Models to predict nitrogen mineralization in soil

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Abstract

Modeling N mineralization in soil may serve both scientific and practical interests. Over the last fifty years, various models have been proposed to describe N mineralization. However, most of them have to be considered as research tools and few are proposed to predict N supply by soil under actual agro-ecological conditions. Development of models requires a strong cooperation between modelers and experimentalists; models have to be validated in the field and calibrated under various experimental conditions before their use as predicting tools.

WHY TO USE MODELS?

Nitrogen mineralization is one of the most important processes among N microbial transformations in soil. It influences N availability and N uptake by plants and may have consequences for N losses through runoff, leaching and denitrification. The respective importances of mineralization and humification processes are determined by the dynamics of soil organic matter. The soil N cycle is complex due to: (i) a synchronous occurring of different N microbial transformations (e.g. mineralization and immobilization or denitrification and immobilization); (ii) environmental influences (e.g. temperature, moisture, aeration) and agricultural practices. This complexity makes it necessary to analyze the N cycle in soil using mathematical or simulation models.

Models are of a scientific interest (Powlson, personal communication; Jenkinson and Smith, 1988). They can be considered as a tool for organizing knowledge. They allow to obtain a better conceptual understanding of complex problems and to test new concepts and hypothesis. They can be used to show gaps in present knowledge and promote new research strategies.

Models might also have a predictive value and can be useful to test changes and scenarios, for example, models to determine optimal strategies of N fertilization (Germon *et al.*, 1989; Jensen and Paustian, 1989; Neeteson *et al.*, 1989). On the other hand, expert systems for crop management (e.g. cotton, maize) which include both plant and soil simulation models provide insights about cropping systems (Kroll, 1992) and assist in the development of guidelines for best management practices.

In: J.J. Neeteson and J. Hassink (eds.), 1994. Nitrogen mineralization in agricultural soils; proc. symp. held at the Institute for Soil Fertility Research, Haren, NL, 19-20 April 1993. AB-DLO Thema's, AB-DLO, Haren, pp. 241-243.

If models are a useful tool to understand and simulate complex transformations, they remain an imitation of a real system and cannot be a substitute for experiences and investigations.

WHICH KIND OF MODELS?

Since the forties different models have been published to describe or simulate N mineralization in soils (Tanji, 1982; Jenkinson, 1990; Molina *et al.*, 1994). Models differ in both type and complexity, but are characterized by the purpose for which they have been developed (de Willigen, 1991): empirical models (regression models) which fit a mathematical function to a set of data and mechanistic (deterministic) models which simulate one, several or all N transformations in soil. Mechanistic models include organic matter dynamics models (Molina *et al.*, 1994) and biological (e.g. food web) models which are concerned with N dynamics on a relatively short time scale (within years) or with annual N mineralization on a relatively small spatial scale (laboratory experiments, plots within fields...) (Hunt *et al.*, 1987; de Ruiter *et al.*, 1993).

Disadvantages of empirical models are their static nature: the re-calculation of coefficients and parameters is necessary if different sets of data are considered. By contrast, the dynamic nature of mechanistic models takes into account various conditions (e.g. environment, soil, practices) (Godwin and Jones, 1991) and integrate the notion of time.

The complexity of organic matter dynamics models depends on the number of organic functional pools considered. N mineralization has been described using one, two or several organic pools (Jenkinson, 1990). However, some models of decomposition (Bosatta and Agren, 1985) consider organic matter as a continuum. Pools are defined by their stability and position in the network (Molina *et al.*, 1994). The rates of C and/or N fluxes between the different pools has been described using first-order kinetics (Van Veen and Frissel, 1979) and/or Michaelis-Menten kinetics (Hunt *et al.*, 1985). While N mineralization has been simulated with one active pool (e.g. potentially mineralizable N proposed by Stanford and Smith in 1972), recent models are more complex and consider the role of the living component (e.g. microbial biomass) and the links between C and N transformations (McGill *et al.*, 1981; Molina *et al.*, 1983; van Veen *et al.*, 1984, Nicolardot *et al.*, 1994).

Most of the proposed models have to be considered as research tools and cannot be directly applied to answer practical problems. However, development of too simple models may induce the omission of important parameters and may present a limited interest if they cannot be used for various conditions.

LIMITATIONS OF MODELS

Modelers and users of models must be aware of the validity and limits of their tools. In preference model's components (e.g. parameters, coefficients, pools) must have a chemical, physical and biological meaning (Molina *et al.*, 1994).

The spatio-temporal scale for which the model has been designed has to be checked. Some models have been made to describe small-scale (e.g. incubation experiment) or large scale (e.g. regional models) systems. Another element of model's applicability is the resolution considered; some models properly describe long-term dynamics, but are unable to account for short-term evaluations (e.g. fast immobilization or re-mineralization).

N mineralization models have to be validated with field experiments under various soil and environmental conditions to be of practical use. Numerous field experimental data, especially if they include tracer data (e.g. ^{15}N), will allow to improve the validity and performance of the model (Nicolardot and Molina, 1994). Finally, some soil models do not consider plant growth; their use to predict nitrogen mineralization under field conditions will require a link with plant and water balance models.

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