Alternative Cropping Systems Study: Spatial Variability of Soil N Mineralization

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Introduction

Consumers are becoming more aware of potential impacts of agricultural practices on food quality and safety, and on environmental sustainability. To provide a better understanding of the effects of various crop diversity levels and intensity of use of pesticides and fertilizers on soil and environmental quality, Agriculture and Agri-Food Canada initiated a long-term field study at Scott, SK (Brandt et al. 1996). In this study, we used soil samples taken just before initiating the study to determine the relationships and distribution in the landscape of total soil N and of two estimators of soil N mineralization potential (Nmp) throughout the study area.

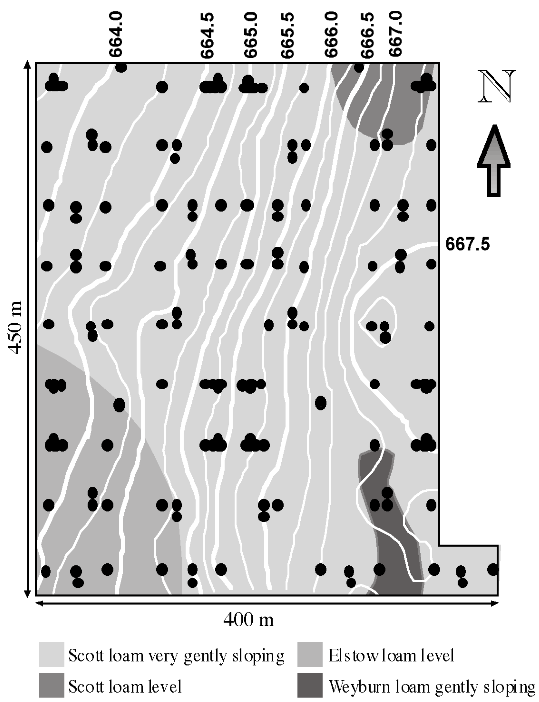

Figure 1. Map of experimental area showing soil series, sampling locations (circles), and elevations

Materials and Methods

The soil at the experimental site is a medium-textured Dark Brown Chernozem (Typic Haploboroll) developed from modified glacial till (Clayton and Ellis, 1952). The southwest corner of the field is mapped as Elstow loam, while the rest of the field is mapped as Scott loam, a shallow phase of the former soil, with a minor inclusion of Weyburn loam towards the southeast corner. The field has gentle slopes, ranging from 1 to 3%, with the highest elevations towards the eastern edge of the field (Fig. 1).

In June 1994 we removed 160 soil samples from the 0-7.5 and 7.5-15 cm depths with a coring device at predetermined locations within the field. The samples were distributed so that they covered the entire field, and a wide range of distances between samples. The soils were brought back to the laboratory, were sieved (< 2 mm), air-dried, labeled, and stored until analyzed. When the soil samples were collected, field operations, including fertilizing (urea banded) and seeding, had already been done. Nitrogen derived from fertilizer affected the estimates of Nmp in the 0-7.5 cm depth; consequently, we examined only the 7.5-15 cm layer.

Nitrogen mineralization potential was measured using a biological and a chemical procedure. The biological procedure consisted of incubating a subsample of each core at 35°C and optimum moisture for 24 wk, with intermittent leaching of the mineral N formed with dilute $CaCl_2$ followed by a nutrient solution devoid of N (Campbell et al., 1993). The total amount of N mineralized (Nm) was used as a biological index of Nmp. The chemical procedure consisted of extracting another subsample from each core with 2 *M* KCl, heated to 100°C for 4 hr (hot KCl-N), followed by steam distillation to collect extracted NH_4-N (Jalil et al., 1996). Total organic C and N were determined by grinding soil to < 153 µm and measuring C and N with an automated combustion technique (Carlo Erba™, Milan, Italy).

Maps of N distribution in the field were determined after a regular grid of values was calculated by kriging following determination of semivariograms (Selles et al. 1999).

Results and Discussion

All variables were log-normally distributed according to the Shapiro-Wilk W test. The data for the variables analyzed had large CV's (range of 33 to 63%); total-N and hot KCl-N, which were determined by chemical procedures, had CV values one-half those of Nm, which was determined by a biological procedure (Table 1). The magnitude of the CV's determined in this study were much larger than those determined for similar soil properties in Kansas (Mahmoudjafari et al., 1997).

Table 1. Moments of N mieralized in 24 week incubation (Nm), NH_4-N extracted with hot KCl-N (HKCl), and total-N.

Variable	Mean	Maximum	Minimum	CV
Nm (ppm)	63.9	200	14	63
HKCl (ppm)	11.7	25.9	4.7	34
Total-N (g/kg)	2.23	4.35	1.07	33

Because the variables were log-normally distributed, we calculated the semivariograms on the log-transform of the data. The semivariograms revealed that a large proportion of the variance (54-74%) was attributable to random processes, with the remainder explained by spatial structure. All semivariograms showed the evidence of an underlying cyclic pattern, similarly to that reported in a study of spatial variability of N mineralization (Mahmoudjafari et al., 1997). The semivariograms of Sum-N and total N indicated that these variables were relatively continuous in space, as indicated by their large range of influence (150 to 200 m), while hot KCl-N was more discontinuous, with a semivariogram range of only 50 m.

Field maps prepared using the 4x4 block kriged estimates of these variables (Nm, hot KCl-N, and total-N) showed that the variables were generally well related, and followed a similar distribution in the landscape. However, in a nearly flat level area (0-0.5% slope) close to the northwest of the field, total N showed some of the highest levels for the whole area, while the estimators of Nmp had only medium to low levels. A similar trend, but not as extreme, showed up in an area with the steepest short-range slopes of the field (2.5-3% slope) towards the center east of the plot area (Fig. 2).

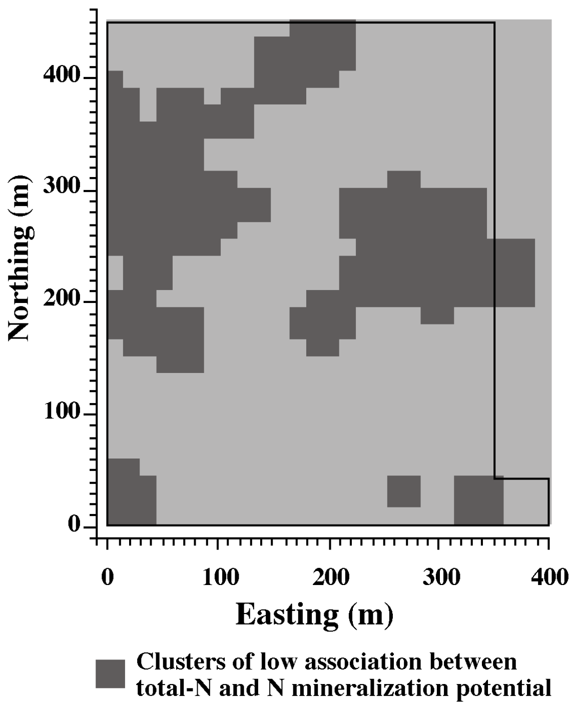

Figure 2. Position of samples with low correlation between total soil N and estimators of N

Regression analysis showed a close relationship between the two indices of Nmp ($r^2 = 0.72$, $P \leq 0.0001$), suggesting that the biological and chemical determination of Nmp indices access similar forms of N in the pool of soil organic N. Both indices of Nmp were positively correlated with total N ($R^2 = 0.54$ for hot KCl-N and $R^2 = 0.57$ for Nm). However, these relationships improved significantly when soil pH, bulk density (d_b), and geometric mean diameter of soil separates (GMD) were added to the regression model (Table 2). The multiple regression models were able to explain 66% of the variability in Sum-N and 76% of the variability in hot KCl-N. The regressions indicated that Sum-N and hot KCl-N were directly proportional to total N, but were inversely proportional to pH, bulk density, and GMD.

Because of the significant role of pH, d_b, and GMD on the relationship of total-N with Nm and hot KCl-N, we used a clustering procedure (SAS Institute 1985) with pH, d_b, and GMD as clustering variables. The procedure identified 40 samples (clusters), of the total of 160, as belonging to a separate population characterized by significantly lower ($P \leq 0.05$) total-N and hot KCl-N, 36 of which were located in the areas identified earlier as showing poor association between estimators of Nmp and total-N. Twenty-three of the samples isolated were clustered together in an area near the northwest corner of the plot area; 13 samples were clustered towards the central east border of the field; and four samples were scattered along the southern edge of the field (Fig. 2).

The samples separated by the clustering procedure not only showed significant differences in N content, but the soil within the clusters had significantly higher pH, d_b, and GMD than the rest of the field (Table 3). Total-N explained just a fraction of the variability observed in Nm and hot KCl-N for the samples within the clusters, but it explained a large proportion of the variability in samples located in the rest of the field (Table 4). Furthermore, the slopes of the regressions of total-N with Nm and hot KCl-N were significantly lower for samples within the clusters, indicating that in these areas a smaller proportion of organic N has the potential to mineralize and contribute to plant nutrition. On the other hand, the regression between Nm and hot KCl-N was not affected by position of the samples, suggesting that these two estimates access the same fractions of soil organic N (Table 4).

Table 2. Summary of regressions relating estimators of N supplying power among themselves and with total-N.

Regression model	Term	Estimate	Prob > $\lvert t \rvert^z$	$R^2_{adj}{}^y$
HKCL-N vs. Nm	Nm	0.085	0.0001	0.72
HKCL-N vs. (Nm, pH, GMD, d_b)	Nm	0.073	0.0001	0.76
	pH	-0.54	0.012	-
	d_b	-9.22	0.0001	-
HKCl-N vs. Total-N	Total-N	4.0	0.0001	0.54
HKCl-N vs. (Total-N, pH, GMD, d_b)	Total-N	4.4	0.0001	0.72
	pH	-1.03	0.0001	-
	GMD	-18	0.0001	-
	d_b	-7.15	0.004	-
Nm vs. Total N	Total N	41.0	0.0001	0.57
Nm vs. (Total-N, pH, GMD, d_b)	Total-N	43.8	0.0001	0.65
	pH	-6.25	0.015	-
	GMD	-121.3	0.0006	-
	d_b	-45.32	0.09	-

[z] probability of obtaining a larger absolute value of t by chance alone
[y] R^2 adjusted to account for number of parameters in model

Table 3. Mean pH, d_b, GMD, N mineralized in 24-week incubation, hot KCl-N and Total N in cluster area and rest of field.

Variable	Cluster	Rest of field	Prob > $\lvert t \rvert^z$
n	40	120	
pH	5.9	5.4	0.01
d_b (g/cm^3)	1.41	1.30	0.01
GMD (mm)	0.33	0.23	0.01
Nm (ppm)	58	66	0.30
Hot KCl-N (ppm)	10.3	12.2	0.01
Total-N (g/kg)	2.45	2.16	0.05

[z] probability of obtaining a larger absolute value of t by chance alone.

These results suggest that because of the poor association of total N with Nm and hot KCl-N in selected areas of the field, total soil N provides a much weaker estimator of potential N mineralization than either Nm or hot KCl-N. The close association of the biological and chemical estimators of Nmp, and the previously reported high correlation between grain yield and Nm (Campbell et al. 1996) suggest that the more easily determined hot KCl-N could constitute a useful index for separation of areas of a field based on their capacity to supply N to crops.

Table 4. Details of simple linear regressions among Total-N, N mineralized in 24-week incubation, and hot KCL-N as affected by sample grouping.

Regression	Place	Parameter	Estimate	Lower	Upper 95%
Total-N vs. Nm	Cluster	Intercept	-4.4	-33.0	24.0
		Slope	25.5	14.3	36.7
		R^2	0.34		
	Field	Intercept	-37.8	-51.0	-24.6
		Slope	48.0	42.3	53.8
		R^2	0.70		
Total-N vs. Hot	Cluster	Intercept	3.3	0.1	6.5
		Slope	2.8	1.6	4.1
		R^2	0.34		
	Field	Intercept	2.0	0.8	3.2
		Slope	4.7	4.2	5.3
		R^2	0.73		
Nm vs. Hot KCl-N	Cluster	Intercept	4.9	3.6	6.2
		Slope	0.09	0.07	0.11
		R^2	0.69		
	Field	Intercept	6.7	6.0	7.4
		Slope	0.08	0.0	0.09
		R^2	0.73		

[z] Lower and upper 95% confidence limits of parameter estimates.

Conclusions

This analysis allowed us to establish some spatial relationships between total soil N and estimators of soil N mineralization. The auxiliary variables pH, d_b, and GMD improve these relationships and allowed us to separate areas were the spatial distribution of the variables suggested weak association between total-N and the estimators of N mineralization. Hot KCl-N and Nm appeared to extract similar fraction of soil organic N and thus, the more easily determined hot KCl-N procedure might provide a useful index of N supplying capacity of the soil.

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