Delivering improved Biodiversity conservation and Ecosystem Services provision: Using integrated ecological-economic models to guide policy design

Prof. Mette Termansen

European landscapes, and Danish landscapes in particular, are intensely managed with approximately 60 percent in agricultural production and 14 percent allocated to forestry. It is therefore recognized that initiatives to protect biodiversity and increase provision of ecosystem services needs to include land mainly managed for food and timber production. Large parts of Europe, and elsewhere, have a long history of environmental policy development to address water quality of fresh and marine waters. In Europe, early policy initiatives include the implementation of the Nitrates Directive. In 2000, the European Water Framework Directive was agreed, introducing a binding target of achieving good ecological status in all natural surface and ground waters. However, with multiple pressures on ecosystem services and biodiversity (e.g. mounting climate change challenges and continuing threads of extinction of rare species) it is increasingly realized that environmental policies that integrate improved delivery of more ecosystem services in cost-effective ways will potentially perform better than single service targeted policies. However, there is also the risk that policies that are not sufficiently targeted towards specific policy objectives, will be ineffective. The presentation will explore the trade-offs between policy design for single services and multiple services (including biodiversity). The presentation will illustrate that the economic case for joint policy development will depend on i) the specificity of the policy measures, ii) the spatial variability and iii) the co-correlation of biodiversity and ecosystem service potential. The analysis will rely on spatially specific integrated ecological-economic models of biodiversity and ecosystem services. To develop the analysis, we will depart from the case of optimal water quality policies and then introduce the interaction with other policy targets. The analysis will utilize integrated models utilized to support the evaluation of initiatives to meet the Water Framework Directive and further developed to address the EU policy strategy to map and value ecosystem services.

Regulating freshwater and marine water quality

The negative impacts of anthropogenic nutrient emissions from agriculture is a classic case of an environmental externality. Excessive loads of nitrogen and phosphorus cause eutrophication and alter freshwater and marine ecosystem dynamics, resulting in negative impacts on the services derived from these ecosystems. In the absence of policy intervention polluters have little incentive to reduce the emissions resulting in overall welfare loss. In most countries, the policy response to achieve good ecological status has been uniform regulation and command-and-control instruments. The choice of these instruments can be explained by the non-point source characteristics of the emissions and by the fact that they are hard to monitor and control. However, these instruments do not provide farmers with incentives to reduce emissions to the sea in the most cost-effective way, and do not provide incentives for a cost-effective distribution of effort between farmers. To improve NPS regulation a growing interest in environmental performance-based regulation and differentiated regulation has emerged, both in Europe and the US. These efforts include more spatially targeted regulation to address the variability in agricultural production potential and hydrology in agricultural catchments.

Implementation of such spatially targeted differentiation is challenging. One reason is that measuring and controlling each polluter's N loads and abatement effects is technically difficult, and if feasible, there are tradeoffs between the accuracy of information and the information costs. Since reliable and affordable equipment for measuring the individual nutrient emissions has not been developed for metering at large scale, use of models to estimate emissions to the downstream recipient might be useful in policy development and implementation. As an example, nutrient retention models have been developed to provide spatial information of the differences of the nutrient transport from the root zone to downstream water bodies. This information can help evaluate where in the landscapes policy implementation would be most effective.

Integrated economic and biophysical models can be used as for guidance on the development of NPS-regulation when empirical testing is difficult to perform. The models can be used to estimate how alternative abatement measures change individual emissions (at field and catchment level) and overall costs, by using empirical, experimental and modelled data on inputs and ambient concentration of pollutants. A non-linear optimization catchment model, TargetEconN, has been developed to elicit cost-effective, spatial allocation of abatement measures to reduce N loads from agricultural NPS to the marine environment. We explore the use of this type of model for assessments of the economic case for spatially targeted policies, the effects of uncertainties in biophysical dynamics and the implications for allocation of abatement efforts and costs between farms.

Even when integrated models like the TargetEconN can identify optimal policy measures, identifying efficient policy mechanisms is still a challenge for policy makers. Economic instruments such as input taxes will take heterogeneity of costs between farms into account, but do not account for the spatial heterogeneity in hydrological factors and variation in environmental sensitivity of downstream water bodies and have also been politically difficult to implement.

Furthermore, voluntary policy mechanisms relying on state funded incentive schemes to compensate land-owners for implementation of mitigating measures have proven to be excessively expensive and new mechanisms are needed to target the effort, reduce costs and share the costs between beneficiaries of the environmental improvements. To realise the potential cost savings from more spatial targeting more flexible abatement policies are needed, enabling redistribution of effort between farms. One method to achieve such flexibility is to allow trade of nutrient mitigation between farms, i.e. introduce a tradable nutrient permit scheme. The literature on water quality trading, has primarily focused on trading between point source dischargers and non-point sources. However, studies of trading schemes between non-point dischargers, such as agricultural farms, are emerging. However, the research has mainly been based on theoretical models and only very few empirically parameterised models have tested the scope for such policies. The presentation will illustrate how integrated ecological-economic models implemented in different parts of the world can be used to assess cost-effectiveness of alternative policies and help develop more cost-effective policies.

Trade-offs and synergies in biodiversity and ecosystem service policies

Using similar methodologies TargetEconN is expanded with additional ecosystem services and biodiversity indicators. This multi-service tool is developed to analyse the changes in provision of a range of different ecosystem services and their economic values resulting from setting aside land in agricultural or forestry production. In particular, the tool is developed to enable the analysis of synergies and trade-offs between services. Using the tool, it is possible to identify areas where significant synergetic effects can be obtained across several important ecosystem services, with relevance for land use policy and planning. Furthermore, identification of potential conflicts areas is also a potential use of the tool. Application of the tool is illustrated for a case study area. A set of core ecosystem services is identified, and subsequently a number of stylized scenarios are generated in order to facilitate the analysis of interactions between the ecosystem services and biodiversity indicators.

The analyses in the report include the following ecosystem services: food production, timber production, water quality regulation in the form of nitrogen retention, climate regulation in the form of carbon sequestration, hunting and recreation. In addition, the analyses also encompass the impacts of the land use changes on biodiversity indicators, i) coverage of areas important for protection of rare species, ii) spatial connectivity of habitats and habitat structure.

Examples from the six different scenarios of land use change are used to illustrate the potential use of the model in development of spatially targeted policies. The 6 scenarios are: 1) a water scenario where the conversion of agricultural land to semi-natural areas is prioritised in order to maximise N-retention, 2) a climate scenario where the conversion of agricultural land to forest is prioritised in order to optimise carbon sequestration, 3) a recreation scenario where conversion of agricultural land to mixed forest and semi-natural areas is prioritised to increase the number of recreational visits to the new recreational areas, 4) a biodiversity scenario where the conversion of productive forest land is targeted towards areas of high species score, 5) a habitat connectivity scenario where the conversion of agricultural land to semi-natural areas is prioritised to improve the connectivity of areas with high species scores, and 6) a habitat structure scenario where the conversion of agricultural land to semi-natural areas is targeted at improving the structure of existing habitats.

The analyses of the different scenarios are focused on the effects of the land use changes. The effects are measured in terms of changes in ecosystem services and biodiversity indicators assessed in biophysical units. When possible the assessment in biophysical units is supplemented with an assessment of economic value. The qualitative results of the scenario analyses can be summarised in a scenario-effect matrix (Figure 1). The intensity of the cells signifies the increase in the magnitude of the service or indicator.

The scenario-effect matrix can be used to quantify synergies and conflicts between different types of land use change. This analysis is conducted by comparison across the rows of the matrix, and it makes it possible to identify the consequences of targeting land use changes at specific services or indicators.

Scenario prioritised according to:	Change in indicators for the different ecosystem services and biodiversity dimensions								
	Change in food production	Change in timber production (m3)	Change in Nitrogen leaching to the Limfjord (ton)	Change in carbon sequestration (ton)	Change in number of recreational visits	Change in hunting opportunities	Change in biodiversity protection	Change in habitat connectedness	Change in habitat structure
Water quality		N/A					N/A		
Climate							N/A		
Recreation							N/A		
Biodiversity hotspot					N/A				
Habitat conectivity		N/A			N/A		N/A		
Habitat structure		N/A			N/A				

Figure 1: Scenario-effect matrix: The results of the scenario analyses are assessed as the scenario induced changes in the indicators for the ecosystem services and biodiversity relative to current land use

In conclusion, the analyses show that the positive interactions between ecosystem services are modest when scenarios are based on prioritization of single ecosystem services. This implies that the magnitude of the co- benefits is limited. This indicates that it is necessary to specifically include all essential ecosystem services in the planning of land use changes.

The analysis illustrates that it is very effective to target land use changes towards an increase of a specific ecosystem service. This is especially the case for ecosystem services, which can only be supplied at a high level in few and very specific types of areas. In the present analysis, this is particularly evident for land conversions motivated by biodiversity protection and climate regulation. If significant increases in the supply of these services are to be realised through land conversion, it is necessary to target the land use changes at the areas where the potential for these ecosystem services (carbon sequestration or biodiversity protection) is highest. However, this also means that the side effects in terms of increased provision other ecosystem services will be modest.

Another implication of the analysis is, that if land use policies aim to increase several services, then it is necessary to explicitly include all services in the prioritisation and to agree the relative weighting between the services. Analyses where several weighted ecosystem services enter simultaneously show that it is possible to achieve increased synergy between services. More specifically the analysis shows that a relatively high weight ascribed to climate regulation result in a positive interaction with recreation and hunting. This is because conversion motivated by climate regulation result in large spatially connected areas with a high degree of afforestation.

Over all, the research shows that it is possible to combine existing spatial data layers and models thereby facilitating analyses of the effects of land use changes across many ecosystem services and biodiversity indicators. Moreover, the research development shows that it is possible to combine bio-physical modelling of ecosystem services with spatially specific data and economic valuation data. The joint inclusion of ecosystem services and biodiversity indicators provides a tool for analysing land management in a common framework. Accordingly, the modelling tool makes it possible to analyse the consequences of land use management in situations where different production, environmental and biodiversity considerations need to be integrated and analysed in a consistent data and modelling framework. Future research will explore how alternative policy mechanisms can be developed to improve joint delivery of ecosystem services and biodiversity conservation objectives.

Acknowledgements: The work presented builds on ongoing research reported in Konrad et al. (2017), Hansen et al (2017), Hasler et al. (2018), Termansen et al (2017) and Smart et al (2018). Further references to key scientific literature can be found in these papers.

References:

Hasler, B., Hansen, LB, Andersen, HE, Termansen, M (2018). Cost-effective abatement of non-point source nitrogen emissions – the effects of uncertainty in retention. Unpublished manuscript, early versions of the paper presented at the EAERE conference in Helsinki 2016.

Konrad, M., Andersen, H.E., Thodsen, H., Termansen, M. and Hasler, B. (2014), Cost-efficient reductions in nutrient loads; identifying optimal spatially specific policy measures, Water Resources and Economics, Vol. 7: 39-54.

Konrad, MT; Andersen, HE; Gyldenkaerne, S; Termansen, M (2017). Synergies and trade-offs in spatially targeted water quality and climate change mitigation policies. Land Economics, Vol. 93(2):309-327.

Termansen, M., Konrad, M., Levin, G., Hasler, B., Thorsen, B.J., Aslam, U., Andersen, H.E., Bojesen, M., Lundhede, T.H., Panduro, T.E. & Strange, N. 2017. Udvikling og afprøvning af metode til modellering af økosystemtjenester og biodiversitetsindikatorer med henblik på kortlægning af synergier og konflikter ved arealtiltag. Aarhus Universitet, DCE – Nationalt Center for Miljø og Energi, 80 s. - Videnskabelig rapport fra DCE - Nationalt Center for Miljø og Energi nr. 226. http://dce2.au.dk/pub/SR226.pdf

Hansen, LB; Hasler, B; Termansen, M (2017). Identifying demand and supply for potential N abatement trading: A hypothetical market experiment among Danish farmers. Conference paper, Nordic Environmental and Resource Economics conference, Helsinki 2017.

Smart, JCR & Hasan, S (2018). Nitrogen Trading – modelling principles from Australia's Great Barrier Reef: parallels and contrasts with the Baltic. Bonus conference – The 3rd Bonus Symposium: Sustainable Ecosystem Governance under Changing Climate and Land Use in the Baltic Sea Region, GDANSK, 14-16 March, 2018.