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Requirements and efficiency of agricultural nitrogen reduction measures in the Federal State of Mecklenburg-Vorpommern (Germany)

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Mecklenburg-Vorpommern is the most north-eastern of the 16 Federal States of Germany, covering an area of 23 200 km2 with a population of ca. 1.6 million inhabitants. About 62 % of the territory is used for agriculture, whose emissions have contributed to the deterioration groundwater and surface water quality. One of the essential aims of the European framework directive (EU-WFD) is the sustainable use and effective protection of all water resources including groundwater, surface waters and coastal waters. According to the status assessment of the groundwater bodies in Mecklenburg-Vorpommern, the achievement of the good status is unclear or rather unlikely for 35 % of all groundwater bodies, mainly due to high nitrate concentrations. Eutrophication from nutrient inputs due to agriculture and atmospheric N-deposition is still one of the most challenging ecological problems of the North and Baltic Sea. Presently, about 80 % of the nitrogen load of the North and Baltic Sea arises from anthropogenic sources. According to a status assessment, all of German water bodies failed the good ecological status in 2009. Therefore, a further reduction of the nutrient inputs into the North and Baltic Sea is required.

We used an interdisciplinary model network consisting of a nutrient balance model, a water balance model (GROWA), a reactive nitrate transport model in soil (DENUZ) and reactive nitrate transport model in groundwater (WEKU) to predict the nitrogen intakes into groundwater and the nitrogen losses to surface waters by 10 different pathways. The most important pathways for diffuse nitrogen inputs into river systems include groundwater drainages, natural interflow, erosion, wash-off and direct atmospheric deposition on surface waters. As point sources the input via industrial effluents, wastewater treatment plants, small sewage treatment plant and separate sewer systems have been considered.

As a first step, a status quo analysis was performed for the whole Federal State of Mecklenburg-Vorpommern with the resolution on 100x100 m. Results indicate that in total 32300 t N/a reach surface waters. Drainage runoff is the most relevant input pathway for diffuse nitrogen inputs into surface waters (ca. 23000 t N/a), followed by groundwater-borne N inputs (ca. 5900 t N/a). N inputs from point sources are contributing only to a minor extent (less than 5%).

A nitrate concentration in the leachate of 50 mg NO_3/L or less was defined as an environmental target value for groundwater protection. With the model the actual nitrate concentrations in percolation water as well as the tolerable N-surpluses needed to meet the environmental target have been calculated, which allows the quantification of the required reduction of N-surpluses from agriculture. As a result, the N balance from agriculture needs to be reduced by 45 % from presently 91000 t N/a to 49500 t N/a to meet this target value for the entire Federal State. For agricultural areas this would correspond to a reduction from presently 65 kg N/(ha*a) to 42 kg N/(ha*a).

The integrated model was subsequently used to calculate on one hand the present nitrogen concentration of the river systems entering the North and Baltic Sea to assess the current status under consideration of the most important diffuse and point sources pathways and the retention in the river systems. On the other hand, the tolerable N-balance from agriculture to meet the environmental targets was determined. Model results show that the target concentrations would be reached for almost all river basins of Mecklenburg-Vorpommern in case the environmental targets for groundwater protection are reached as well.

Conclusively, five nutrient reduction scenarios have been analysed with respect to its effects on the nitrogen pollution of the groundwater and river systems. The most effective scenario, a restriction of the nitrogen surplus from agriculture to 50 kg N/(ha*a), would lead to a reduction of the nitrogen outputs of about 10000 t N/a. The same reduction range can be achieved by a combined application of the individual measures. Still, for many regions of Mecklenburg-Vorpommern this amount would not be sufficient to meet the environmental target.