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Mitigating diffuse nitrogen losses in the Nordic-Baltic countries

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ABSTRACT

Concerns over deteriorating water quality in both freshwater and marine waters have initiated efforts to control diffuse nitrogen (N) losses in all Nordic-Baltic countries. The national strategies for combating diffuse nitrogen losses including selection of mitigation measures, areal extent of measures and incentives for farmers to use the measures differ between the Nordic-Baltic countries. Effects of legislation and other incentives to change agricultural practices and hence to reduce N losses from agriculture are first observed by monitoring close to the source of these losses. Consequently, all Nordic-Baltic countries have set up monitoring programmes including small agriculturally dominated catchments where inputs, outputs and loss of N are followed closely at plot, field and/or catchment scale. We explore the connection between political decisions and regulations, provide an overview of measures and incentives used in the Nordic-Baltic countries, and assess the effect of the measures based on data from national monitoring programmes.

1. Introduction

The Baltic Sea is the world's largest body of brackish water (377,400 km^2) and ecologically unique. Due to its special geographical, climatological, and oceanographic characteristics, the Baltic Sea is highly sensitive to external impacts (Leppäranta and Myrberg, 2009; Voss et al., 2011). Human activities, both in the sea itself and throughout its catchment area, have over the last centuries put considerable pressure on its marine ecosystem (e.g. HELCOM, 2002, 2009). Eutrophication is a major problem in the Baltic Sea. Since the beginning of the 20th century, the Baltic Sea has changed from an oligotrophic clear-water sea into a highly eutrophic marine environment with wide-spread algal blooms (Larsson et al., 1985). The abundance of toxic algae populations has also increased, adding to the problem (HELCOM, 2011).

Data on historic N loading of the Baltic Sea are scarce. Even 100 years ago the impact from human activity on nutrient losses was substantial. Natural fertilizers were used in agriculture, and the construction of water supply and sewage systems increased the output of waste to inland and coastal waters (Savchuk et al., 2008). Additionally, the widespread draining of lakes and wetlands which led to a loss of nutrient retention capacity was mainly done at the end of the 19th century and in the first decades of the 20th century (Hoffmann et al., 2000; Schernewski and Neumann, 2005). Using different approaches, two studies have estimated that total nitrogen (TN) loading of the Baltic Sea as a whole over the last 100 years has increased by a factor 2 (Savchuk et al., 2008) or 2.4 (Schernewski and Neumann, 2005). Gadegast et al. (2012) and Behrendt et al. (2008) found that TN loadings from the Oder system increased by a factor 4.6 between 1880 and 1980. The most recent compilation of nutrient loads to the Baltic Sea reports loadings via rivers and coastal point sources of respectively 638,000 t TN yr^{-1} and 28,370 t total phosphorus (TP) yr^{-1} (HELCOM, 2011). Rivers draining the southern cultivated part of the catchment account for the majority of the nutrient inputs to the Baltic Sea (HELCOM, 2004). Many rivers of the north of Sweden and Finland are still largely in a pristine condition (Humborg et al., 2003). A source apportionment for the total riverine TN loading of the Baltic Sea in 2000 reveals that natural background losses accounts for 28%, diffuse losses for 64%, and point source discharges for 8% (HELCOM, 2004). Agriculture accounts for 70–90% of the diffuse TN load (HELCOM, 2011). Following the disintegration of the Soviet Union and the transition

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from state controlled to free market economy, the highly industrialized and centralized agricultural production system in many Eastern European countries collapsed in the late 1980s and early 1990s. In Estonia, e.g., fertilizer use in 2005 was only 13% of the peak in 1987–1988 (Iital et al., 2010). However, the joining of the Baltic countries, Poland and Czech Republic to the European Union (EU) in 2004 has intensified agricultural land use and may significantly increase future diffuse nutrient losses.

Concerns over deteoriating water quality in both freshwater and marine waters have put reduction of agricultural N losses on the political agenda in the Nordic-Baltic countries for several years. The aim of this paper is to provide an overview of important mitigation measures used in the Nordic-Baltic countries and to discuss the effect on N losses as it can be assessed from national monitoring programmes.

2. Materials and methods

2.1. Study area

The Nordic-Baltic countries all lay within the drainage basin of the Baltic Sea either completely: Estonia, Latvia, Lithuania, or partly: Denmark (72%), Norway (3%), Sweden (98%), Finland (89%). The Baltic Sea drainage basin comprises 1,720,000 km^2 and can be divided into a northern boreal region that drains into the Gulf of Bothnia and a southern region that drains into the rest of the Baltic Sea. Climate ranges from sub-polar in the north to oceanic temperate climate in the south with annual mean temperatures from below zero to 10 °C. Annual precipitation ranges from 400 mm to 1000 mm. Topography also plays an important role especially for precipitation amounts, which tend to be greater at high altitudes. In addition, there are land-sea contrasts in temperature and precipitation. The input of nutrients to the aquatic environment is largely dependent on human activities in the catchment area but variations in meteorological and hydrographical conditions also have a significant impact on the amount of nutrients entering the sea. Increased precipitation increases runoff from land, and wet years generally result in increased nutrient losses and inputs from diffuse sources to surface waters. In the northern Baltic Sea region, winter snow and ice cover help to reduce runoff during a large part of the year (HELCOM, 2011). The length of the growing season (i.e. the number of days per year with daily average temperature of at least 5 °C) varies from less than 3 months in northern Sweden to more than 8 months in parts of Denmark and Germany, Fig. 1. The growing season defines the period in which excess nitrate in the root zone can be utilized by plants and thus prevented from leaching. Nitrogen retention by denitrification (the bacterial conversion of nitrate to nitrogen gas) also largely is limited to periods with soil temperatures above 5 °C (Braker et al., 2010). Hydrological pathways and differences in natural nutrient retention capacity play an important role in determining nutrient transfer from land to sea. When comparing nutrient losses from small agricultural catchments in the Baltic and Nordic countries, Vagstad et al. (2004) found that high groundwater contributions in the catchment discharge might lead to lower N losses due to denitrifcation processes in groundwater. Deelstra et al. (2014) calculated the relative contribution of groundwater to total streamwater flow in 34 Nordic-Baltic catchments and found generally a much smaller groundwater contribution in steeper Norwegian catchments compared to more topographically flat Danish catchments.

Despite being neighbouring countries, large differences exist in physiography and thus in crop growth potential (Fig. 1), and in political-economic history and thus in agricultural management (Table 1). Agriculture dominates in the southern part and makes up from 7% of the total land area in Finland and Sweden to 60% in

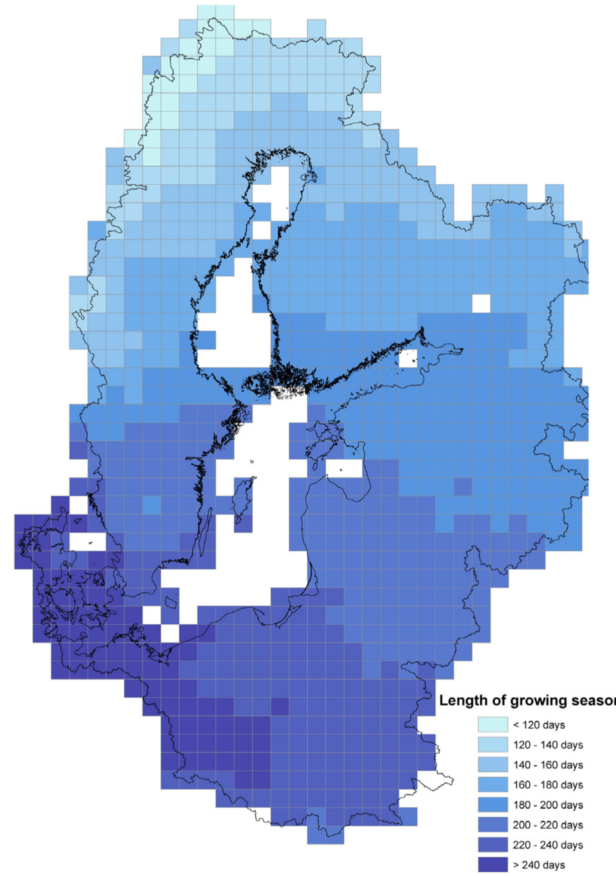

Fig. 1. Length of the growing season (number of days with daily average temperature of at least 5 °C) in the Baltic Sea drainage basin
(data from MARS50, mean values for 1995–2006, JRC, 2013)

Denmark, Table 1. The agricultural production is intensive in large parts of Denmark, Germany, southern Sweden and Finland and to a lesser extent Poland, whereas a more extensive agricultural production is seen in the Baltic States. The agricultural structure differs remarkably between countries: in Finland 58% of the area is owned by small farms less than 30 ha, whereas in Denmark the majority of farms are larger than 100 ha (FAO, 2003; Benoist and Marquer, 2006a,b,c,d,e,f,g).

2.2. Data sources

The review of legislation and implemented measures in the Nordic-Baltic countries presented in this work draws on a number of published or electronically available sources from international institutions including HELCOM (1988, 2002, 2004, 2007, 2009, 2011, 2013), FAO (2003, 2013), Eurostat (2011), the European Commission (1991a,b, 2000, 2011, 2012), the European Environmental Agency (AEE, 2007) as well as results from a recent EU funded research project Baltic Compass (2009–2012) (Baltic Compass, 2012a,b).

3. Results and discussion

3.1. International directives and plans to reduce diffuse nutrient losses

Attempts to reduce agricultural N losses have been on the political agenda in the Nordic-Baltic countries for several years. The increases in N consumption in European agriculture which took