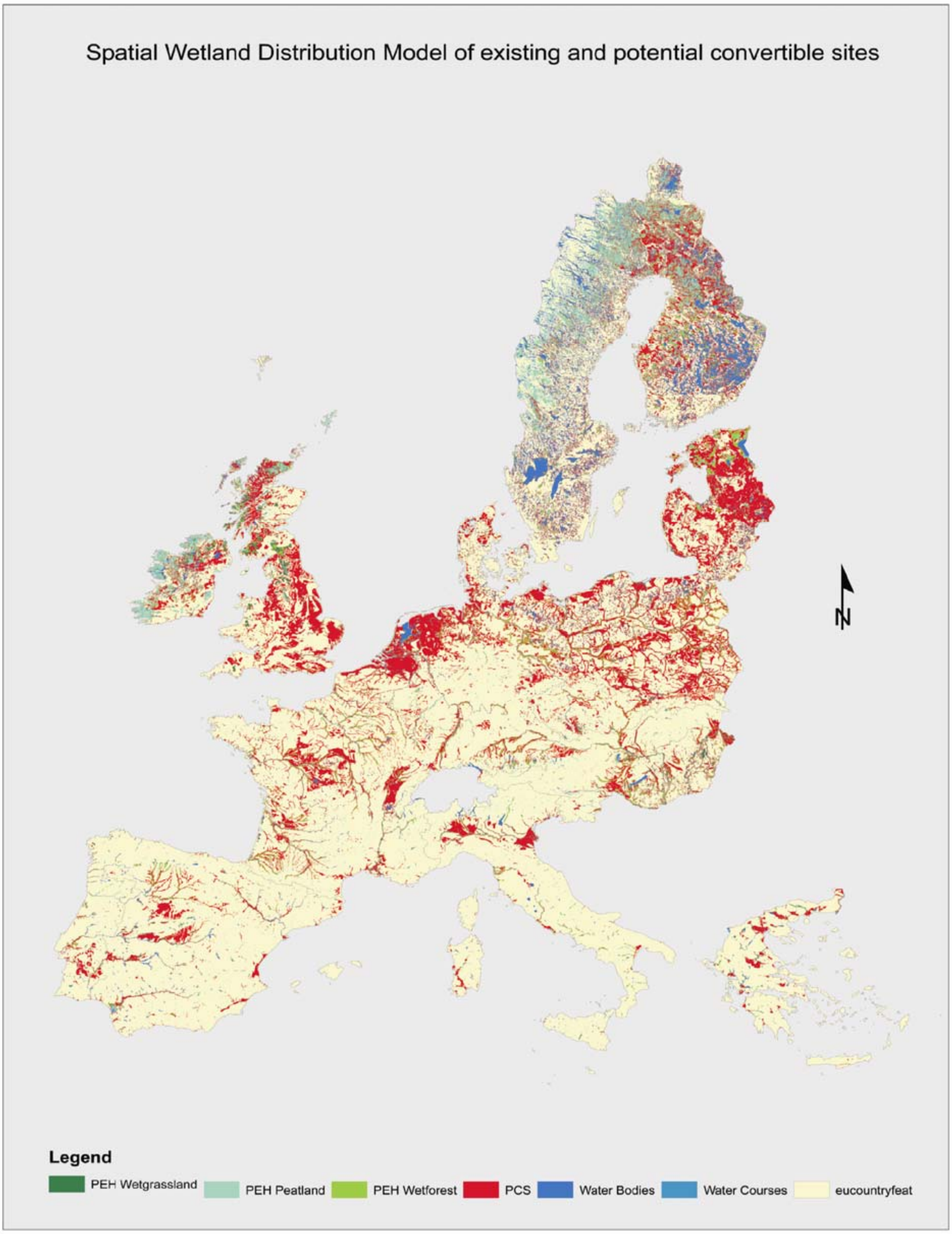

Fig. 2. Map of the spatial distribution of existing habitats and potential wetland restoration sites

Figure 3 gives an overview of the total area (in 1 000 ha) of potential existing and the potential convertible wetland sites per country. Open waters are excluded from the evaluation. Finland and Sweden own by far the most extending existing wetland areas with about 3.8 million ha wetlands. Also Ireland has great amounts of existing wetland areas (about 1.3 million hectares) but less in comparison to the Scandinavian countries. Finland and Sweden also lead in the amount of potential convertible wetland sites. In this category Poland, Great Britain as well as France and to a certain extent Germany as well show high amounts of land suitable for wetland restoration.

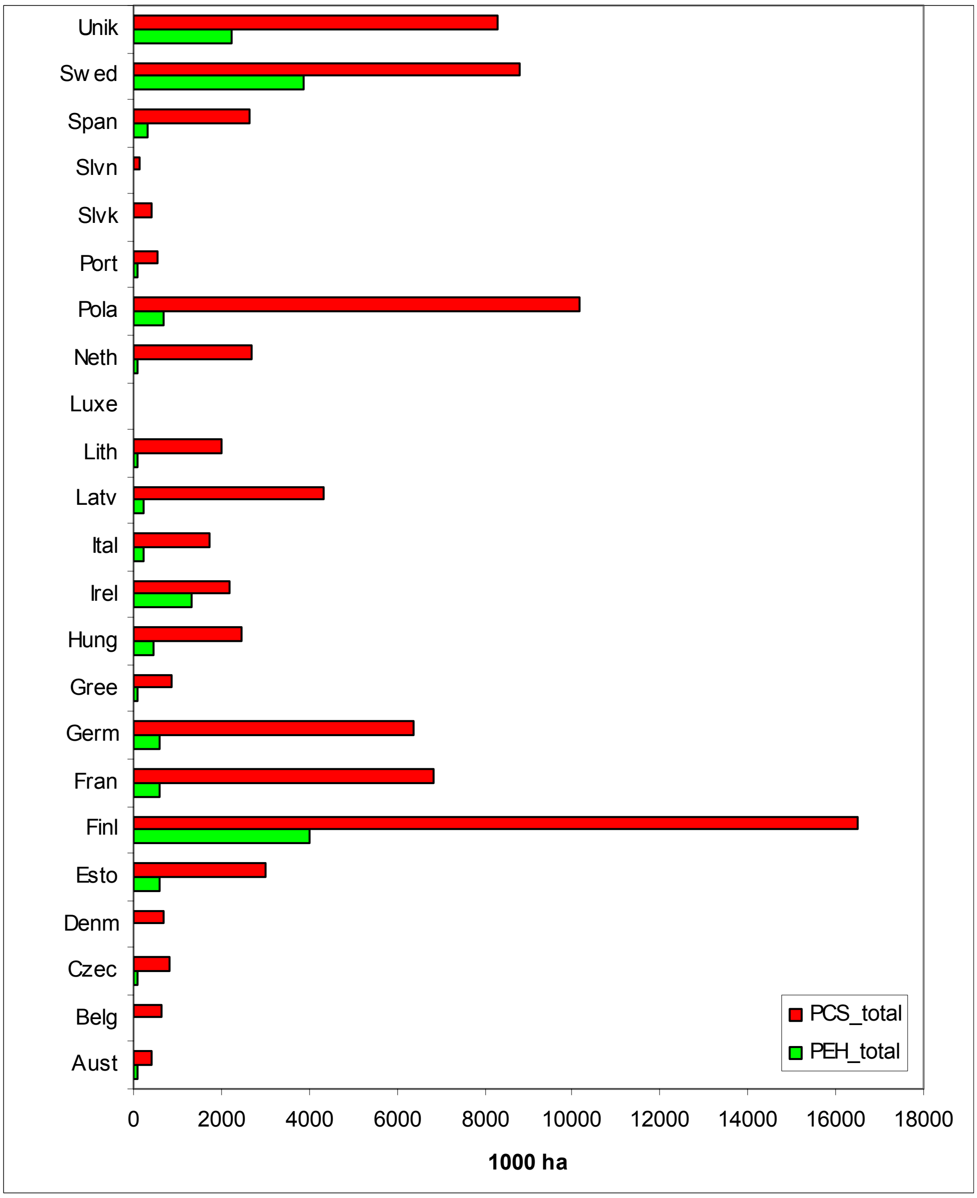

Fig. 3. Total wetland area (in 1000 ha) per country

If we now look at the relationship between wetland areas and country size (see Figure 4) we get a different picture: Now Ireland shows the highest wetland rate (PEH) with about 19% of its country area, followed by Estonia (13%) and Finland (12%). Concerning the PCS per country area, Latvia (68%), the Netherlands (75.6%), and Estonia (66%) have the highest relative potentials. The PCS rate of Finland, Poland, Great Britain, and Ireland amounts to between 31 and 49% per country area. In this case Denmark, Sweden and Germany have potentials of about 16 to 20% and the PCS rate of all other countries amount between 5.1% as lowest rate in Austria and 12.5% in France.

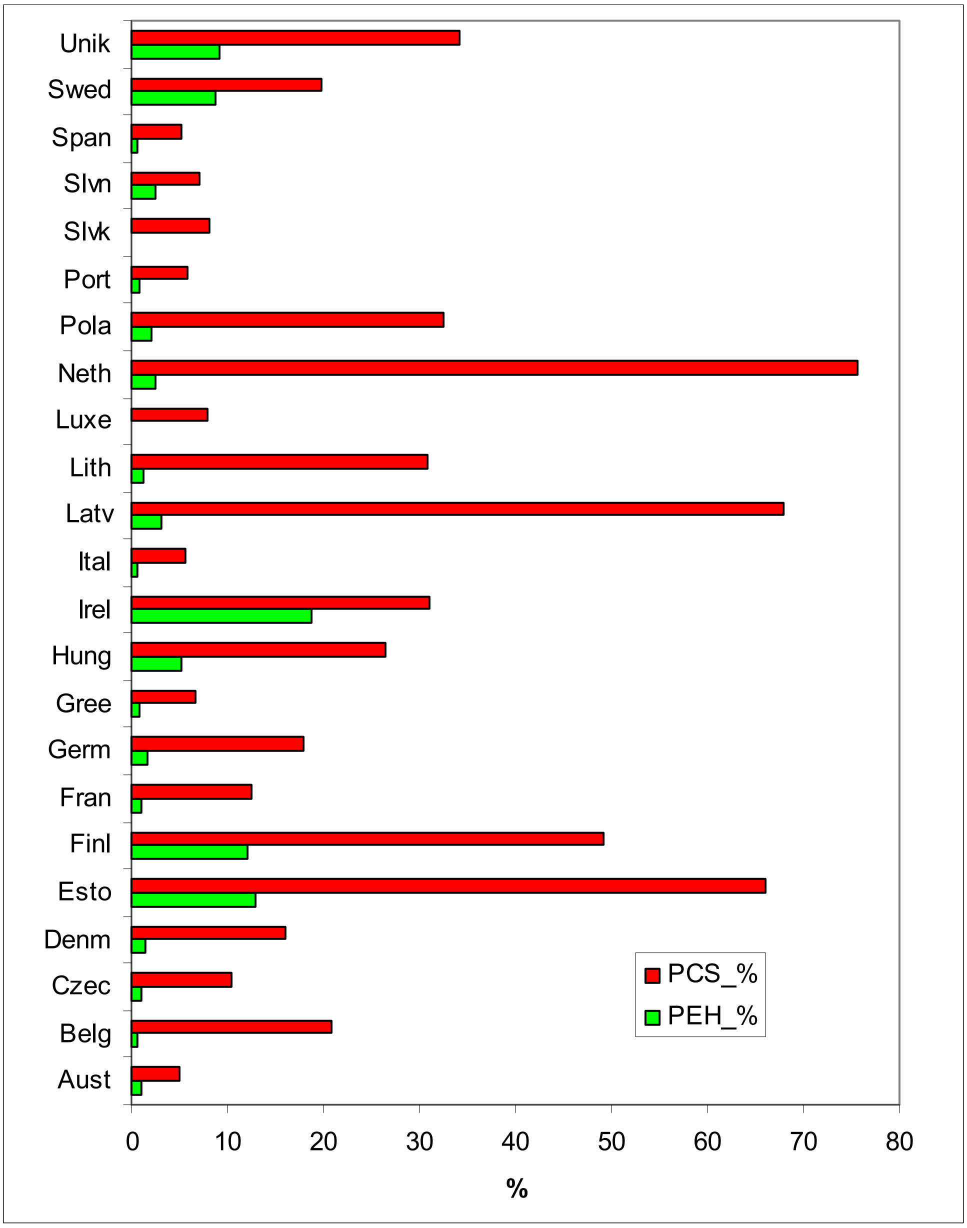

Fig. 4. Relation between country size and wetland area (%)

Discussion

Despite numerous data on land use in Europe, a detailed analysis of the distribution of wetlands and potential restoration sites has been lacking so far. There is a growing demand of policy makers and researchers for high-accuracy landscape information at the European level. We developed a detailed wetland distribution map in European scale with high spatial resolution. Not only does it distinguish between different wetland types but also between potential existing and potential convertible wetland sites. Whereas the evaluation of existing wetlands relies on a cross-compilation of existing spatial datasets, the potential wetland restoration sites are determined by definition of flexible knowledge rules in combination with geographical data. The orientation towards physical parameters and the allowance of overlapping wetland types characterizes the Swedi model. The detailed spatially explicit wetland classification of the Swedi model allows connections to other habitat databases, for example EUNIS, as well.

The accuracy of the Swedi model is strongly restricted by the availability and quality of geographical data. For example, the soil information is generally poor and often misleading from the standpoint of wetland functionality. Another uncertainty is the state of the ecosystem of the PEH. In Swedi we are not able to make statements about the naturalness of the site. Nevertheless, the validation with independent datasets of wetland biotopes proved high accuracy of the existing wetland sites in the Swedi model and the area sizes are mainly reproduced within the uncertainty range. The utilization of GIS makes the methodology applicable and easily to improve concerning data sources.

The knowledge of the extent and distribution of wetlands is important for a variety of applications. It is of utmost importance to provide accurate base data for the management and planning of conservation areas. This study applies an empirical distribution model to wetland ecosystems in European scale. The Swedi model on the other hand is meant to be integrated into the economic optimization EUFASOM model (Schneider et al. 2008) to evaluate the economic wetland potentials per EU-country (Schleupner & Schneider 2008a); furthermore it is going to be the base for biodiversity studies of endangered wetland species (see below) and is used as basis for a cost-effective spatial wetland site-selection model (cf. Schleupner & Schneider 2008b).

B Impact of spatially explicit wetland data on results of a habitat allocation model

Introduction

On the densely populated European continent, competition for land is high. Agricultural and forestry land use lead to habitat loss, degradation, and fragmentation. These are the most important threat factors for biodiversity.

Considering land scarcity and demand for alternative uses, efficiency in biodiversity conservation strongly depends on the efficiency in land allocation. Systematic conservation planning provides tools to identify optimally located priority areas for conservation (Margules and Pressey 2000, Possingham et al. 2000).

The applied model allocates species habitats by minimizing the costs for setting aside land for conservation purposes. We compare two different versions of the model. In the non-GEOSS version there are no restrictions on the available habitat area per planning unit, in the GEOSS version we include explicit modelled wetland habitat data.

Methods

We employ a deterministic, spatially explicit mathematical optimization model programmed in General Algebraic Modelling System (GAMS). It is solved with mixed integer programming.

We apply the minimum set problem from systematic conservation planning. Its objective is to minimize resources expended, subject to the constraint that all biodiversity features meet their conservation objectives (Possingham et al. 2000, McDonnell et al. 2002). Conservation objectives account for the two principal conditions of systematic conservation planning: representation and persistence of the biodiversity features (Margules & Pressey 2000, Sarkar et al. 2006).

The objective function minimizes opportunity cost. Opportunity costs are treated exogenously, they do not change during the model runs. The cost minimization is subject to ecological and spatial constraints. Ecological restrictions ensure that each biodiversity feature reaches a given representation target, meets its area requirements for viable populations, and is allocated to its necessary habitat types. Spatial restrictions ensure that the available habitat areas per planning unit is not exceeded and consider the spatial arrangement of the planning units.

The model is applied to European wetland species. 69 wetland vertebrate species of European conservation concern serve as surrogates for biodiversity. Vertebrate species are common surrogates for biodiversity as there are good occurrence data available and they usually have greater area demands than invertebrates, plant species, and even most ecosystems. The species are derived from the two European directives in relation to wildlife and nature conservation: the Birds and the Habitats Directive (79/409/EEC, 92/43/EEC).

As input to the model we use three types of data where the spatial resolution is of relevance:

- species occurrence data
- habitat areas
- land opportunity costs

Species occurrence data have a resolution of about 50 x 50 km (atlas data originate from Gasc et al. 1997, Hagemeijer and Blair 1997, Mitchell-Jones et al. 1999). The model is based on planning units derived from the species occurrence data. Spatially, the model encompasses the European Union 25, resulting in 2016 planning units.

For the habitat areas, two different procedures are applied. In the non-GEOSS version there are no restrictions on the available habitat area per planning unit, whereas in the GEOSS version we include explicit modelled high resolution wetland habitat data (see report chapter A).

Land opportunity costs differ between countries (agricultural land costs are derived from Eurostat and Farm Accountancy Data Network (FADN) data). For a detailed description of model and input data see Jantke & Schneider (2008).

Results

The model is solved for representation targets 1 to 10 and the two different versions of representing habitat area data. Figure 1 and 2 show the area allocation to the wetland habitat types as well as the total area from model runs with 69 species. The area is shown in million hectares for representation targets from 1 to 10. Each representation targets ensures that each species has enough land on required habitat types to form at least one viable populations in locations where it actually occurs.

Implementation of detailed habitat area data in the GEOSS-version increases the total area and leads to substantial differences in the habitat type shares. A further habitat type had to be introduced in that version which is important especially for area-demanding species that could otherwise not be represented adequately.

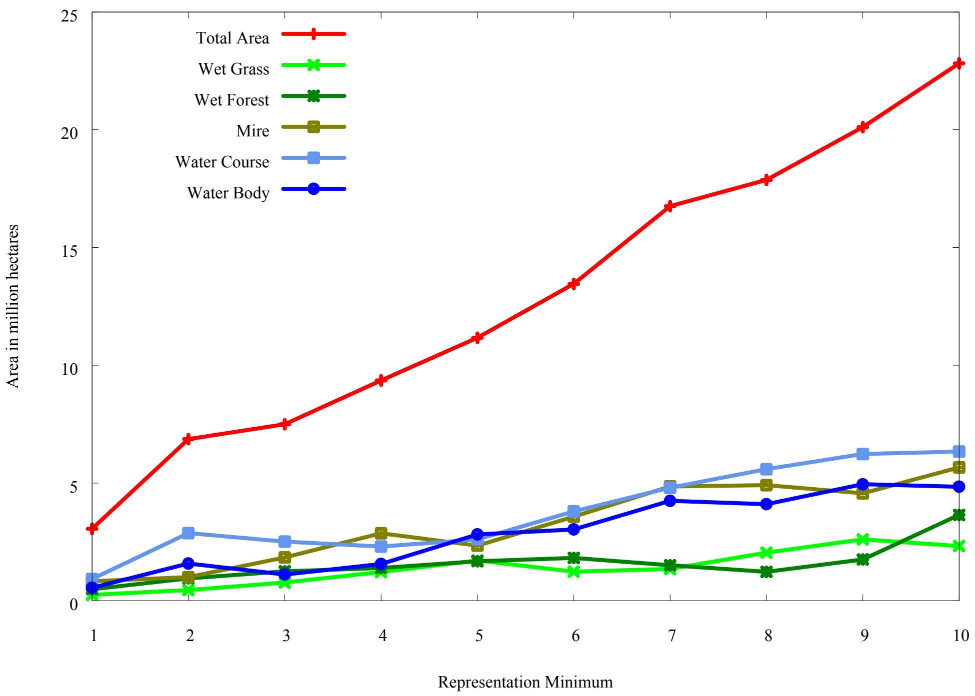

Figure 1: Habitat allocation to habitat types: non-GEOSS version

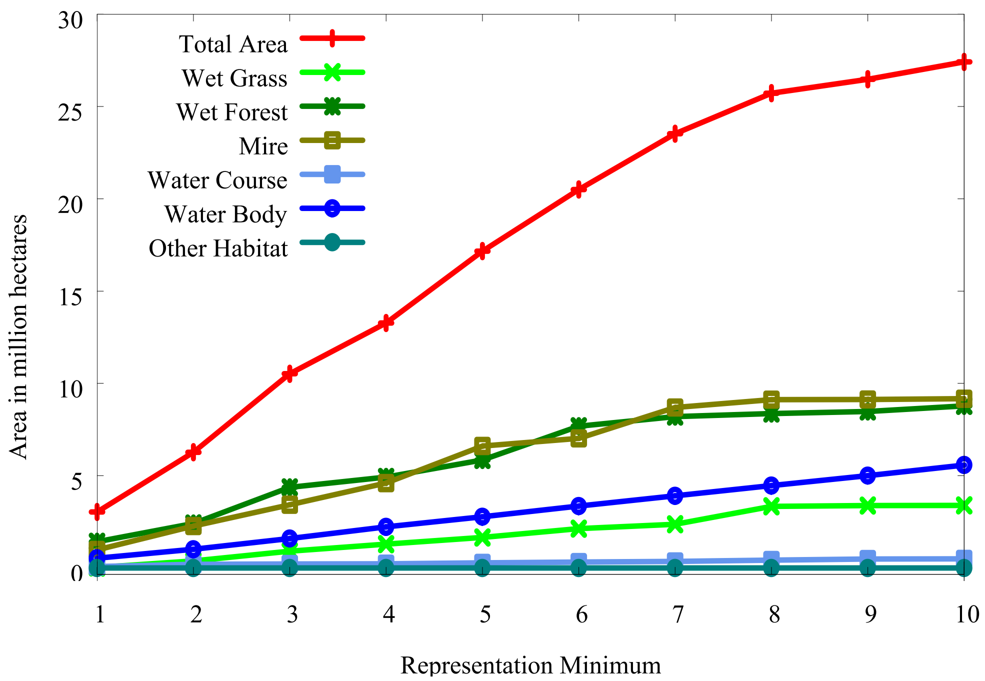

Figure 2: Habitat allocation to habitat types: GEOSS version

Figure 3 displays the opportunity costs for achieving the land needed for habitat protection. The non-GEOSS model version underestimates the costs substantially.

Figures 4 and 5 show the allocation of the total habitat area to the European Union 25 countries. In both versions, most of the habitat is allocated to the five countries Latvia, Lithuania, Estonia, Poland, and Slovenia. The non-GEOSS model version overestimates the available habitat area in Latvia, Lithuania and Estonia. To reach the conservation objectives, the GEOSS version allocates more habitat area in Poland.

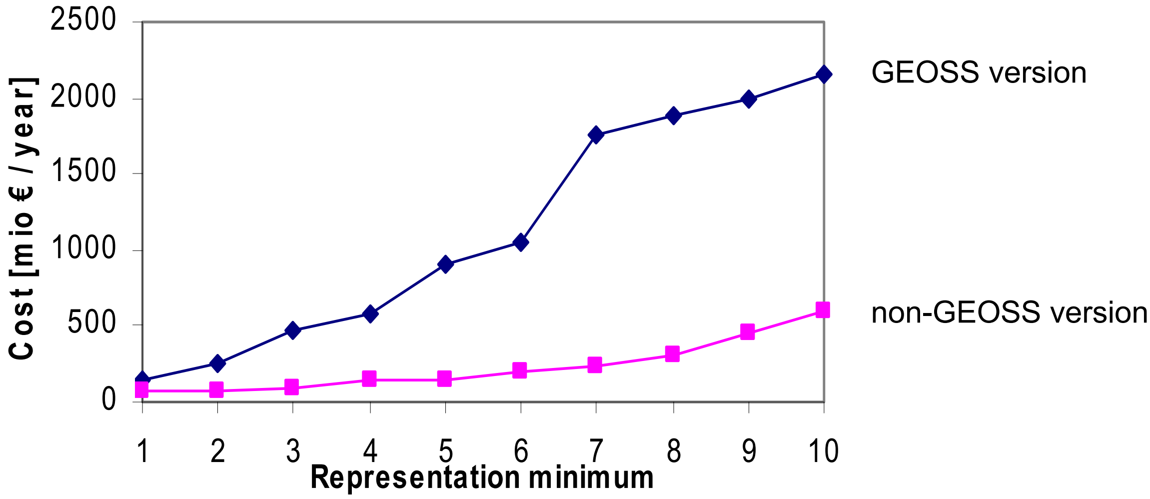

Figure 3: Opportunity costs of habitat protection

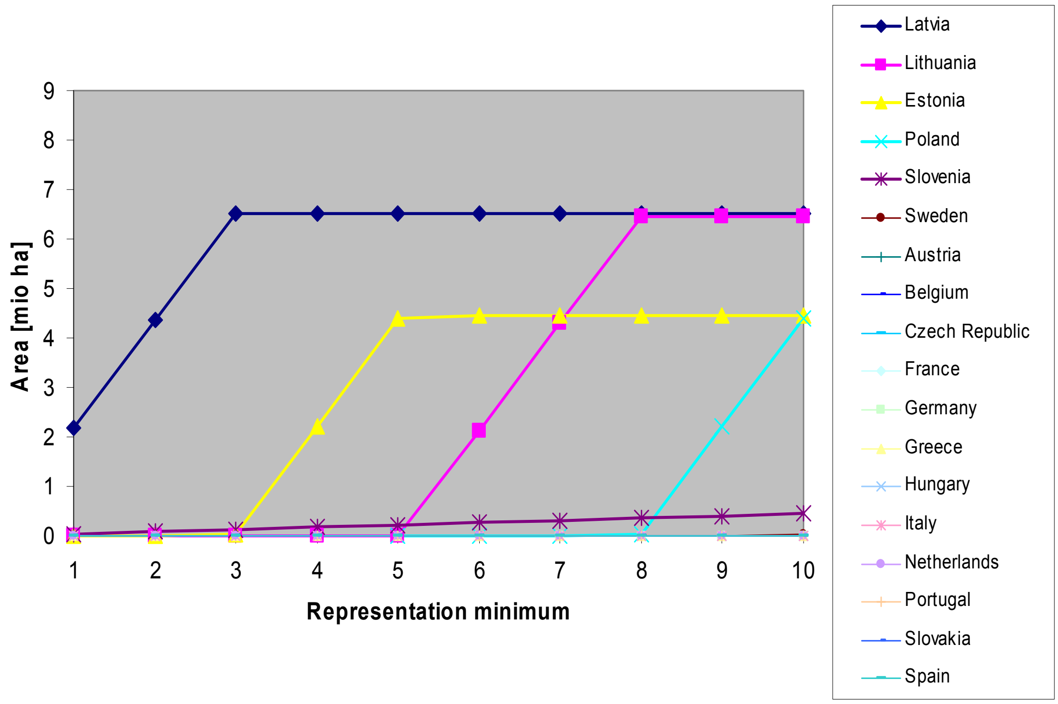

Figure 4: Allocation of habitats to EU25 countries: non-GEOSS version

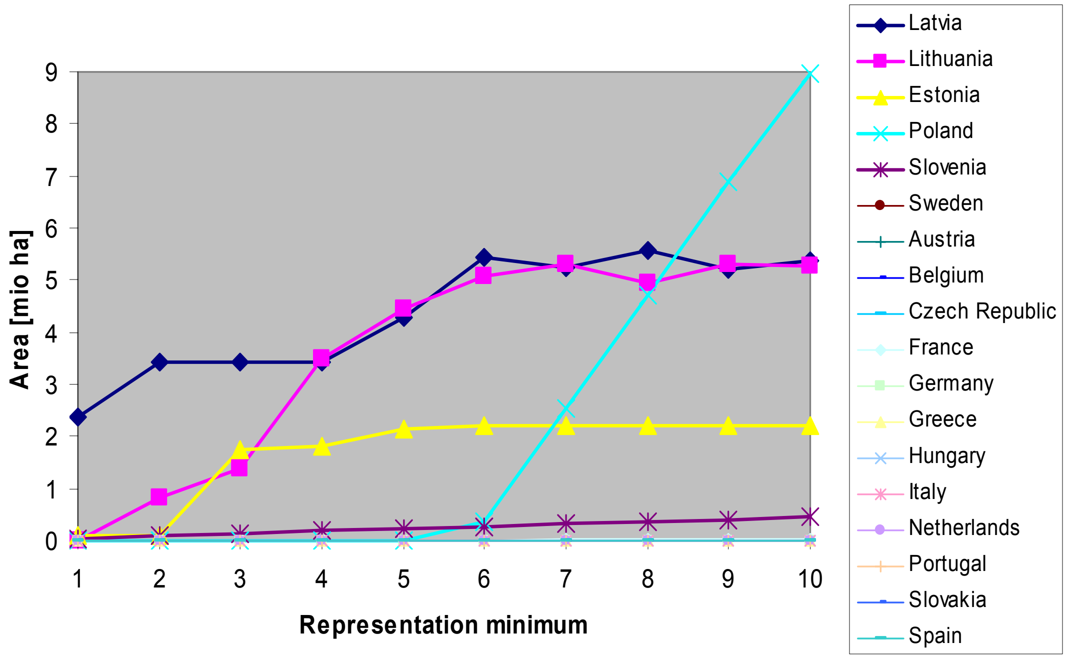

Figure 5: Allocation of habitats to EU25 countries: GEOSS version

Conclusions and Outlook

Conservation planning tools benefit from the integration of high resolution habitat area data. They enable more reliable estimations on area requirements, habitat shares and the opportunity costs of habitat protection. Especially the costs of habitat protection were severely underestimated in our non-GEOSS model version.

We plan to implement opportunity costs on homogenous response units (HRU) (see Skalský et al. 2007 for details) level which will further improve the model accuracy.

Comprehensive species occurrence data with a higher resolution are not available for the spatial scope of the model. Downscaling would therefore be an option to work on smaller scales (see Araujo et al. (2005) for an example on European atlas data).

The spatial wetland distribution model is going to be extended to whole Europe.

Acknowledgements

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