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Climate Change Affects Nitrogen and Sulphur Load in Percolated Water from Agricultural Landscapes

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Abstract

Global and climate changes influence the basic conditions for agriculture. Therefore there is not only a demand for a strict climate protection but also for an adaptation of agriculture to changing conditions. For a study region of 60x40 km within the moraine landscape of North-East Germany mainly used for agriculture, water balance, nitrogen and Sulphur loads and crop yields were calculated for the present and for a possible future. The comparison between the Scenario 2050 and the Initial Situation in 2000 revealed significant changes of the water balance (decrease in percolation water, increase in actual evapotranspiration) and the concentration of nitrogen and Sulphur in the percolation water. The crop yields decrease only slightly if the CO_2 fertilizing effect is taken into account. Measures adopted in response to the changing climate conditions to achieve an economically and sustainable agriculture are recommended.

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Keywords: climate change; impact assessment; nitrogen load; sulphur load; water balance; moraine landscape

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1. Introduction

One of the most fundamental questions facing humanity today is how global climate change will impact the terrestrial ecosystems, i.e. the cultivated landscapes. For a sustainable development of rural areas, a highly productive and environmentally sound agriculture plays an essential role. It can be expected that climate change has an increasing impact on agricultural productivity and the environment (Eulenstein et al. 2005; Lana 2013). For European agricultural sector, the entire range spanning from local dramatic losses in crop production to relatively positive effects is predicted (Maracchi et al. 2005; Ewert et al. 2005; Audsley et al. 2006). Especially for the nitrite leaching into the groundwater and the nitrogen gas emission as N_2O into the atmosphere. Another change in water landscape causes prevailing water deficiency for non-production ecosystems (Wessolek and Asseng 2006). Researches always rest on a model that usually bases on roughly discriminated land use types, e.g. cropland/grassland/forest (Rounsevell et al. 2006) with a low spatial resolution, or otherwise selective examinations.

Wessolek and Asseng (2006) predict yields and water balance for North-East Germany with a high temporal resolution. However, the prediction for 2050 is restricted to one crop at two sites with characteristic soil substrates. Model-based research on climate impact on regions is still dominated by agriculture and considers mostly yield development, landscape water balance, nutrient dynamics and nutrient loads or endangerment of habitats separately. There are hardly any comprehensive eco-systemic simulations based on extensive, real site and land use data of an entire landscape section collected over several years.

An analysis of an eco-systemic sensitivity on the agriculture under the actual climate situation of 2000 and under a regional climate change scenario for 2050 (Gerstengarbe et al. 2003) are used as an example. The analysis is based on the current land use, taking extensive field-specific data of a typical agrarian landscape in the partially drought endangered climate of North-East Germany as a representative. In this study a) elements of the water balance, b) nutrient loads and percolation water focusing on nitrate and sulphates and c) performance of agricultural crops were modelled and applied for the study region. As conclusion, climate change impacts on agriculture can be mitigated using adapted and/or new land use systems and management practices.

2. Study region

The Brandenburgian district “Märkisch-Oderland” region is located within the moraine landscape of North-East Germany. The area covers the area about 60x40 km and is situated approximately 50 km east of Berlin (between Berlin and the Oder River). The north-west and the south-west of the study region are parts of sandy-loamy moraine plateaus called “Barnimer Platte” and “Lebuser Platte”, respectively, with about 60 m MSL for both plateaus. The south-eastern part of the study region is located in the valley bottom of the “Oderbruch” region at 5-12 m MSL with mostly clayey alluvial soils.

The recent climate of the study region is a semi-continental climate with a significantly decreased precipitation gradient from west to east. In the study region, the major part of the land is used for agriculture (about 54,000 ha) across 54 farms from 50 to 7,200 ha with 1,085 ha on average. No samples or replications were carried out, but extensive surveys were carried out.Winter cereals are grown on 45% of the arable land of the study region, followed by silage maize and rape with about 9% each, alfalfa with 3% and sugar beet with 2%. Land in the study region that is not used for agriculture is predominantly for forestry and has been excluded in this study.

3. Model and simulation platform

HERMES (for soil nitrogen) and SULFONIE (for soil sulphate), both of which were developed by Kersebaum (1989 and 1995), Willms et al. (2006) and Eulenstein (2008) were applied to assess the consequences of regional climate changes in North-East German landscapes, climatic water balance, the concentrations of both nitrate and sulphate in the percolation water the complex dynamic simulation models. The nitrogen and Sulphur models take into account mineralization, denitrification and transport (by soil water) processes, an atmospheric deposition as well as the uptake by plants. The models operate on a daily basis, with 0.1 m soil depth compartments and confined to the root zone (max. 2 m). Both models contain a layer model for soil water, taking into account a capillary action from below 2 m. The potential evapotranspiration is determined according to Haude (1955) using crop-specific monthly factors.