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A QUANTITATIVE ANALYSIS OF THE VARIABILITY IN  
THE ACTIVITY OF NITRIFYING ORGANISMS IN A SOIL UNDER PASTURE

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## ABSTRACT

Variability in the inputs, outputs and transformations of mineral N under field conditions makes the predictive modelling of the leaching of soil nitrate very difficult. In an attempt to understand and quantify this variability, the activity of nitrifying organisms in the Tokomaru silt loam (a Typic fragiaqualf) under pasture was measured using a short-term nitrification assay (SNA). Spatial dependence of the variability in SNA was examined using geostatistical methods, and the effect on SNA of soil pH change through liming, and of seasonal changes in soil temperature and moisture were investigated.

Nitrifier activity and associated soil properties such as the amount of exchangeable ammonium and the soil nitrate concentration, were found to decrease in value with depth between 0-24 cm. The greatest decrease in SNA was observed between 0-9 cm depth, but due to the need for sufficient quantities of soil to make SNA measurements, and the desire to avoid the possibility of inhibitory effects of grass roots on nitrification, soil was sampled from the 3-9 cm depth range for the bulk of the work reported here. Results indicated that the technique of sieving and mixing samples was satisfactory for removing depth-dependence from the results for spatial variability and other analyses.

The spatial variability of SNA, soil  $\text{NO}_3^-$ , soil moisture content and the pH of the SNA incubation, which was assumed to approximate the field soil pH, was investigated over areas of 9 m<sup>2</sup> and 625 m<sup>2</sup> using a regular 11 x 11 square grid sampling design with minimum sample separations of 30 cm and 2.5 m respectively. However, the results of these analyses proved inconclusive, apparently due to the lack of samples separated by lags that were sufficiently short in relation to the overall dimensions of the sampling area. Accordingly, spatial analysis of the above properties, together with exchangeable ammonium, was carried out over 625 m<sup>2</sup> using a *nested* sampling design that permitted an adequate number of observation points at lags ranging from 12.5 cm to 25 m. This design was a considerable improvement on the regular square design, although it had a number of shortcomings, notably bias caused in the estimation of the sample variance due to the nesting of a large number of data points

within a small area, and bias caused in the estimation of values of the semivariance at some lags due to missing sampling points at some positions in the sampling grid.

The values of SNA,  $\text{NO}_3^-$  and exchangeable ammonium were all highly variable and conformed to lognormal distributions. The range of spatial dependence in the variability of SNA, soil  $\text{NO}_3^-$  and incubation pH was 2.4, 5.4 and 6.1 m respectively. Exchangeable ammonium, SNA, soil  $\text{NO}_3^-$  and incubation pH varied isotropically within the sampling area but  $\text{Ex-NH}_4^+$  showed no spatial dependence. Soil moisture content was strongly anisotropic, and showed no spatial dependence in one direction, but clear evidence of drift in a perpendicular direction. These results are discussed in relation to the most efficient sampling strategy for estimation of the mean field  $\text{NO}_3^-$  concentration. It was concluded that sufficient small localized clusters of samples should be taken to give a low standard error of the mean, with each cluster separated by at least 5 m. In the case of the Tokomaru silt loam, 20 clusters, each comprising 5 samples (bulked), would be required for estimation of the mean field nitrate concentration with 95% probability of  $\hat{\mu}$  being within  $\pm 5\%$  of  $\mu$ , the true mean. This represents a large sampling effort.

The activity of nitrifiers was studied in relation to soil pH and seasonal changes in soil moisture and temperature over two consecutive years in an attempt to explain the spatial variability in SNA values. The pH optimum for nitrifier activity ( $\text{pH}_{\text{opt}}$ ) was defined for four variates of the Tokomaru silt loam with different liming histories. Values of  $\text{pH}_{\text{opt}}$  which varied between the four soils in the range 5.92-6.45 did not vary markedly with season, and it was found that the form of the relationship between SNA and pH remained constant with time. It was further observed that the addition of lime in 1987 had the effect of raising the mean soil pH and  $\text{pH}_{\text{opt}}$  in previously unlimed soil, but had negligible effect on either the soil pH or  $\text{pH}_{\text{opt}}$  in soil that had been limed in 1982. The significance of heterotrophic relative to autotrophic nitrification could not be discerned.

No significant relationships could be found for the four soils between soil pH,  $pH_{opt}$ , SNA, soil moisture content and soil temperature at 30 cm depth. Values of SNA ( $\mu\text{mol N g}^{-1} \text{ soil h}^{-1}$ ) at  $pH_{opt}$  ( $SNA_{opt}$ ) were calculated from equations fitted to plots of SNA vs. the pH of SNA incubation, and these show a more obvious seasonal trend. SNA values calculated for the prevailing soil pH ( $SNA_{pH}$ ) were never very different from values of  $SNA_{opt}$  and follow a 1:1 relationship over a range of values from 0.015-0.110  $\mu\text{mol g}^{-1} \text{ h}^{-1}$ ; that is, the nitrifier activity in the soil, irrespective of variations that were random (unknown influences) or associated with seasonal variables (temperature and moisture), was near the optimum with respect to the soil pH at the time of sampling.

The effect of soil moisture variation on nitrifier activity was further investigated in an experiment in which soil samples were stored for 124 days at different soil moisture tensions. The optimum moisture conditions for nitrifier activity in the Tokomaru silt loam prevailed at pF 3.39. However, this optimum was less clearly defined than was the  $pH_{opt}$ . Since the soil moisture status changes considerably with season, whilst soil pH does not, it was concluded that nitrifiers were more tolerant of changes in pF than changes in pH.

Comparison of these with published results indicates that not only is the soil nitrifier population dynamic, and changes in response to changes in its environment, but the degree to which nitrifier activity is affected by various soil properties is soil-specific. It is therefore concluded that the spatial variability of nitrifier activity will also be soil-specific, and that different soils are likely to have different ranges of spatial dependence for the parameters of mineral N. Furthermore, the fact that SNA is not the only factor governing the soil  $\text{NO}_3^-$  concentration, and that other factors such as plant uptake and leaching are also important, indicates that SNA variability is not necessarily a good estimator of soil  $\text{NO}_3^-$  variability. This conclusion is certainly supported by the geostatistical aspects of this work.

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