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Climate change and the potential effects on runoff and nitrogen losses in the Nordic–Baltic region

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ABSTRACT

Climatic changes will influence the possibilities for agricultural production (e.g. longer growing season), agricultural management practices (e.g. changes in tillage, fertilization, increased use of fungicides) and runoff conditions, and thereby the losses of nutrients from agricultural fields to the environment. Nitrogen (N) is of particular interest in the Baltic Sea region because of its adverse effects on water quality. This paper gives an overview of the expected climatic changes in the Nordic–Baltic region, and the possible effects of these changes on runoff and N losses. Downscaled climate scenarios are used as a basis for evaluating the potential effects of climate change on hydrology, runoff and N losses. Examples from selected catchments in Nordic–Baltic water quality monitoring programmes, including data from extreme events, are presented and used for an assessment of the required adaptations. The analysis shows that there is a strong relationship between annual precipitation and runoff, and between runoff and N loss. The seasonality of precipitation, runoff and N loss indicate high losses outside the growing season. With climate change, increased precipitation is expected to occur mainly outside the growing season – in September–March – and result in increased runoff and thereby increased N losses. Existing data show that extreme events of precipitation have occurred in all seasons during the monitoring period, and have caused high runoff and high losses of N. With the expected increases in N losses, there is an urgent need for efficient measures to reduce N losses in order to fulfil the requirements of e.g. the EU Water Framework Directive (EU-WFD) and the Nitrates Directive and reduction of greenhouse gas emissions (GHG) from agriculture.

1. Introduction

Nitrogen (N) is an essential element, necessary for high yields in agricultural production systems, but at the same time also an important element in runoff and diffuse pollution of fresh water resources. The agricultural sector must fulfil the requirements set by the EU Water Framework Directive (EU-WFD) (EU, 2000) regarding water quality, which has led to high focus on efficient measures to reduce N losses from agricultural fields to water bodies. The agricultural sector is, like other sectors, also under pressure to reduce greenhouse gas (GHG) emissions. An estimated 60% of the emissions of nitrous oxide (N_2O) are due to agricultural activities. In Norway, agriculture is responsible for 73% of the N_2O emissions (Bye et al., 2014). A rapidly increasing population growth will increase the need for more food production, putting pressure on the available land through increased productivity. This might lead to an increased use of N fertilizer with an increased risk of N-leaching (Goulding, 2000; Korsaeth and Eltun, 2000). Internationally, the term "climate smart agriculture" illustrates the need for agriculture to increase production in a sustainable way, which includes minimizing the environmental impact of N losses to water and air.

Many studies have investigated the relationships between runoff and N loss from agricultural dominated catchments (e.g. Stålnacke and Grimwall, 1999; Deelstra et al., 2011). In an analysis

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of data from 35 catchments in the Nordic–Baltic region, Vagstad et al. (2004) found that differences in dominating hydrological processes to a large degree could explain the differences in N losses among catchments. Povilaitis (2006) found similar results comparing seven catchments in Lithuania. A change in climate (both temperature and precipitation) will affect agricultural production and runoff, and will also influence the risk of N losses. To be able to adapt production methods and minimize environmental impacts, a better knowledge of how N losses will be influenced by changes in hydrology as a consequence of climate change is essential. While it is obvious that changed runoff conditions will influence N losses substantially, the influence of climate change on agricultural management practices (e.g. choice of cropping systems, etc.), and the effect this again may have on N losses, is less known (Rötter et al., 2011; Brevik, 2012).

A number of studies based on data from the Nordic–Baltic monitoring programmes have investigated the effects of agricultural activity on water quality, but few studies have so far focused on the effects of climate change (Deelstra et al., 2011). The aim of this paper is to investigate the potential effects of climate change on hydrology and N losses from agriculture in the Nordic–Baltic region. The data analysis is based on results from the Nordic–Baltic Agricultural Environmental Monitoring Programmes. The following specific questions will be discussed: (i) how will a change in precipitation affect runoff and N loss? (ii) Are changes in the Nordic–Baltic countries expected to be similar or do possible differences require different strategies for adaptation in the various countries? (iii) What are the potential effects of the hydrological drivers related to other drivers for N loss to water?

2. Methods

2.1. Expected changes in climate in the Nordic–Baltic region

The expected changes in temperature and precipitation for the Nordic–Baltic region are derived from IPCC (2007), as well as national reports. Uncertainty related to future GHG emissions together with limitations in general circulation models (GCMs), different methods for regional downscaling, and the time periods for expected changes, all affect the uncertainty in predictions of the future climate (Hanssen-Bauer et al., 2009). Reference is made to selected national reports about climate changes, but we do not compare and discuss the different methods and scenarios used. Mean values and the direction of changes (e.g. whether a reduction or increase in precipitation is expected, seasonal and regional changes, and extreme weather) are important in the evaluation of possible effects of climate change on runoff and on N loss processes as considered in this paper.

For Sweden, the expected changes in temperature and precipitation are presented by (SMHI, 2014), and is based on the mean of nine different global GCMs and two emission scenarios, including the Representative Concentration Pathways (RCPs) 8.5 and 4.5, respectively (IPCC, 2013). RCPs have recently come into use and represent a future energy/atmospheric concentration of GHG which will result in, for 2100, a combination of economic, technologic, demographic and political development. RCP 8.5 represents a very high baseline emission scenario, whereas RCP 4.5 represents a medium stabilization scenario. The other national reports referred to are based on IPCC (2007), where A1B, A2, B1, B2 represent increased, reduced or stabilized emission scenarios. Hanssen-Bauer et al. (2009) give regional overviews of expected changes in temperature, growing seasons, precipitation and snow conditions for Norway based on eight different global models and emission scenarios A1B, A2 and B1 (Nakicenovic et al., 2000; IPCC, 2007). The uncertainty in climate change prediction is taken into consideration by indicating lower, mean and maximum expected future changes. In this paper, the mean values of expected changes are used for the Norwegian case studies. For Latvia, climate change predictions are based on the results of Latkovska et al. (2012) for two emission scenarios (A2 and B2). For Estonia, Keevallik (1998) has predicted monthly changes for the period 2086–2115 with three different emission scenarios and two models. Kont et al. (2003) have used 14 different models for predicting changes for the western and eastern parts of Estonia for 2100. For Lithuania, climate predictions are derived from Bukantis (2007) Kriaučiūnienė et al. (2008) and Jakimavičius and Kriaučiūnienė (2013). These predictions are based on two global climate models and the emissions scenarios A2, A1B and B1 for the future periods from 2011 to 2040, 2070 and 2100, and are carried out for the Neumas River basin, that covers 72% of Lithuania.

2.2. The Nordic–Baltic agricultural environmental monitoring programmes

The study is based on data and experiences from selected catchments in the Nordic and Baltic Agricultural Environmental Monitoring Programmes. In the analysis, monitoring data on runoff, precipitation and N loss from 31 small agricultural catchments in Sweden, Latvia, Lithuania, Estonia, Finland, Denmark and Norway are used. The catchment characteristics and the monitoring methods for runoff and N loss are described by Deelstra et al. (2014). The programmes represent ongoing farming practices as a response to actual weather situations, as well as to political decisions and support systems.

2.3. Analysis of the potential effects of climate change on runoff and N losses

Results from the Nordic–Baltic monitoring programmes are used to: (i) give an overview of the current status of total and seasonal N losses; (ii) establish relationships between precipitation runoff and N losses on an annual and seasonal basis; (iii) document the effects of extreme events on N losses and (iv) analyse the potential effects of expected climate change (as described in Section 2.1) on runoff and N losses from agricultural areas.

The following situations will be investigated:

1. Change in climate and potential effects on runoff and nitrogen losses from the current production system: seasonality is calculated for precipitation, runoff and N losses based on existing monitoring data from the 31 selected catchments. The seasonality is calculated for the periods summer (May–August), autumn (September–November), winter (December–February) and spring (March–April). The same months are used for seasons in all catchments even though differences in the length of the growing season and the onset of the winter season might differ slightly. For some of the analyses, only results from 10 out of the 31 catchments are presented. Changes in future seasonality are discussed in light to the expected changes in climate.
2. Change in climate and the potential effects on runoff and nitrogen losses when agricultural production systems also change: the paper discusses how changes in climate may influence agricultural cropping systems and management practices in relation to risk of N losses. The length of the growing season influences the choice of crop, use of fertilizer, and timing and type of tillage, which again influence the risk of N losses.
3. Change in extreme events and the effect on runoff and nitrogen loss: selected events from the monitoring programmes are used to document effects of extreme events on N losses in different seasons. Timing of events, runoff, transport pathways and N losses (total and concentrations) will be analysed.