Nitrate retardation in a Ferralsol from New Caledonia : consequence on nitrate leaching beyond the rootzone using the WAVE model

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Retardation mechanisms can be especially important in highly weathered soils that hold high levels of iron and aluminium oxides with positive variable surface charges. These mechanisms have to be taken into account to predict the fate of anions such as nitrate through the soil. In subtropical and tropical regions, the highly weathered soils are widely distributed. Because of the abundant rainfall and high temperature, this type of soil is considered as one of the most important agricultural soils in the world. The aims of the paper is therefore i) to determine the retardation factor for nitrate in a highly weathered Ferralsol from New Caledonia; ii) to use this factor in the WAVE model to examine its ability to predict the fate of nitrate through the soil and assess the importance of retardation.

On Maré Island in New Caledonia the risk of groundwater pollution by nitrate is expected to be high because of heavy use of nitrogen fertiliser coupled with high rainfall rates and permeable soils. However, Ferralsols from Maré are variably charged and can retard non-specifically adsorbed anion transport such as nitrate. A three year field experiment was carried out to monitor water and nitrate movement through soil under different agricultural practices.

In a previous paper (Duwig *et al.*, 1999), we presented and validated a simple methodology using sectionable columns, called Perroux tubes, to measure the retardation of anions during unsteady flow under unsaturated conditions. Here we used this method to determine the entire nitrate isotherm of the different horizons of the soil profile. These are characterised by different organic matter contents. High retardation values (1.15 to 2.05) were found in deeper horizons with low content of organic matter whereas these values remained low in surface horizon (1.10). In deeper horizons, retardation varies with nitrate concentration of the input solution (5 to 1000 ppm $N\text{-}NO_3^-$).

The field data were used to examine the ability of the WAVE model (Vanclooster *et al.*, 1995) to predict the fate of surface applied nitrogen fertiliser. WAVE is a holistic model which is mechanistic and deterministic, based on full numerical solution. These types of holistic models, while being more complex, still face limitations in terms of parametrisation and validation. Values for about half of the parameters were measured in the field or in the laboratory. Reactive solutes are considered in the model by assuming a linear isotherm, and the distribution coefficient for nitrate was inferred by using results from our Perroux tube experiments. Appropriate values for the remaining parameters were obtained from the literature and some of them (organic matter turn-over parameters, crop water and nutrient uptake) were adjusted using field data from the year with the largest number of data (1996), which was also the wettest one (2173 mm of rainfall). Measurements and simulation of water content, nitrate concentrations at different depths, cumulative drainage and nitrate leaching at the base of the rootzone of a corn plot were compared by means of statistical and graphical

criteria to assess the model performance in a deterministic context. The extrapolation capacity of WAVE was then evaluated using data from the same corn crop in 1995, which was a much dryer year (1366 mm). Standard sensitivity analysis was done to determine the relative importance of each parameter.

The nitrate retardation factor was found to be a sensitive parameter towards cumulative nitrate leaching, for both years. Nitrate concentrations and cumulative leaching at the base of the rootzone were simulated, with and without retardation factor (Figure 1). Sorption process not only retards the arrival of the peak and increases the amount of nitrate stored in the soil profile but also decreases the peak height. This has a direct consequence on nitrate leaching because at the peak dates, there were heavy rainfall 490 mm between 23/02 and 15/03/1996, and 180 mm between 30/01 and 3/02/1995). Cumulative nitrate leaching was reduced by 38 % in 1996 and 20 % in 1995 thanks to sorption on soil particles and retardation of nitrate transport.

By assuming a correct calibration of the WAVE model, we could determine the extent to which nitrate retardation obtained through independent measurement could be used to describe observed behaviour in the field. WAVE also allowed us to assess the importance of this process in the loss of nitrate beyond the rootzone. Simulations could be improved by taking into account variations of retardation with input concentrations into the model.

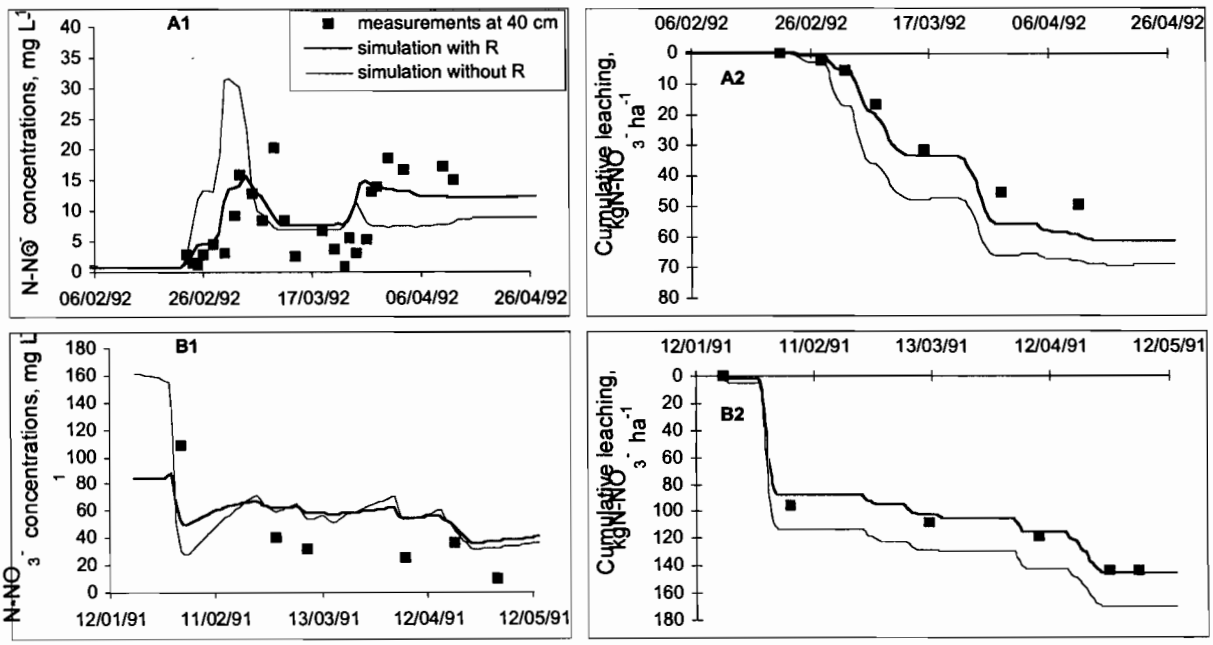

Figure 1 : Measured and simulated nitrate concentration in 1996 (A1) and 1995 (B1) and cumulative leaching at 40 cm deep in 1996 (A2) and 1995 (B2), with and without retardation

References

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