Nitrogen leaching from a grass-dominated catchment simulated with the Daisy model

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Introduction

Models are fundamental tools for quantifying the effects of regulations imposed on agriculture in order to reduce nutrient losses.

In this study we demonstrate how the 1-D mechanistic soil-vegetation-atmosphere model Daisy can be used for calculating root zone losses of nitrate at the catchment scale.

Materials and methods

In 1989 Denmark introduced a programme with intensive registration of agricultural management at the field scale in five small catchments (5–10 km²). Choice of crops, date of field managements, fertilizer consumption, and yield are reported by the farmers in the catchment in a questionnaire survey. Selected fields in the catchment are instrumented with suction cups below the root zone and piezometers for monitoring of nitrate concentration and groundwater level (figure 1). At the outlet of the catchment nitrogen concentrations and water discharge are measured. The catchment area of the brook Bolbro Bæk is 7.6 km². Soil types are mainly loamy sand with a large humus area in the north-western part of the catchment. Arable land constitutes 7 km², of which about 25% is grass and grass/clover (figure 3). The groundwater level is high, about 1.5–2 m below soil surface and may rise seasonally to 0.5 m below soil surface. The Daisy model was calibrated towards root zone nitrate concentration (figure 2) and nitrogen yield for the eight selected fields for a period of 14 years. A total of 400 relevant spatial combinations of soil type, crop rotation, and groundwater level were defined and simulated with Daisy for the period 1990–2007.

Figure 1. The orange dots show the selected fields and the green dot show observing station in the brook.

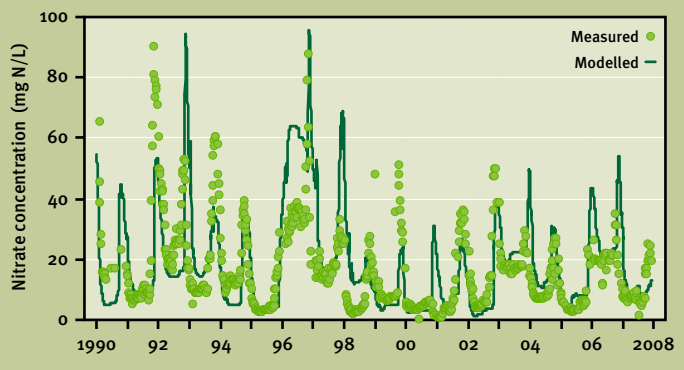

Figure 2. Modelled and measured nitrate concentration.

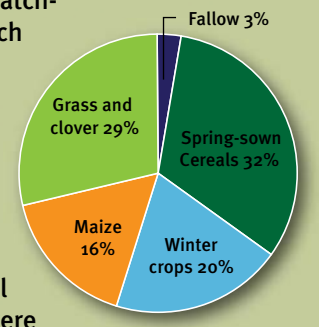

Figure 3. Crop distribution.

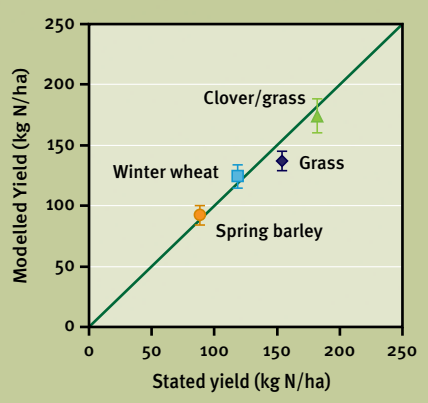

Figure 4. Harvest yield. Error bars show the 95% confidence interval (2×SE).

Results

The simulated average yields are in accordance with the yields reported by the farmers for the four main crops (figure 4). Similarly good results are obtained by comparing modelled net precipitation to stream water discharge (figure 5). The curves show the same dynamics, but the modelled net precipitation for the agricultural land is higher than the stream water discharge. This is due to the extra evapotranspiration from wetlands and scrubs. The simulated root zone nitrate losses from the agricultural land are higher than the measured nitrate transport in the stream (figure 6), which is a result of the high nitrate reduction taking place during groundwater transport. Agricultural nitrate losses are reduced throughout the period. The two very dry years 1992 and 1996 are the cause of the high simulated nitrate losses in 1993 and 1997. During dry years nitrate is accumulated in the soil. Some of this nitrate is lost from the root zone when the soil is rewetted to the extent that percolation occurs. The last peak level in nitrate losses in 2007 is due to a combination of high manure application in the dry year 2006 followed by a high net precipitation in 2007.

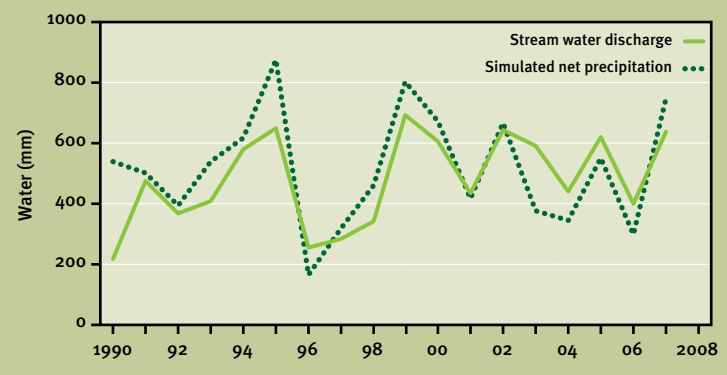

Figure 5. Simulated net precipitation and stream water discharge.

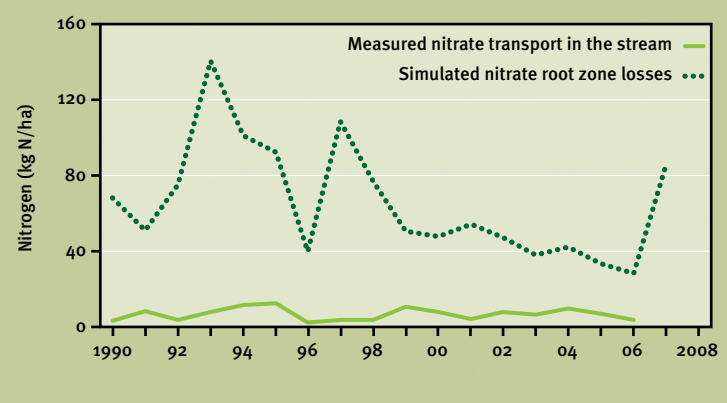

Figure 6. Simulated root zone nitrate losses and measured nitrate transport in the stream.

Conclusions

The study demonstrates that the model concept is a tool well suited for analysing and predicting the effect of agriculture on water quality.