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Analysis

Water Quality Management and Climate Change Mitigation: Cost-effectiveness of Joint Implementation in the Baltic Sea Region

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ABSTRACT

This paper explores the scope for simultaneously managing nutrient abatement and climate change mitigation in the Baltic Sea (BS) region through the implementation of a selection of measures. The analysis is undertaken using a cost-minimisation model for the entire BS region, the BALTCOST model. In the present research, the model has been extended to include greenhouse gas (GHG) emissions effects, enabling us to analyse the trade-offs between cost-effective GHG and nutrient load reductions. We run the model for four different scenarios in order to compare the environmental and economic consequences of contrasting strategies: single environmental objective management versus joint implementation strategy. The results show that implementing land-based measures with a sole focus on water quality (to meet the HELCOM's 2013 Baltic Sea Action Plan nutrient abatement targets) can produce climate change mitigation co-benefits equivalent to 2.3% of the 2005 emission level (from agriculture and waste water combined) for the entirety of the BS region. More interestingly, a joint implementation strategy can deliver further climate change mitigation benefit (i.e. up to 5.4%) at a marginal cost that is comparable to mitigation costs reported by other studies for efficient technologies. All in all the results demonstrate that a joint strategy to improve water quality and to reduce climate change is economically beneficial. Our findings show that the cost and the outcome of the implementation vary between countries. This illustrates the need to develop a joint regional policy for water and climate regulation that fully considers the asymmetry in both the expected effects and cost distribution across the countries in the region.

1. Introduction

The Baltic Sea is an example of an international sea area where collective actions have been agreed by intergovernmental fora to regulate environmental quality. One of these fora is the Helsinki Commission (HELCOM). Nutrient loads to the sea are responsible for the eutrophication of large parts of the central and coastal Baltic Sea area, and HELCOM has declared eutrophication as one of the most serious threats to obtain healthy ecosystems in the Baltic Sea and the delivery of important ecosystem services. The HELCOM contracting parties (9 riparian countries, of which 8 are EU member countries) have agreed on nutrient reduction targets and adopted in the Baltic Sea Action Plan (BSAP) (HELCOM, 2007, 2013). The BSAP defines maximum levels of total phosphorus and nitrogen loads to the sea such that the sea ecosystem can recover and a good environmental status can be reached in the future. The load quotas are measured as maximum allowable inputs from each of the riparian countries and to each of the 7 sea basins. The BSAP targets were first agreed in 2007, and revised later in the HELCOM Copenhagen Ministerial Meeting in October 2013 (HELCOM, 2013).

The HELCOM contracting parties have agreed to align the implementation of the BSAP with other policy objectives in order to enhance efficiency and to reduce conflicts between policies (HELCOM, 2013). One of these policies is the international and EU policy to reduce greenhouse gas emissions (GHG). The implementation of policies and measures to control both nutrient losses and GHG emissions might lead to conflicts, but also synergies. Most policy evaluations to date deal with the assessments of individual policies, but coherence and co-ordination of policies are required to attain efficient outcomes (Bennear and Stavins, 2007).

Previous research have developed models to analyse the cost-effectiveness of nutrient reduction policies to the Baltic Sea at various spatial scales and with different types of data (Elofsson, 2010; Gren et al., 2013; Wulff et al., 2014; Hasler et al., 2014; Hyytiäinen et al., 2014; Ahlvik et al., 2014; Gren et al., 1997; Turner et al., 1999; Ollikainen and Honkatukia, 2001; Schou et al., 2006; Gren, 2008). Elofsson (2010) provides a comprehensive review of this research. The Baltic wide studies on nutrient load reduction conclude that restoring

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the Baltic Sea will be expensive. It is therefore of policy relevance to explore how national and regional/international implementation of collective actions to reduce nutrient loads and GHG emissions, individually and simultaneously, influence the total costs of achieving the environmental objectives. Furthermore, it is of policy relevance to study the distribution of costs and abatement between countries, as well as how synergies and potential conflicts influence the costs and abatement of the policies. Spatially explicit modelling of abatement effectiveness and abatement cost has proven to be essential for identifying cost-effective combinations of abatement measures (Konrad et al., 2014; Iho, 2005; Iho and Laukkanen, 2012). In the Baltic Sea region this is especially important because of the heterogeneity in catchment characteristics, land use and agricultural production as well as differences in the sea regions capacity for receiving nutrient loads.

GHG reductions are regulated at an international multilateral level according to the United Nations Framework Convention on Climate Change (UNFCC), but also EU has made a unilateral commitment on 20% reductions of GHG emissions from 1990 levels by 2020. The EU policy includes the Emission trading scheme (ETS), which regulates industry, and the Effort sharing decision scheme (ESD). The ESD includes most sectors not included in the EU ETS, such as agriculture and waste, as well as buildings and transport (except aviation and international maritime shipping) (EC, 2016). Emissions and removals from land use, land-use change and forestry (LULUCF) are currently not included in the ESD (EC, 2015). The difference between the ETS and the ESD is that while sectors are allowed to trade across country boundaries in the ETS, the ESD implies binding annual GHG emission targets for Member States. Similar to the BSAP the allocation of the GHG reduction targets are set according to equity and fairness, but not cost-effectiveness (De Cara and Jayet, 2011). According to De Cara & Jayet's analysis the costs of a 10% reduction in EU could be reduced by a factor of two to three compared to the fixed targets; if a flexible cap-and-trade system were introduced and a more cost-effective distribution among these countries could be obtained. Their results indicate that an introduction of cap and trade would imply that new member states (Poland, Lithuania, Latvia and Estonia) would sell permits to old (Denmark, Germany, Finland and Sweden), and thereby the allocation of emissions reductions would change considerably.

A literature review by Balana et al. (2011) highlights that existing studies on cost-effectiveness analysis of implementing measures to mitigate water pollutants have focused solely on the direct impacts, and neglected potential co-benefits and unintended consequences. Since this review in 2011 only a few studies have been accomplished addressing the costs and effects of implementing nutrient and climate policy objectives simultaneously (e.g. Eory et al., 2013; Gren & Säll, 2015; Konrad et al., 2017). These studies have very different spatial coverage. Eory et al., 2013 focused on the UK. The work of Konrad et al. studies a catchment (Limfjorden catchment in Denmark), whereas the work of Gren & Säll (2015) covers the entire BS region. Gren and Säll (2015) analyse cost-effective multi-target management of nutrient and GHG emissions in the Baltic Sea, and state that simultaneous management of targets on both nutrients and GHG-emission reduce costs compared with separate management, if measures are complementary in pollutant abatement and the same source emits more than one pollutant. The study includes sources being inside and outside the ETS. They conclude that the multi-target implementation reduces total costs by 11% compared to separate management. The Gren and Säll (2015) study use data on nutrient emissions from Gren (2008) and on GHG emissions from Gren et al. (2013). It appears that the multi-target analysis compares results from minimization of the costs of abating GHG emissions and nutrient loads from model versions with different assumptions, being run for different years. Gren and Säll (2015) furthermore claim that the location of the source does not matter for the climate impact, which we agree on in principle, but GHG emission effects of land-use measures do, as they vary according to climate zone, soil types etc. A more spatial approach is therefore justified, taking heterogeneity between catchments into consideration for the optimal localization of measures.

A number of land-use changes and measures are spatially specific in terms of the effects and costs and some measures cause changes in both GHG emission and nutrient load levels. We therefore find that it is of high relevance to investigate the scope for jointly delivering cost-effective nutrient abatement and reductions in GHG emissions within a spatial modelling framework for the Baltic Sea. By applying the analysis to the Baltic Sea the paper contributes as an example of how international collaborative agreements can be improved by cost-effective allocation. This is done by comparing the costs of Baltic Sea level cost-effective and flexible allocation of measures with the country specific implementation of emission targets agreed on in the BSAP and ESD. The analysis is undertaken using and further developing a cost-minimisation model for the entire Baltic Sea region, the BALTCOST model (Hasler et al., 2014), which is an economic-hydrological model applied with high spatial resolution data for the entire Baltic Sea catchment. In the present paper, the model has been extended to include GHG emissions at the same spatial resolution as the nutrient load modelling. More specifically the present paper aims to model scenarios for cost-effective, joint water and climate strategies; investigating the economic consequences of different implementation scenarios compared to the current policies.

The remainder of the paper proceeds as follows. Section 2 describes the additions made to the BALTCOST model to include GHG effects, together with the data sources and methodologies that were used to estimate cost functions, effect functions on GHG and nutrient loads, capacity constraints and nutrient retentions for each abatement measure in each main drainage basin. Section 3 presents the modelling results. Section 4 discusses the results and Section 5 concludes the paper.

2. Methods

2.1. Modelling Platform

To meet the objective of the paper, we extend the hydro-economic model BALTCOST (Hasler et al., 2014). The methodological contribution of the present paper is the incorporation of climate change mitigation objectives, effects and capacities for GHG reduction of each of the measures into the BALTCOST model.

BALTCOST is a non-linear optimisation model for the Baltic Sea developed collaboratively by natural scientists and economists (Wulff et al., 2014; Hasler et al., 2014). The model divides the Baltic Sea region into the countries (9), the sea basins (7), and the drainage basins (22) (Fig. 1). The new BALTCOST model version (further specified below) optimises choice of measures and calculates the minimum total abatement cost incurred to deliver Nitrogen (N) and Phosphorus (P) load reduction targets to the sea regions, as well as GHG-emission reduction target for the entire Baltic region. The solutions are found, within modelled abatement capacity constraints of the measures at the main drainage basin resolution.

BALTCOST includes 6 different abatement measures, outlined in Table 1, for each of 22 main Baltic drainage basins. Each measure is characterised by cost of implementation, the total capacity for N, P and GHG reductions, effect on the N leakage and retention, the effect on GHG emissions and for some of the measures also the P load reductions (Table 1). More information regarding the characteristics of the measures can be found in Appendix A. Cost- and effect-components in BALTCOST are tightly integrated as both elements draw on the same database of spatially-specific biophysical 10 × 10 km grid cell data used to estimate the costs of each of the measures when implemented in the drainage basins.

BALTCOST is specified assuming that the 6 abatement measures can be implemented independently within the Baltic sea catchments, implying that more than one measure can be implemented at the same