Modelling the hydrological behaviour and long-term nitrogen losses of artificially drained lowland catchments

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Background and Objectives

- Artificial drainage is a common agricultural practice to improve soil moisture and aeration conditions, but it can lead to increased diffuse pollution of surface waters.
- Furthermore, preferential flow may result in an unexpected fast response of the tile drains.
- As tile drainage has rarely been explicitly included into distributed hydrological models, the model MHYDAS-DRAIN was developed to account for anthropogenic impacts and a fast flow component in small catchments.

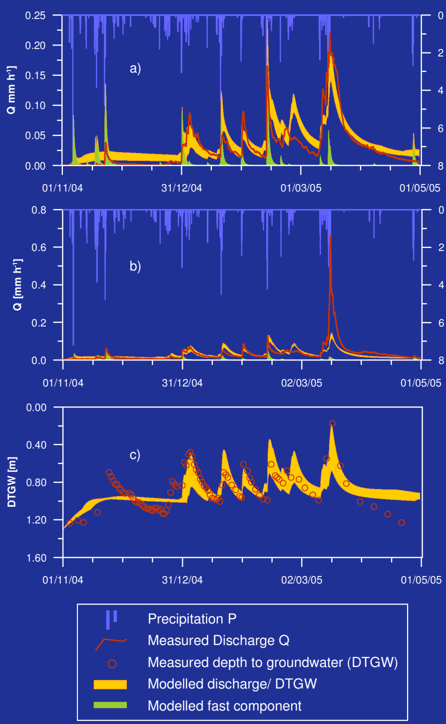

Figure 4: Precipitation, measured and modelled total and fast discharge Q and Q_{fast} a) at the collector drain outlet and b) in the ditch; c) measured and modelled depth to groundwater during the winter half-years of 2004/05 (calibration period).

Results & Discussion I

- A global sensitivity analysis may be used to identify suitable calibration parameters for each model compartment (Fig. 3).
- Discharge rates and groundwater levels can be modelled well both during the calibration (Fig. 4) and validation period (not shown).
- However, snow melt events could not be captured satisfyingly.

Regression NO_3-N-Losses L:

$$L_{drain} = 0.146\, Q_{drain} - 0.156\, Q_{drain,\ fast} \qquad R^2 = 0.85 \qquad \text{(Eq. 1)}$$

$$L_{ditch} = 0.175\, Q_{ditch} - 3.374\, Q_{ditch,\ fast} \qquad R^2 = 0.86 \qquad \text{(Eq. 2)}$$

Thanks: Marianne Kietzmann, Tilo Hartwig and everyone else who helped with field & laboratory work.

The Study Site

- Small, extensively tile-drained pleistocene catchment in North-Eastern Germany (ø P = 664 mm, ø PET = 561 mm) under arable land use with automatic sampling stations (Fig. 1) for hydrology and hydrochemistry.

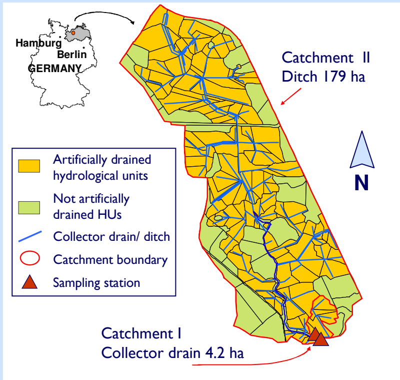

Figure 1: Delineation of the study catchment into hydrological units (HU).

- Analysis of daily to weekly composite samples for nitrate (NO_3^-) using ion chromatography.

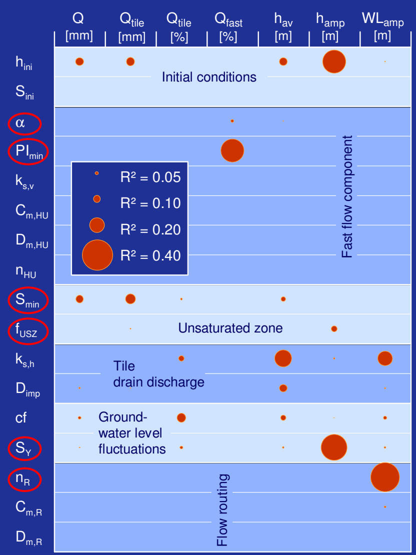

Figure 3: Results of the sensitivity analysis. The radii of the bubbles are proportional to the coefficients of determination R^2, and all shown correlations are significant at $p < 0.05$. Ordinate: model parameters; abscissa: model outputs.

Conclusions & Outlook

- MHYDAS-DRAIN is a suitable model for catchments dominated by tile-drainage.
- However, to increase the reliability of the model estimates, wetter years and a suitable snow melt routine should be included.
- Overall, tile drained fields will have to be addressed with priority if a reduction of the diffuse nutrient pollution in lowland catchments is intended.
- Therefore, management approaches for tile-drained areas need to be developed.

The model MHYDAS-DRAIN

- Spatially distributed model (Tiemeyer et al., 2007) based on hydrological units derived from tile drainage and land use maps and connected to the drainage network.
- Tile drain discharge is assumed to be composed of preferential and matrix flow (Fig. 2), which are calculated with the Hooghoudt-equation and a transfer function approach.
- Estimates of discharge rates and NO_3-N losses for a range of meteorological conditions were derived using a regression approach and disaggregated long-term meteorological data.

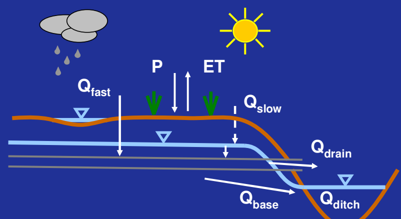

Figure 2: Conceptual model for MHYDAS-DRAIN

Results & Discussion II

- The fast flow component tends to reduce nitrate-nitrogen losses (Eq. 1-2).
- This regression model (Eq. 1-2) was significantly improved by taking into account modelled fast flow component in addition to the measured Q.
- Higher NO_3-N losses than measured so far have to be expected during wetter weather conditions in winter (Fig. 5).
- Artificially drained areas dominate the hydrology and the solute loss patterns.

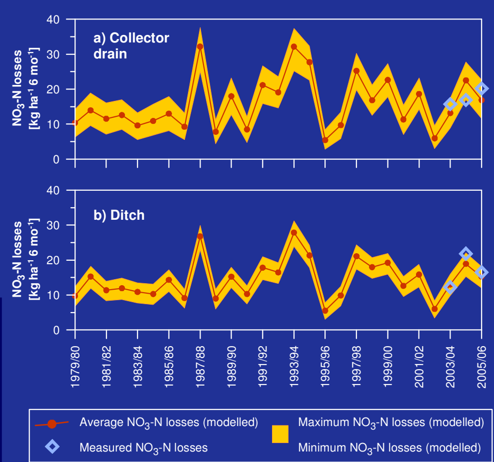

Figure 5: Modelled minimum, maximum and average nitrate-nitrogen losses during the winter half-years at the collector drain (a) and in the ditch (b). Measured nitrate-nitrogen losses for 2003/04 to 2005/06.

References: Tiemeyer B., Moussa R., Lennartz B. and Voltz M. 2007. MHYDAS-DRAIN: A spatially distributed model for small, artificially drained lowland catchments. Ecological Modelling 209: 2-20.

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