WATER FLOW AND NITRATE TRANSPORT SCENARIO SIMULATIONS TO DERIVE GROUNDWATER PROTECTIVE FARMING

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Introduction

Water is an essential input for agricultural production. But ground water is strongly impacted by the intensification of land use and food production. The determination of groundwater-protective and sustainable agricultural cropping management systems is of vital importance for regions where groundwater is used for drinking water supply. Since 1987 a large scale agricultural experiment (32 test fields with an extent of 1000 m² each) is being run in Wagna, south of Leibnitz (Styria, Austria), to investigate the impact of growing corn (*Zea mays* L.) as a monoculture compared to crop rotations on nitrogen leaching into the groundwater using different fertilizing schemes. The soil types at the test fields are representative of the regional distribution. Since 1992 nitrate leaching to groundwater is monitored using different types of lysimeters in the test fields. Soil water and nutrient transport models, which are calibrated on local lysimeter data, may be used as decision support systems to identify the best groundwater protective cropping systems for different soil types and soil depths, which is the objective of this paper.

Materials and Methods

Based on Lysimeter evaluation results the numerical soil water balance model SIMWASER (Stenitzer, 1988), and the nitrogen transformation model STOTRASIM (Feichtinger, 1998) were validated (Fank et al., 2004). Meteorological data have been measured close to the test site since 1976. Detailed soil physical investigations show 8 different soil types, their spatial pattern as well as the thickness of the fine grained soil laying above the quaternary gravelly and sandy sediments were derived from geophysical investigations. ARC/GIS was used to intersect the different soil types, the areas with different soil thickness and the test fields with different cropping systems to delineate 278 individual "hydrotops" (unique combination of weather, cropping system, cultivation, soil thickness and soil type). The modelling system was applied to compute the leaching of nitrogen from every individual "hydrotop" to the groundwater (Kupfersberger et al., 2008). 5 scenarios (corn as a monoculture), KM1, KM2, KM3, KM4, and KM4/a with varying amount of N-fertilizer (Fig. 1) and different fertilizing schemes (liquid manure, mineral fertilizer, mixed fertilization) were defined. The modelling system has been used to calculate groundwater recharge and nitrogen concentration in seepage water close to the groundwater table (laying 3.5 to 5 m below surface) on a daily basis for the period 1976 - 2006. Here, we analysed the results for the 1987-2006 time period.

Results

Long term scenario simulations show the effect of different amounts of fertilizer on nitrate concentration in the seepage water, while groundwater recharge (330 mm a^{-1}) is little affected.. The simulated time series of nitrate concentrations between 1987 and 2006 on a daily basis show strong variations over time: depending on the weather conditions the nitrate concentration in the seepage water of scenario KM2, as an example, fluctuates between 20 and 95 mg l^{-1}, at a mean level of 44 mg NO_3 l^{-1}.

Taking the legal nitrate concentration for drinking water (50 mg NO_3 l^{-1}) as the target value for the mean nitrate concentration of the seepage water, scenarios KM1, KM4, KM4/a and KM2 are groundwater protective farming systems. Reducing the level of N-fertilization below the optimum (scenario KM4/a; Fig. 1) leads to only little reduction of nitrate concentration in the seepage water, but to a large reduction of dry matter (and of corn yield). Summarizing modelling results, the risk of different soil types on nitrogen leaching is being detected (Fig. 1). As a mean value for the hytrotops of the whole test field an amount of 150 kg ha^{-1} a^{-1} (scenario KM2) shows a mean long term nitrate concentration in the seepage water of about 50 mg l^{-1}. For a loamy sand the optimum N-fertilization level can be found at about 120 kg ha^{-1} a^{-1}, for a sandy loam at 160 kg ha^{-1} a^{-1} respectively.

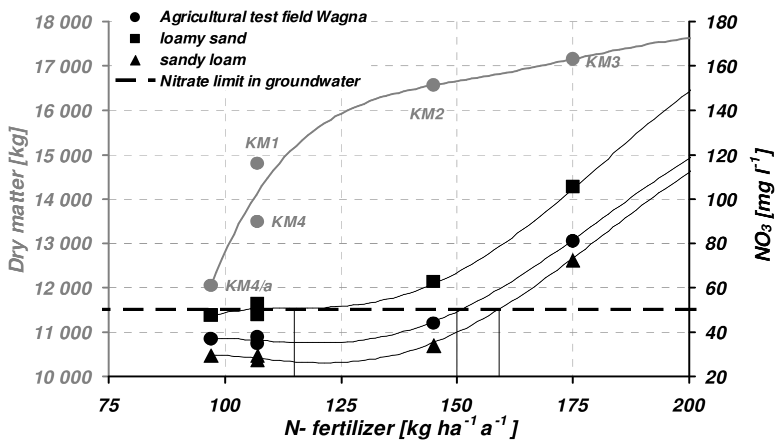

Fig. 1. Dry matter simulated depending on N-fertilizer amount. Mean nitrate concentration expected in seepage water in relation to the permitted value in drinking water as a mean for the test field and for two soils

Conclusions

Final results are used to advise the farmers on the use of nitrogen to get optimal yield taking into account the local requirements for groundwater protection in an area intensively used for drinking water supply. Under the same conditions of farming and climate, the maximum N-fertilization rates compatible with the 50 mg NO_3 l^{-1} limit in seepage water vary strongly according to soil type. In the long run every soil type has its typical yield potential; the amount of optimized N-fertilizer is closely correlated to the amount of nitrogen taken up from the field by crops. A N-fertilization beyond this optimized value will lead to little increase in corn yield but to a sharp increase of the nitrate concentration in seepage water recharging the groundwater.

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