

## 2. Sustainable Agriculture: Cation Movement

### Nutrient Balance for Cropping Systems Based on Legume Green Manures in Oxisols and Ultisols

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#### Objectives

The objectives of this study are 1) to develop cropping sequences using legume green manures which keep losses of Ca, Mg, K, and  $\text{NO}_3$  to economically and environmentally sound levels, and 2) to develop models that describe the losses of Ca, Mg, K, and  $\text{NO}_3$  under different soil and climatic regimes and to define the input data required for these models.

#### Procedure

An experimental area has been established at UEPAE/EMBRAPA, Manaus, Brazil. The soil and climatic regime at Manaus is nearly ideal for this study. The climatic regime is favorable for continuous crop production: precipitation is greater than potential evapotranspiration, so leaching potential is high but not excessive. The soil structure is favorable for deep rooting provided the chemical limitations are ameliorated by liming. The erosion potential is appreciable but not excessive. The Oxisols and Ultisols furnish superior experimental soils for developing cropping systems with acceptable losses of Ca, Mg, and K. This is because the total of these elements is usually small enough that any appreciable loss can be measured over a period of a very few years.

Rotations of legume green manure and corn have been implemented, and soil hydraulic properties measured. Collection of soil samples with depth have been initiated. Soil pH in water and KCl, exchangeable ions, and  $\text{NO}_3$  analyses are being performed.

A method for describing uptake and leaching of  $\text{NO}_3$  is being developed. Another model has been developed to describe the uptake of Ca, Mg, K, and  $\text{NO}_3$  for individual roots (Bouldin, 1989). The resulting models will be combined and expanded to describe the uptake and leaching of these ions.

#### Results

The goal of this program is to collect the necessary data for a nutrient balance sheet for rotations of legume green manure and corn in the humid tropics. During the past 14 months, two corn crops and two legume green-manure crops have been grown on the experimental area. Soil water tension has been recorded in both fallow and cropped plots. Field data needed for a water release curve,

and data on unsaturated conductivity have been collected. Three sets of soil samples to a depth of one meter have been collected, and some parameters have been measured. This field work continues.

Laboratory studies of soil samples taken at CPAC and Manaus showed negligible  $\text{NO}_3$  sorption in the surface 30 cm, but sorption increased with depth. In the Manaus samples, at a depth of about one meter, 40 to 60% of  $\text{NO}_3\text{-N}$  was sorbed when soils contained about 100 kg/ha of  $\text{NO}_3\text{-N}$ .

A relatively simple water flow model has been developed as the first part of a model to describe base cation and nitrate loss. The model represents nitrogen mineralization, transport and  $\text{NO}_3$  sorption. Experiments at CPAC have routinely included  $\text{NO}_3$  analysis of soil samples to a depth of as much as two meters, so some of this data was used to evaluate the model. Data was taken from fallow plots in which different green manures had been incorporated at the beginning of the previous dry season (Carsky, 1989).

During the dry season, the plots were irrigated periodically, and considerable  $\text{NO}_3$  accumulated. During the wet season,  $\text{NO}_3$  leached fairly rapidly from the upper 30 to 45 cm of soil and accumulated below 90 cm, indicating that  $\text{NO}_3$  was sorbed in the lower portions of the soil profile (Figure 1). Data were collected 203 to 354 days after incorporation of the legume green manure. Precipitation during this period was 134 cm. Using the model gave an estimated nitrogen mineralization of 80 kg N/ha. Leaching loss at 180 cm was 60 kg N/ha. While this model is preliminary and results should be interpreted with caution, they do indicate that  $\text{NO}_3$  leaching was very sensitive to estimated  $\text{NO}_3$  sorption and relatively insensitive to estimated water movement. In fact, to agree with experimental results, the model must include  $\text{NO}_3$  sorption increasing significantly with depth. Similar results were obtained using data from both wet and dry seasons at CPAC and from Manaus.

#### Conclusions and Implications

Preliminary observations and model results indicate several important implications for management of N and green manures. First, anion sorption reduces the hazards of  $\text{NO}_3$  leaching. In effect it retards the rate but does not stop leaching. Because of differences in the degree of sorption with soil depth,  $\text{NO}_3$  tends to accumulate below 45 to 60 cm and only slowly moves beyond this point. Second,  $\text{NO}_3$  in the lower part of the soil profile presumably will be available to plant roots growing into this zone. However,  $\text{NO}_3$  efficiency probably will be lower for the subsoil than the upper zone because  $\text{NO}_3$  sorption reduces the mobility of  $\text{NO}_3$  and hence its movement toward the plant roots by mass flow or diffusion. Perhaps one green-manure crop could supply nitrogen for two nonlegume

crops with modest nitrogen demand by using the “storage capacity” associated with  $\text{NO}_3$  sorption. Most of the current systems using green manures are based on a rotation of green manure and nonlegume crops. This means that cropping time allocated to the green manure must be approximately equal to the cropping time allocated to the nonlegume. Perhaps a rotation of legume green manure, nonlegume, nonlegume is feasible if the second nonlegume is deep rooted and the green manure adds sufficient N for both crops.

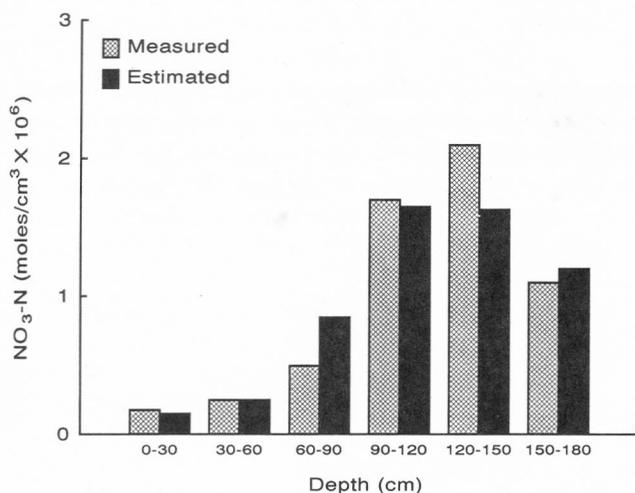


Figure 1. Measured and estimated concentration of  $\text{NO}_3\text{-N}$  in specified layers of soil at day 354.

### Literature Cited

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