NITROGEN MODELLING FROM FIELD TO WATERSHED AND REGION

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Introduction
Nitrogen dynamics and its simulation is a topic for different actors at various scales. Farmers are mainly focussing on short-term behaviour at the field scale to optimize nitrogen fertilization. Water suppliers, watershed managers and policy makers are more interested in long-term analyses at a watershed or regional scale with emphasis on land use planning and environmental issues, such as water quality. Models of different complexity exist to simulate nitrogen dynamics at different scales. However, the complexity of a model has to be optimized regarding their structural error and their parameter error. This has to consider the uncertainty of input data at the different scales but also the purpose of modelling.

Modelling at field scale
Finding a nitrogen fertilization level optimal for agricultural production is still a challenge because the temporal behaviour of nitrogen supply from soils as well as of the demand from crops has to be considered. Using models for fertilizer recommendations under operational conditions is not very common in agriculture. Only few examples can be found in different countries (e.g., Kersebaum & Beblik 2001, Melkonian et al. 2007). The reasons are mainly because often the input requirements of models developed at a plot level are quite demanding, especially for soil characteristics. General soil information from soil maps is often not sufficiently precise at the field scale. During the last decade the agro-technological development allows the spatial variable application of nitrogen fertilizers according to a demand which is determined at the sub-field level. Considering spatial variability within fields requires soil information with a high spatial resolution. Consequently, several techniques to obtain high resolution maps of soil properties were developed. However, the improved data situation in turn requires an increasing sensitivity of models for spatially variable inputs. It is well known that the spatial and the temporal scale are closely linked together: if a high spatial variability, which can be observed even within very small distances, is to be explained with a model, the chosen approach needs to consider processes with a high temporal resolution. On the field scale, daily time steps are commonly used. At the field scale, models using net mineralisation approaches were successful assuming a spatially uniform distribution of crop residues and fertilizers. However, they might fail at a lower scale, where e.g. the spatial distribution of crop residues and mineral fertilizers is heterogeneous and where rapid microbial biomass dynamics cause a spreading in the spatio-temporal behaviour of processes. Coupled C/N models are more suitable to reflect the rapid processes of mineralization and immobilization. However, such a high resolution in space and time is not required to help farmers optimizing their nitrogen management. The uncertainty to predict the crop nitrogen demand during the season is another major problem to be solved. In some cases processes on the sub-field scale need to be considered. Structured fields for row crops often provide different conditions for water infiltration, temperature distribution and dependent processes such as organic matter mineralisation on a small spatial scale. This is even more the case, if an uneven distribution of irrigation water is used for the cropping system. 2-dimensional modelling approaches for vegetable roots (Pedersen et al. 2009) or for soil temperature in asparagus ridges (Gräfe 2005) have been applied to consider the effects of the structure on crop growth. Even 3-dimensional approaches are applied to simulate root systems and nutrient uptake of row crops (e.g., Wu et al. 2007).
Topography has an impact on the radiation input, which in turn affects soil temperature, a major driving factor for nitrogen transformation processes, or crop growth. Reuter et al. (2005) showed effects on cereal growth within a hummocky field. Lateral fluxes of water and nitrogen may occur through interflow over distances of several meters. However, detailed information on the physical, chemical and geometrical properties of soil horizons is required, which is laborious to obtain.

**Modelling at catchment and regional scale**

Modelling nitrogen dynamics at catchment or regional scale is mainly linked to the use of hydrological models. Although a large number of complex models exist for the pedon scale, their input requirements do not match the scarce data availability at the regional scale. At a medium scale, complex nitrogen process models were linked to hydrological models, e.g., DAISY and MIKESHE (Styczen & Storm 1993). SWAT-N (Pohlert et al. 2007) or INCA (Wade et al. 2002) use more simplified descriptions of soil and crop growth processes. However, with increasing size of the area, input data required for nitrogen models get increasingly uncertain and generalized. Remote sensing has long proven its value for acquiring spatialized data on land use. However, it is not an operational way to generate spatial information on management practices for large areas. Moreover, this tool will obtain only partial knowledge of practices, since many technological options, e.g. for fertilizer use, are available which cannot be detected remotely. Management data from administrative surveys are often not available to public bodies for processing.

Another problem for modelling large areas is the lack of data for calibration and validation. Nitrogen concentrations measured in surface and groundwater bodies can only be used if the response to the management applied to adjacent fields is relatively fast (e.g. shallow groundwater level or drained areas) and the input requirements, e.g. for crop rotation and management, are covered by historical data for the respective period. This limits the size of a catchment which can be used for calibration, since the measured concentration at the outlet reflects a mixture of leached nitrogen from different time periods at different locations. Even if a removal of nitrogen in the aquifer is assumed for transit times larger than 50 years, these 50 year period can usually not be covered by existing data. Despite this fact, many studies show comparisons of measured and simulated concentrations at gauges, even though the size of the catchment indicates travel times of several decades or even centuries.

For larger scales, robust model approaches are preferred which are less sensitive to uncertain inputs. An uncertainty analysis can give information on the usefulness of a complex process model for a certain scale. Detailed management data is usually not sufficiently available for large areas. Therefore, a lower temporal resolution should be preferred and rapid processes need to be modelled in a simplified way.

**References**


