Hybrid modeling of nitrate fate in large catchments using fuzzy-rules

Sven van der Heijden, Uwe Haberlandt

Motivation and Aims

The presented study deals with nitrate fate modeling in large catchments as a possible field of application for fuzzy-rule based modeling (FRBM), with special focus on the applicability for decision support. FRBM permits the creation of simple, efficient, easily understandable and interpretable models, which show acceptable accuracy in their results. The chosen approach is a hybrid meta-model. This means the generation of the fuzzy-rules is achieved through training with data produced by a process-based model (SWAT), and the subsequent coupling with a water balance model.

Methods and Data

Step 1: Setup of the process-based model SWAT (Neitsch et al., 2005) and production of the training data (Upper Leine catchment, ~1,000 km²).

Fig. 1: Study area.
- Data: Soil map of Germany 1:1,000,000, CORINE Landcover, climate and precipitation network of the German Weather Service (DWD), SRTM DEM 90 m
- Calibration and validation employing five discharge gauges and three water quality gauges (Fig. 1).
- Simulation on monthly time-steps over 25 years.

Step 2: Identification and selection of variables influencing the nitrate pathway.
- Selection on the basis of two criterions: strength of the influence and availability of measured data

Step 3: Development of the fuzzy modules.
- Physically meaningful splitting of the nitrate pathway into three parts: 1) vadose zone, 2) groundwater, 3) watercourse (Fig. 3)
- For each of the three modules: set-up of a training database with the chosen variables, choice of the rule number, training of the rule system using simulated annealing (discrete, non-linear optimization method)

Results and Outlook

- Calibration and validation of SWAT for the water budget (daily) and nitrogen load (monthly) gives good results.
  → SWAT reproduces the real catchment dynamics well and thus can be employed to produce training data (Fig. 4).

- For development the fuzzy modules should be employed coupled to an a priori calculated water balance data base to allow ad-hoc calculations of scenarios.
  → Once fuzzy rules for a study area have been set up, land use change scenarios, fertilization strategies and the like can be calculated easily, without having to run the process-based model again.
- In a second step it will be evaluated how an online-coupling with a water balance model can be realized and how robust the fuzzy rules are for regionalization.

Literature