Evaluation of European wetland restoration potentials by considering economic costs under different policy options

Christine Schleupner, Uwe A. Schneider
Research Unit Sustainability and Global Change,Hamburg University & ZMAW, Bundesstr. 55, Hamburg
christine.schleupner@zmaw.de

Introduction

This study focuses on inland freshwater wetlands of Europe. While fens and floodplain forests have been drained and cleared since the early Middle Ages, the main decrease in wetlands happened over the last century and is still continuing (RAMSAR COMMISSION). Ongoing drainage, conversion, pollution, and over-exploitation of the wetland resources make them to be among the world's most threatened ecosystems (JOOSTEN & CLARKE 2002). The last decades have seen increasing interest not only in wetland conservation but also in the restoration of wetlands. Restoration and conservation management are increasingly viewed as complementary activities and restoration measures are therefore often included in conservation management (YOUNG 2000; HOBBS 2005; MANNING 2007). Many existing reserves in highly modified human cultural landscapes are too small or too isolated to provide for the full biodiversity benefits. It is therefore necessary to acquire additional land with habitat value or restoration potential (MILLER 2007). Europe is densely populated in some parts and without protection and management, agricultural and forest demands would leave space for nature conservation in marginal areas only. Counteracting these problems, several directives at EU-level were established to safeguard biodiversity and valuable natural biotopes. For example, under the *Habitats Directive* (1992) the European member states are required to identify and designate Special Protection Areas which are important habitats for the protection of species covered by the directive. Within this directive wetland habitats receive a special status.

In this study we use wetland *restoration* as generic term. This includes not only an improvement in degraded wetlands, but also *re-creation* on sites where similar habitat formerly occurred as well as wetland *creation* in areas where wetlands are established for the first time - within historical time span (MORRIS ET AL. 2006).

Over the last decade, rising political demand for bioenergy in the context of climate change mitigation policies has posed an additional obstacle to ecosystem preservation and restoration. NILSSON ET AL. (2007), for example, found very large bioenergy resource potentials for Poland. Bioenergy demands increase the value of land and thus, increase the opportunity costs for protected nature areas. As land rents rise, designing space and property for nature conservation has grown to a critical economic and social issue without ignoring production land uses. Protected areas cannot be sustained in isolation from the economic activities in and around them. It is of importance that humans are considered as part of the environment and not only as the underlying problem (LINDENMAYER & HOBBS 2007). Socio-economic considerations and temporal restrictions limit the realization of a chosen restoration goal for a certain wetland or parts thereof. The evaluation of the socio-political interests also includes cost analyses, because all conservation and restoration options incur costs. However, costs have not received much consideration in designs aimed at expanding reserve networks in broader scales (NEWBURN ET AL. 2005).

The principle in the presented study is to optimize different land uses to allow for the persistence and reintroduction of ecosystems by considering bio-geophysical as well as socio-economic factors. This way we can demonstrate the tradeoffs between obtaining higher levels of a conservation target and the increase in cost necessary to obtain it. An important research question is also the potential influence of biomass supply on wetland restoration efforts. The analysis of this study has been executed in European scale by using the EU-25 countries, because conservation planning at broad scales can help to identify areas or regions in which the payoff for conservation efforts is likely to be greatest (WIENS 2007). So far conservationists have mainly focused on finer scales. But there are increasing requests among scientists for embracing and engaging conservation planning at broader spatial scales to obtain a holistic view of the landscape (FRANKLIN & SWANSON 2007; SCOTT & TEAR 2007; WIENS 2007). It is recommended more and more often that the scale of the goals and objectives must also match the scale of the challenge. This implies that a good deal of conservation action must be directed at the scale of land use and of socio-political interests.

Methodology

The Spatial Wetland Distribution (SWEDI) model

Before evaluating the economic wetland potentials the total wetland area per country needs to be determined. Because of missing base data a methodology to identify wetland distributions including their area potentials has been developed for this study. This resulted in the SWEDI model (SCHLEUPNER 2007). The SWEDI model estimates the spatial distribution of European wetlands by distinguishing between existing wetlands and wetland restoration sites. Five wetland types (bog, fen, alluvial forest, swamp forest, wet grassland) are differentiated. SWEDI is a GIS-based model that relies on multiple spatial relationships. It covers the whole EU-25 area excluding Malta and Cyprus at resolution of 1 km². Geographical and physical borders of different wetland types are well reproduced by the SWEDI model as an accuracy assessment with RAMSAR data on selected wetland sites revealed.

The model also differentiates between six wetland size classes, and assesses the restoration success of a potential wetland restoration site after area quality and potential natural wetland vegetation (cf. SCHLEUPNER & SCHNEIDER 2008). The results of the SWEDI model were aggregated to country level by maintaining their accuracy in details. Table 1 documents its outcome concerning the wetland types. Wetland types of the wetland restoration sites are allowed to overlap because often the wetland type depends on the successional vegetation state and build biotope complexes. A clear separation is neither useful nor tenable in these cases.

In all EU-25 countries, the total restoration potentials amount to 82.5 mio ha and by far dominate the existing wetland areas of about 15.7 mio ha. In Ireland the share of potential existing to the total wetland potential (existing wetlands + restoration sites) is with 26% highest, whereas most countries only show marginal existing wetland areas in comparison to their potentials.

Table 1 Country aggregated SWEDI data (in 1 000 ha).

a. Existing wetland areas per wetland type and country

Country	Peatland	Wetforest	Wet-Grassl.	total
Aust	29.65	66.15	0.68	96.48
Belg	11.72	9.90	0.25	21.88
Czec	8.25	77.11	0.39	85.75
Denm	51.40	9.90	2.58	63.88
Esto	186.91	393.56	6.49	586.96
Finl	2 231.91	1 760.87	0	3 992.79
Fran	82.51	492.74	8.81	584.07
Germ	136.28	455.36	13.74	605.38
Gree	25.06	45.39	36.80	107.26
Hung	100.68	299.46	78.14	478.28
Irel	1 162.17	124.01	30.62	1 316.80
Ital	18.62	179.67	18.48	216.77
Latv	152.09	55.02	0.15	207.25
Lith	56.29	22.04	0	78.33
Luxe	0	97	0	0.10
Neth	33.77	47.88	10.85	92.50
Pola	106.98	563.85	0.15	670.97
Port	9.79	57.50	8.36	75.64
Slvn	8.55	5.99	0.06	14.59
Slvk	4.59	46.33	0.97	51.88
Span	66.60	164.75	65.24	296.59
Swed	2 937.68	934.11	5.15	3 876.93
UK	1 423.72	354.26	470.62	2 248.60
total	**8 845.22**	**6 262.85**	**2 080.21**	**15 769.68**

b. Wetland restoration sites per wetland type and country (in 1 000 ha)

Country	Peatland	Wetforest	Wetgrassl.	total
Aust	301.04	196.89	175.31	425.23
Belg	539.48	541.23	118.55	632.74
Czec	596.92	587.05	313.29	819.20
Denm	409.19	414.08	281.20	689.15
Esto	2 682.17	58.21	1 223.29	3001.56
Finl	8 569.11	339.77	12 448.27	16 474.34
Fran	5 118.12	2 939.47	2 241.04	6 836.74
Germ	4 203.85	4 398.47	2 494.23	6 383.74
Gree	797.47	105.75	175.56	886.31
Hung	1 087.72	1 212.59	16 679.25	2 470.16
Irel	1 386.53	406.99	1 229.42	2 171.43
Ital	1 278.66	277.71	558.31	1 720.42
Latv	3 984.41	912.29	891.84	4 350.08
Lith	1 452.77	945.56	674.07	2 005.32
Luxe	17.97	18.81	1.09	24.08
Neth	2 437.53	2 540.10	457.96	2 683.82
Pola	7 850.70	7 863.86	3 333.67	10 154.42
Port	374.42	60.37	159.57	535.73
Slvk	318.26	338.07	182.80	395.79
Slvn	114.13	90.25	38.51	143.18
Span	2 165.02	201.34	660.94	2 659.48
Swed	1 093.35	368.73	8 339.62	8 796.84
Unik	7 362.83	4 783.36	1 274.12	8 294.67
total	**54 141.64**	**29600.89**	**53 951.91**	**82 554.44**

EUFASOM Scenarios

We used the European Forest and Agricultural Sector Optimization Model (EUFASOM) (SCHNEIDER ET AL. 2008) to compute the competitive economic potential of wetlands. EUFASOM is a dynamic, partial equilibrium model of the European Agricultural and Forestry sector, which has been developed to analyze economic and environmental impacts of changing policies, technologies, resources, and markets (SCHNEIDER ET AL. 2008). Land management choices link land, labour, water, forests, animal herds, and other resources to food, fibre, timber, and bioenergy production and their markets. The land management choices include explicitly all major arable and dedicated energy crops, all major livestock categories, more than twenty tree species and forest types, and alternative management systems regarding soil tillage, irrigation, crop fertilization, animal feeding and manure management, and forest thinning.

The geographically explicit resolution of EUFASOM involves member states within EU-25 plus eleven international regions which cover the entire earth. For each EU member state, additional spatial variation can be integrated implicitly via area shares. These differences include a) natural variations pertaining to altitude, soil texture, and slope, b) variations in the state of land and forests pertaining to soil organic carbon levels, forest type, and forest age and c) variations in enterprise structure pertaining to farm size and farming type. However, current computational restrictions do not allow a simultaneous representation of all the above listed differences. The temporal resolution of EUFASOM comprises 5-year periods starting with the 2005-2010 period and terminating anywhere between 2005-2010 and 2145-2150. Exogenous data on state and endowment of resources, land management options and processing technologies, commodity demand, and policies can be adjusted for each period to reflect different development scenarios.

EUFASOM is a large mathematical programming model, which maximizes the discounted sum across regions and time periods of consumer surplus from all final commodity markets plus producer surplus from all price-endogenous resources minus costs for production and commodity trade plus terminal values of standing forests plus benefits from subsidies minus costs from taxes. Restrictions depict resource qualities and endowments, technical efficiencies, crop rotation constraints, environmental impact accounts, political quotas, and intertemporal relationships for forest inventories, soil organic matter levels, dead wood pools, and timber commodity stocks. The non-linear objective function terms are stepwise approximated to allow EUFASOM to be solved as linear program. Each individual model solution yields optimal levels for all endogenous variables and shadow prices for all constraints. Particularly, production, consumption, and trade variables determine land use and land use change, resource deployment, environmental impacts, and supply, demand, and trade of agricultural and forest commodities. Shadow prices on supply demand balances for resources and commodities identify resource values and market clearing prices for commodities, respectively. Shadow prices on environmental targets reveal the marginal costs of achieving them.

For this study, we extended EUFASOM by integrating the spatially explicit wetland distribution data from SWEDI. We aggregated all spatial units within each EU member state but preserved habitat type, size, and suitability classifications. In addition, we assumed conversion and maintenance costs coefficients for all wetland restoration efforts. To assess the economic potential and agricultural impacts of wetland protection efforts, we specified different scenarios. In particular, we distinguished a) joint vs. country specific wetland targets, b) protected vs. unprotected status of existing wetlands, c) size dependent vs. suitability dependent representation of SWEDI data in EUFASOM, d) wetland targets with vs. without simultaneous European bioenergy target, and e) 20 different wetland targets covering the whole range from no protection to maximum protection. Each selected combination of these scenario assumptions corresponds to a separate solution of EUFASOM.

7.3. Empirical Results

Through EUFASOM scenarios economic and environmental impacts of changing policies, technologies, resources, and markets are analysed to find the socially optimal land use allocation. By including the wetland data into EUFASOM the economic potentials of wetlands, its effects on agricultural and forestry markets, and environmental impacts of wetland protection/restoration efforts are determined for different policy scenarios. Figure 1 shows the economic and technical potential of wetlands.

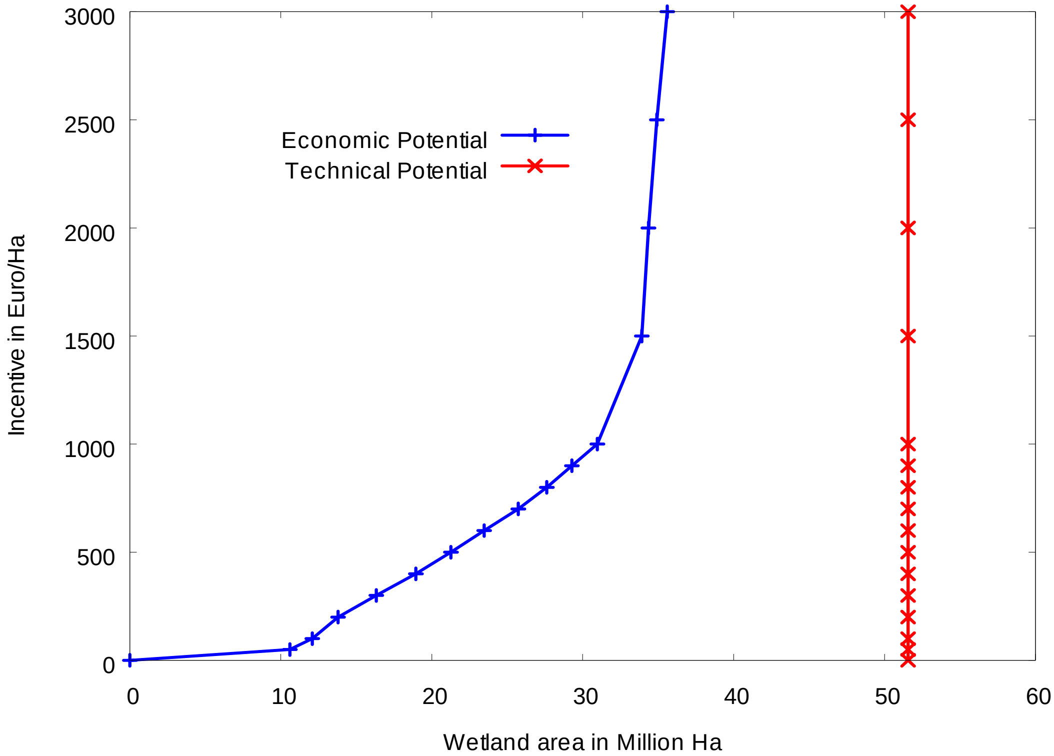


Fig 1 Economic versus technical potential of protected wetlands.

The red curve illustrates the maximum technical potential of wetland area in Europe. Generally, it applies that the more wetland is restored the more expensive the conversion costs become because the marginal costs, i.e. opportunity costs, rise. We included 20 different wetland targets from no protection to maximum protection expressed through incentives in € per hectare converted wetland area. The comparison of economic potential with the technical potential shows that from a certain point on - in this case at incentives of about 1 500 €/ha - additional wetland conversion gets economically unfeasible. As a consequence, the technical potential outreaches the economic potential.

Wetland potentials and its targets are expressed through incentives. As in figure 2 shown can these be considered for each country specifically or combined for all EU-25 states. Both curves differ from each other: In the national scenarios wetland restoration targets in one country stimulates agricultural production in other countries due to market linkages. By adding up all national scenarios we achieve an artificial leakage curve as shown in orange at figure 2. At EU-25 wide scenarios (blue curve) all countries have the same wetland targets and land competition rises. The bias between the two curves is defined as market leakage. This leakage phenomenon reflects in the differences of the national and EU-25 wide curves this way that the national scenarios have more potential wetland area at lower incentives than the EU-25 wide scenarios (Figure 2 panel a).

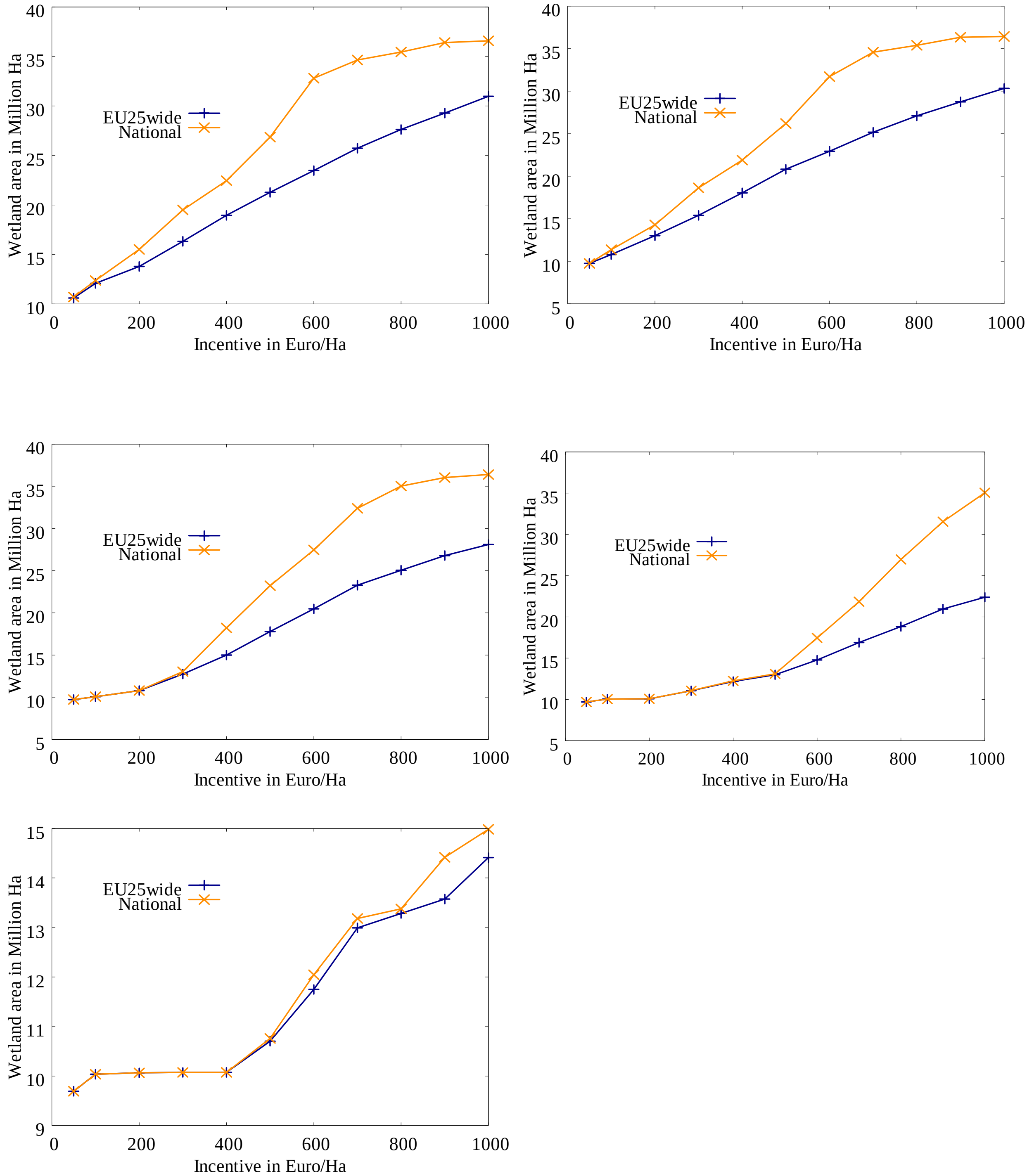


Fig 2. Country specific versus joint wetland targets for biomass targets of 0 (Panel a), 75 (Panel b), 150 (Panel c), 225 (Panel d), and 300 (Panel e) million wet tons.

This means that wetland conversion costs at national incentives are lower because agricultural production may leak to other EU-member states.

The scenarios at figure 2 are additionally differentiated after biomass targets of 0 to 100%. The European Union described bioenergy targets for the year 2010 that involves a share of renewable energy of 21% of the total electricity consumption as well as 5.75% bio-fuels of the total fuel consumption. This target can be fulfilled by a supply of about 300 mio. wet tons of biomass. Comparing the national with the EU-25 wide scenarios under consideration of the biomass targets one observes not only a decline in wetland area potentials. Also the national curve reconciles to the EU-25 wide curve the higher the biomass target is set by starting at lower incentives. At biomass target of 100% both curves almost align because the national wetland targets are outweighed by the biomass targets. Consequently, the inclusion of a third component, the biomass targets, into the model resulted in a reduction of the accounting error caused by the national scenarios.

Other scenarios revealed that the establishment of restored wetlands will have impacts on the food price. At figure 3 food prices, expressed through the Fisher Index, were integrated into the analysis. Shown are scenarios without wetland protection. In this case, the food prices even fall below 100 as unprotected wetland area is converted into agricultural utilization. The curves show also a dependency on wetland incentives, whereas the “national” scenarios result in lower food prices than the EU-25 wide scenarios. The lower the biomass targets the lower are also the food prices due to less competition in utilization demands. The national scenarios with a biomass target of 100% keep clear distance to the other national targets, but show in comparison to the EU-25 wide scenarios hardly a rise in prices even at higher incentives. Again, the leakage factor is visible. At the national scenarios additionally needed food is imported from other countries without wetland targets, whereas at the EU-25 wide scenarios economic costs rise due to competing utilization demands between traditional agriculture, bioenergy plantations and wetland targets. This explains the rise in prices for food.

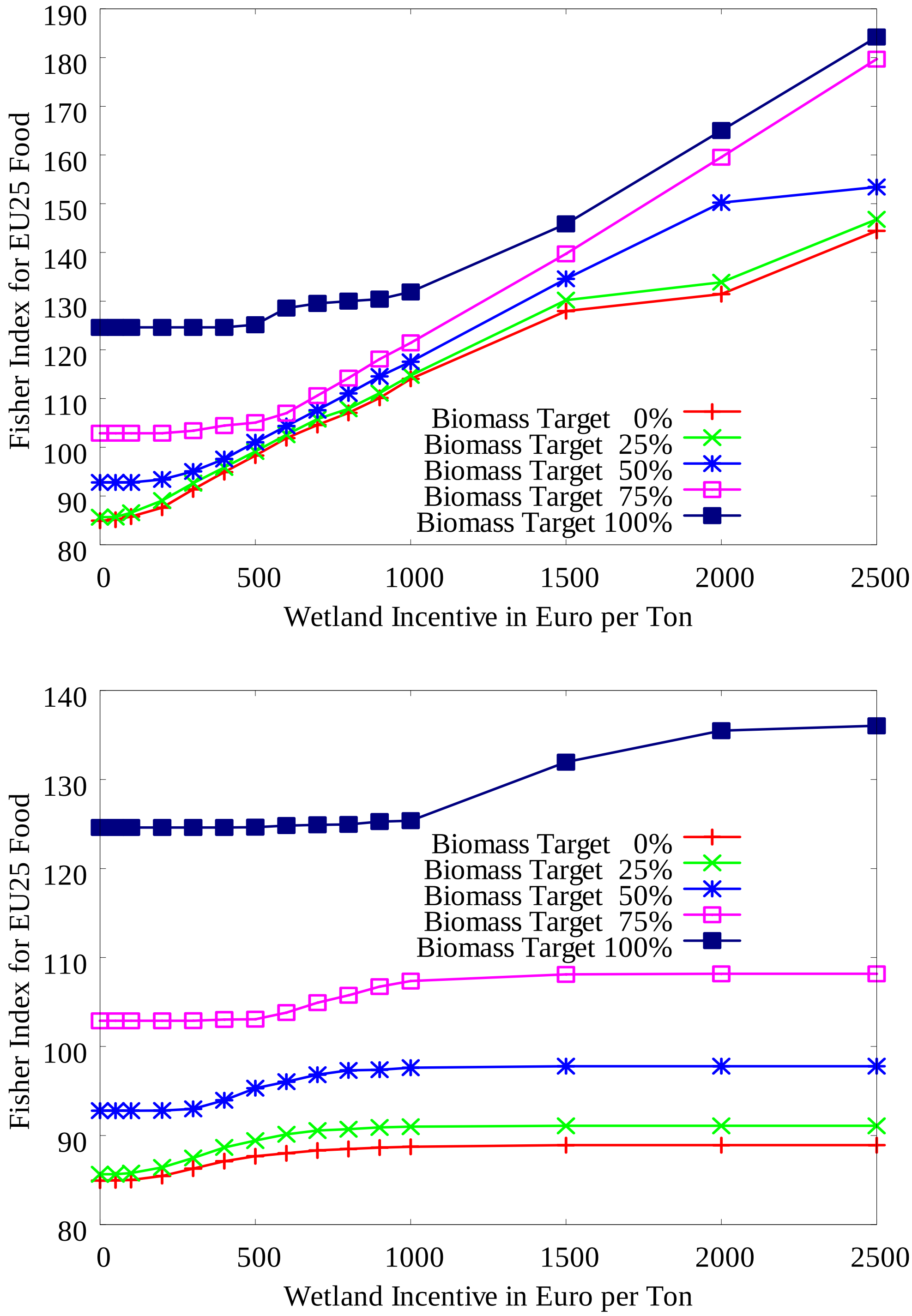
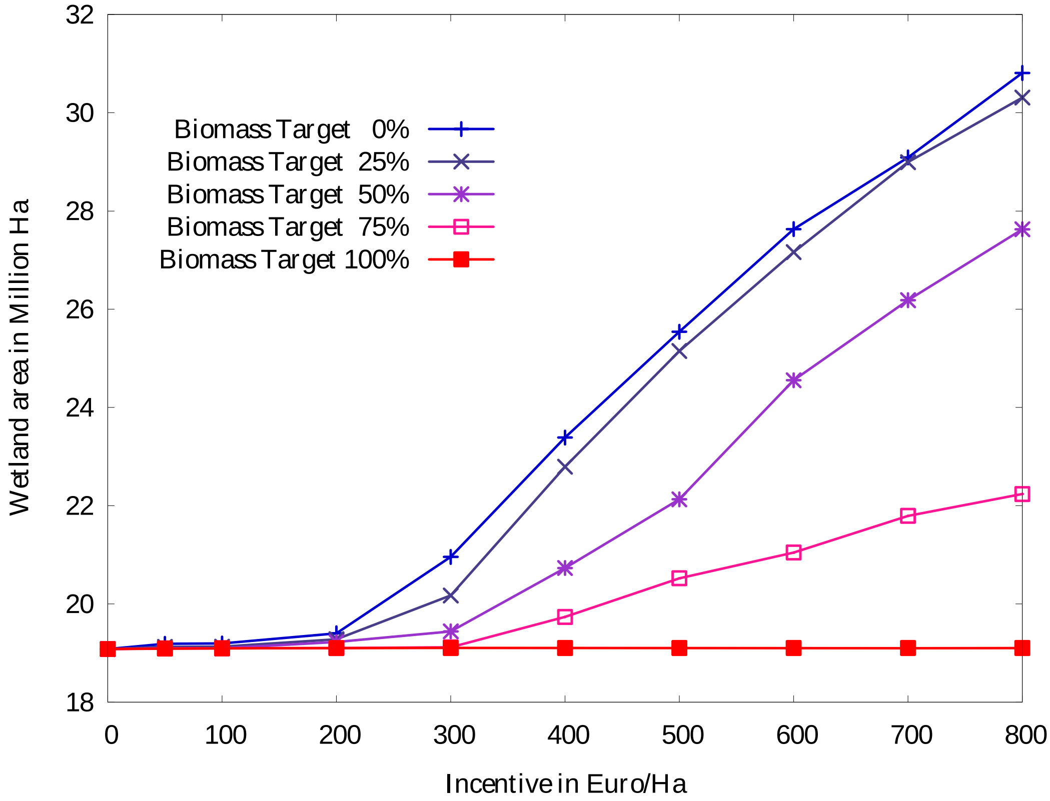


Fig 3 EU-25 wide (a) and national (b) scenarios analysing food prices of the EU-25 states in relation to wetland restoration incentives.

EU-25 wide scenarios with joint incentives for all EU-countries are used for the following scenarios. Figure 4 distinguishes between protected (a. NoX) versus unprotected status of existing wetlands (b. ALL).



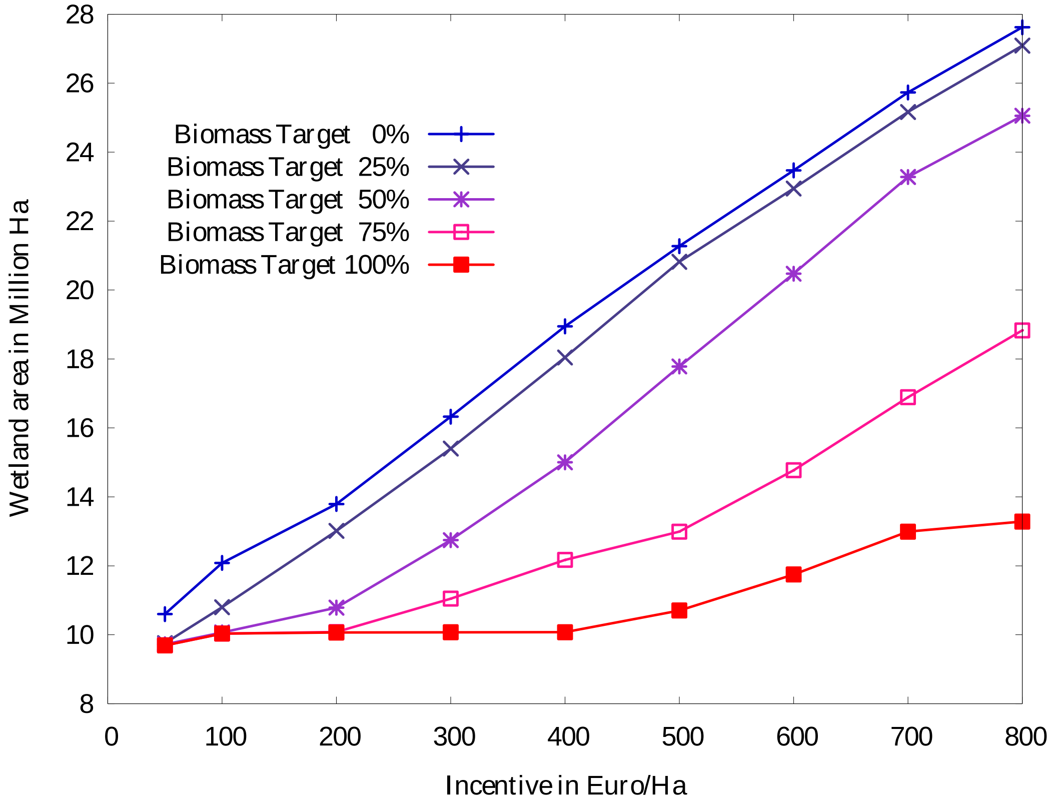


Fig 4 Protected (a) versus unprotected (b) status of existing wetlands for different biomass targets.

The protection of existing wetlands implies that these wetlands are not available to be used as agricultural fields or forests, for example, whereas at unprotected status these wetlands may be used for other utilizations as well (cf. figure 3). The curves show clear differences also due to different values at the beginning. The scenario with unprotected existing wetlands indicates a more intense rise of wetland area at low incentives, but it also starts at small wetland area in comparison to the protected status, where a rise in wetland area is initiated only from incentives of 200 €/ha. At biomass target 100 even no rise happens at all. The protection-scenarios therefore imply that if wetlands would not be protected, most of the biotopes would be converted into other utilization. Only at incentives of about 400 €/ha the wetland area at scenarios without biomass target reaches the starting point of existing wetland area at protected status.

The EUFASOM scenarios in figures 2 to 4 show the integration of bioenergy targets with realisation of 25, 50, 75 and 100 % as well as without such target. The results show that in all scenarios biomass targets for climate change mitigation have enormous effects on wetland conservation and restoration. In the following we are going to use the scenarios of figure 2 for a more detailed analysis. In this case we chose the EU-25 wide curves of wetland area potentials without biomass target (Fig 2.a) and with biomass target 100% (Fig. 2 e). We show exemplarily for both cases the wetland potentials for each country separately at incentives of 0, 1000, and 3000 €/ha. Figure 5 represents maps of the total potential wetland area per country. It illustrates great wetland potentials at the starting point in Sweden, Finland, but also in the United Kingdom. At this stage the total wetland potentials in Ireland, Poland as well as in Estland are also remarkable, whereas other countries like Italy, Greece, but also Denmark or the Netherlands only have minor total wetland potentials. Comparing now the wetland potentials per country at incentives of 1000 Euro per hectare with and without biomass target one gets only one another picture: The wetland potentials remain stable with biomass target 100%, but the wetland potentials without biomass target show most extending rise in wetland area in France, but also the wetlands in Spain, Germany and Hungary grew as well as wetland areas in Austria, Italy and Greece increased.

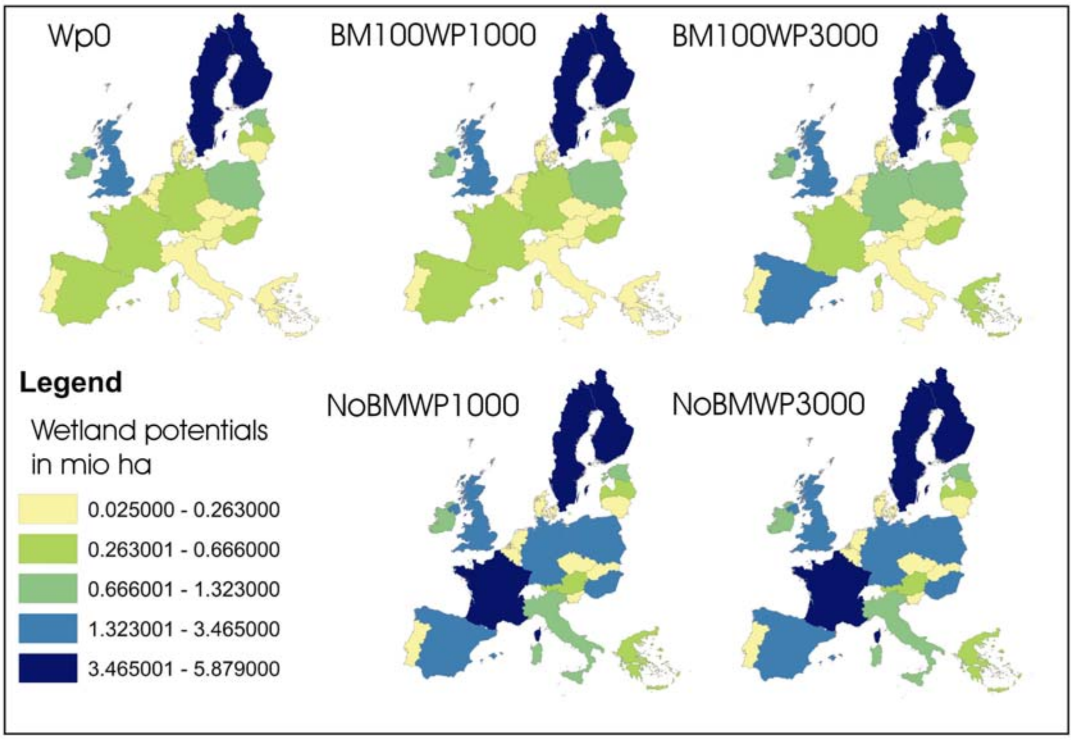


Fig. 5 Total potential wetland area per country at incentives of 0, 1000, and 3000 €/ha (WP) with (BM100) and without biomass target 100% (NoBM).

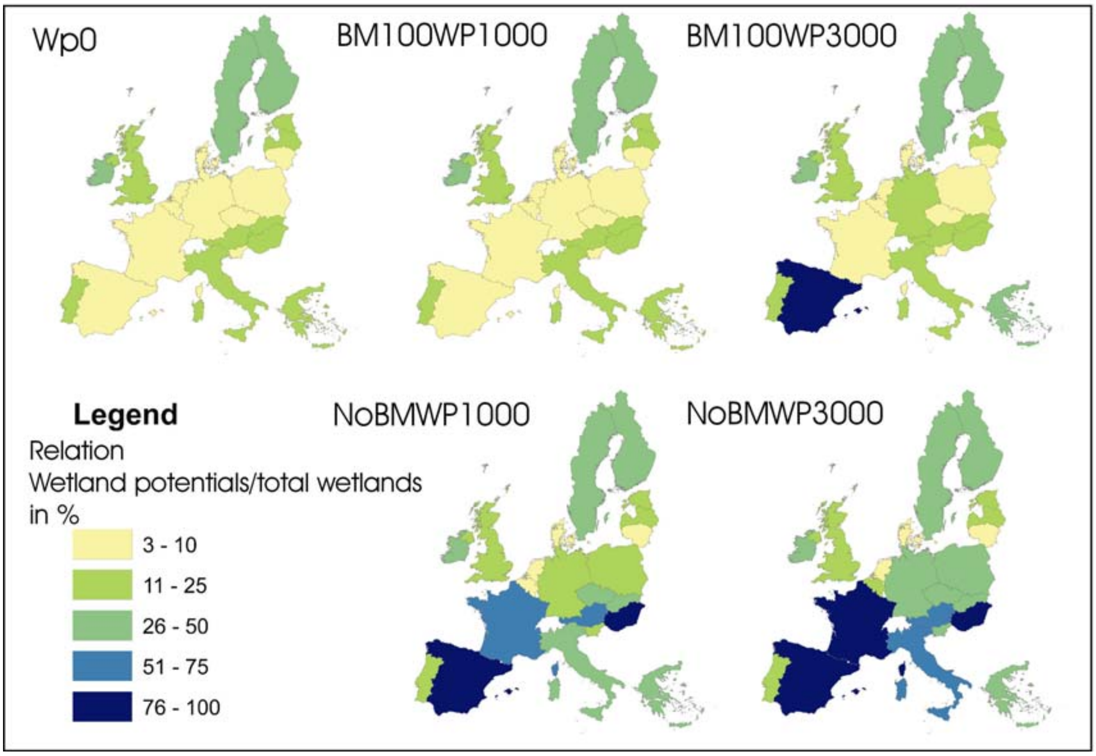


Fig. 6 Relation of potential wetland area to the maximum wetland area per country in percent with incentives of 0, 1000, and 3000 €/ha with and without biomass target 100%.

Even if an increase in wetland area took place as figure 6 illustrates are the changes in wetland potentials not visible on the map. Therefore shows the map at incentives of 3000 Euro per hectare no differences to the scenarios of 1000 Euro per hectare incentives without biomass target. On the other hand are at the stage of 3000 Euro per hectare increasing wetland potentials at scenarios with inclusion of biomass target 100% visible. In these cases the wetland areas of Spain, Germany and Greece rise considerably.

In contrast to figure 5 illustrates figure 6 the share of the respective wetland area in relation to the maximum wetland area in percent depending on the EUFASOM scenarios explained through maps. In comparison to the results of figure 5, France, Poland and Germany only own minor shares of their total wetland potentials at the starting point, whereas now Italy, Greece, Austria, Slovakia and also Portugal have higher relative wetland area compared to their total wetland area. The maps change drastically at the 1000 Euro incentive without biomass targets where besides the above mentioned countries also the Czech Republic shows rising wetland potentials. The results of the 3000 Euro incentives without biomass target indicate that the share of wetland potentials to the total potential wetland area of France, Germany, Poland and Italy increased more than in other countries. The high shares of 76 to 100% of Spain or France, for example, results from relatively small total wetland potentials of that country.

To learn now more about regional differences we aggregated the data of the potential wetland areas into regions (Table 2) to illustrate potential differences in wetland potentials.

Table 2 Definition of EU-25 regions

Regions	**Countries**
Scand	Finland, Sweden
East	Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia
Central	Austria, Belgium, Czech Rep., Denmark, Luxembourg, Netherlands
West	France, Ireland, Portugal, Spain, UK
South	Greece, Slovenia, Italy

Figure 7 illustrates these differences in more detail by comparing scenarios with biomass target 100% and without biomass target.

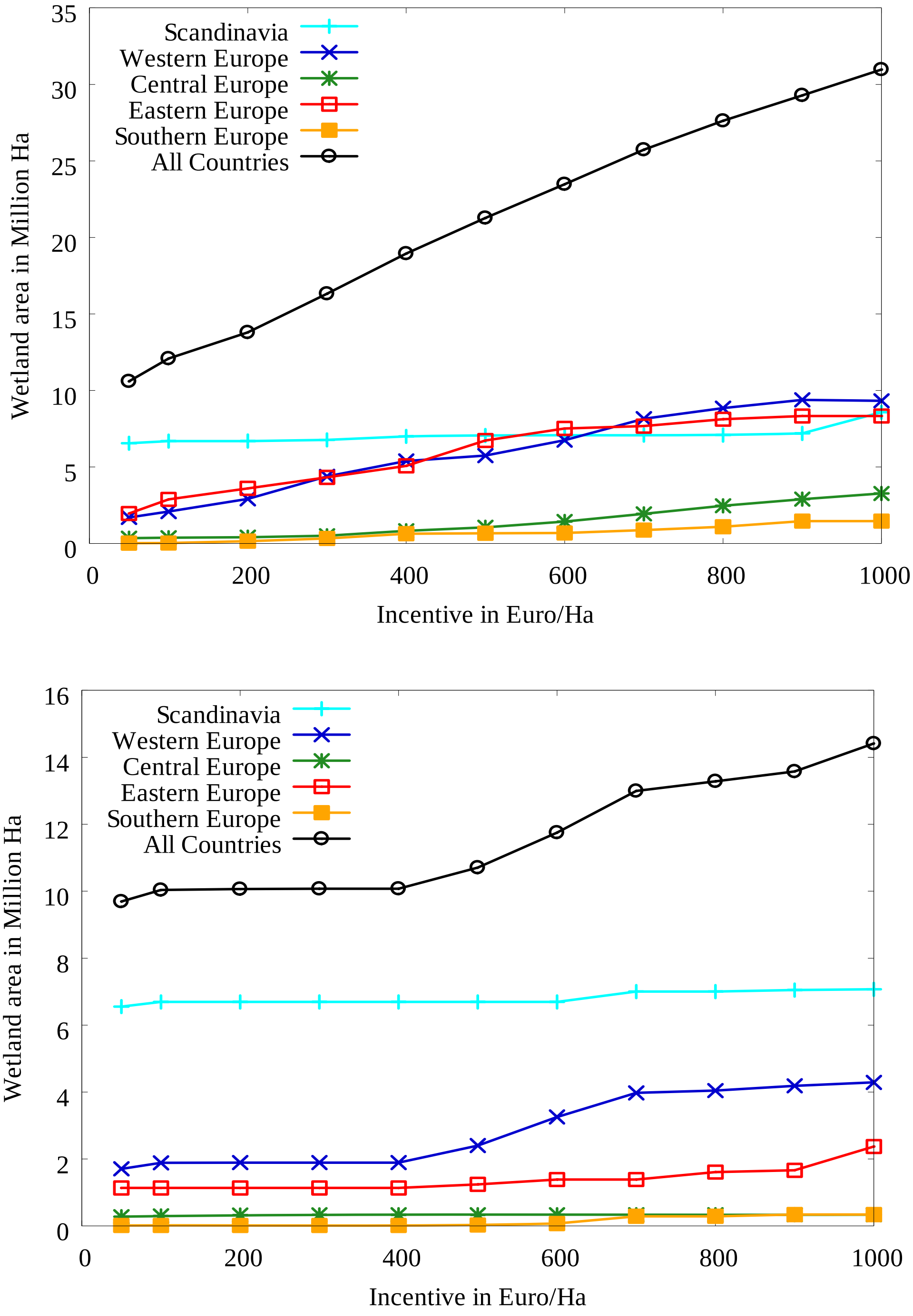


Fig 7 Regional distribution of unprotected wetlands for a. biomass target 100% and b. Biomass target 0%.

The wetland area in the Scandinavian Region keeps nearly constant independent of biomass targets. By far the most extending wetland increase is observed in Western European where the wetland area even raises above the Scandinavian wetland potentials at the scenario without biomass target. Here, also the Eastern European region shows extending growth in wetland area similar to the Western European region. This is not the case at scenarios with biomass targets. The Central and South European regions show an increase in wetland area only at scenarios without biomass targets. In relation to their low total wetland potentials due to geo-ecological factors the share in rise of wetland area can be even rated higher than elsewhere in this case.

Summary and Conclusions

The GIS-based SWEDI model estimates the spatially explicit distribution of existing and potential wetlands. Results show not only a heterogeneous distribution across countries but also large differences between the two areas. Potential wetland areas in Europe are about five times larger than existing wetlands. To evaluate the competitive economic potential of wetland preservation under different policy options, SWEDI data were aggregated and integrated into EUFASOM. This bottom-up, partial equilibrium model portrays the competition for scarce land between agriculture, forestry, dedicated bioenergy enterprises, and nature reserves. Production intensities, prices, international trade, and demand for agricultural and forest commodities are endogenous. As shown above, the spatial extent of wetland preservation is sensitive to incentives. It is relatively inexpensive to achieve moderate levels of conservation but marginal cost rise steadily as the total protected areas increase (ANDO ET AL. 1998; POLASKY ET AL. 2001; NAIDOO & ADAMOWICZ 2005). Note that incentives of several thousand Euro per hectare are easy to simulate with a mathematical programming model but difficult to realize politically.

Wetland targets in one place stimulate land use intensification elsewhere due to market linkages. Thus when wetland restoration in one country reduces agricultural production the market is likely to cause this to be offset by increased production elsewhere (cf. GAN & MCCARL 2007). This leakage phenomenon indicates also that environmental stresses, in this case to wetlands, may be transferred to other countries (cf. BRUVOLL & FÆHN 2006). However, we find that wetland conversion rises when a national rather than an EU-25 wide perspective is employed. On the other hand reduces the introduction of biomass targets the bias between national and EU-25 wide perspectives due to additional land utilization demands.

Large wetland areas impact food production, consumption, and market prices. Higher food prices rise the opportunity costs of wetlands. If these cost changes are ignored, the resulting marginal cost predictions can be substantially underestimated. Similarly, adding nationally obtained cost estimates understates the true cost of EU-wide preservation incentives. In independent national assessments, costs appear lower because agricultural cost changes from simultaneous preservation policies in other countries are neglected.

Existing European wetlands are relatively well protected through EU-policy measures. However, these areas may need to be extended to realize the ambitious political targets related to biodiversity protection.

Bioenergy targets have enormous effects on conservation planning and nature conservation. An enforcement to achieve the EU-bioenergy target, meaning to produce about 300 mio wet tons of biomass per year, would lead to less wetland restoration areas at very high incentives, but even to no additional wetlands, respectively conservation areas, than the existing at incentives up to 1000 Euro per hectare. This also reflects in regional and country-specific analyses.

Regional and country-specific differences in wetland potentials exist as well. The wetlands are not evenly distributed due to their geo-ecological and spatial relationships but also because of economic aspects like land costs, for example.

The presented study helps to find the socially optimal balance between alternative wetland uses by integrating biological benefits – in this case wetlands - and economic opportunities – here agriculture and forestry. The analyses offer insights into environmental conservation effects in European scale caused by policy driven land use changes. Spatial data provide a possibility to build the interface between economic and ecologic models.

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