The Spatial Distribution of N Mineralization and Related Soil Properties

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Introduction

The level of KCl extractable soil N is commonly used to establish the amount of plant available N in the soil to facilitate fertilizer recommendations; however, this does not take into account the amount of N that is made available through mineralization during the growing season (Jalil et al., 1996). With reliable estimations of the soils ability to supply N mineralized from organic matter, we may better match the rates of applied N to the N needs of the crop (Sierra, 1996; Fiez et al., 1994;). Such estimates require an understanding of the spatial variation in the ability of the soil to mineralize N (Gooverts and Chiang, 1993). The objective of this study was to spatially index the N mineralization of a selected soil, along a transect, in a typical Saskatchewan farm field using both biological and chemical methods.

Methods and Materials

The research site was located in the Hepburn area, approximately 40 km north of Saskatoon, Saskatchewan. The site was classified as a hummocky, glacial till landscape of the Thin Black soil zone as part of the Oxbow Association (Agriculture Canada, 1987). The plot layout consisted of a single, 300 metre transect comprised of 100 sample locations equally spaced at 3 metres. Either side of the sample transect was seeded to a 5 row strip of spring wheat bounded by a single row of winter wheat on either side. One strip received a fertilizer application of urea (46-0-0) at 70 kg ha^{-1} (i.e., the recommended rate according to the spring soil test). The other strip was unfertilized. Prior to seeding, a single soil core, 6.5 cm diameter, was extracted from each sample location using a truck mounted punch. Profile descriptions were recorded prior to dividing the core into three sample depths: 0-15, 15-30 and 30-60 cm. Samples were stored at 3-4º C until analysis.

Gravimetric moisture content, KCl extractable soil N, and a biological index of N mineralization was determined using field moist soils. The biological index was an aerobic incubation, as described by Campbell et al. (1993). Each sample location was represented at two depths: 0-15 and 15-30 cm. The samples were incubated at 35ºC and 22.5% moisture by weight and leached every 2 weeks for 16 weeks with 200mL 0.01*M* CaCl2. Each extraction was analyzed for NO_3^-. At the end of 16 weeks, the majority of soils were destructively sampled for NO_3^- and NH_4^+ . Initially both NO_3^- and NH_4^+ were determined; however the extremely low levels of NH_4^+ did not warrant further determinations for this form of mineral N. For the chemical index of mineralization potential the hot KCl extraction of soil N (Jalil et al.,1996) was performed for each sample location at all three depth increments.

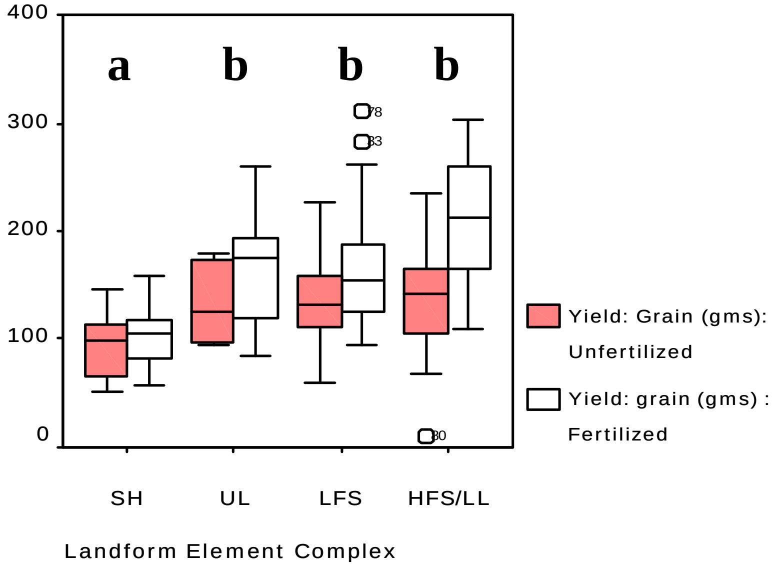
A survey of the sample transect and surrounding landforms was used to systematically identify a landform element for each sample location (Pennock et al., 1987). Landform elements were then grouped into landform element complexes (Pennock et al.,1994) and these were used as a basis to examine the spatial distribution of the soil properties tested. Exploratory and summary statistics were generated using SPSS version 8. Significant differences between landform positions was tested using the non-parametric Kruskal-Wallis test with a multiple comparison extension at a significance level of 0.20 (Pennock, 1994). The statistics presented here were intended for exploratory purposes only, and no attempt has been made at this point to avoid psuedoreplication. This report should be viewed as a pattern analysis, to be followed by more rigorous interpretation.

Results

A landscape effect was evident in both fertilized and unfertilized treatments where wheat grain yield tended to increase down slope from shoulders (SH) and upper levels (UL) through low catchment footslopes (LFS) to high catchment footslopes-lower levels (HFS/LL) (Figure 1). The trend is weak and the SH element complex was the only significantly different unit (Figure 1) for both treatments. However, yield for both treatments, was correlated with landform (Table 1), as were properties related to landform such as soil moisture and cumulative N mineralization. Spring soil N was poorly correlated with yield, by comparison.

Cumulative N mineralization, over a 30 cm profile, was lowest in SH positions and typically was greater in soils sampled at lower slope positions (Figure 2). The trend appears incomplete as HFS/LL were not the highest yielding in terms of cumulative N. However, as these positions are dominantly Gleyed Black Chernozems and Humic Luvic Gleysols, which appear to support thin Ah horizons, this is not unexpected. Prior work by Pennock (unpublished) indicates that lower organic carbon may be expected in these soils.

SH positions, in terms of cumulative N mineralization are significantly different from LFS and HFS/LL positions, but not from UL positions (Figure 2). UL, LFS and HFS/LL were not significantly different from each other. Cumulative N mineralization shows good correlation with yield from both treatments (Table 1). Cumulative N mineralization correlated well with spring moisture and landform. There were weaker correlation with spring nitrate and hot KCl.



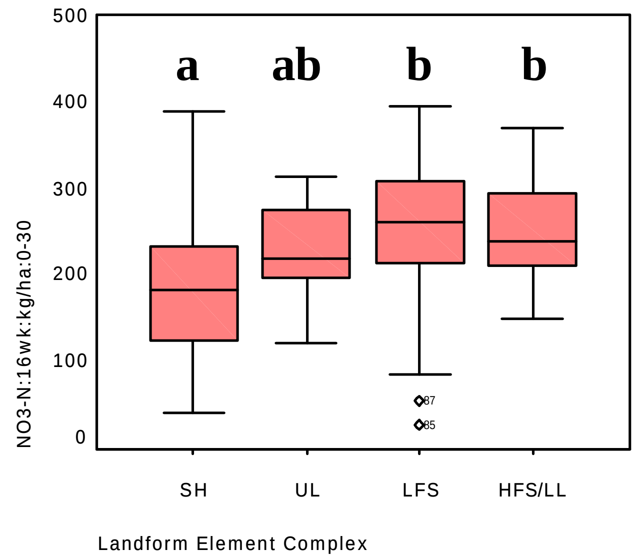
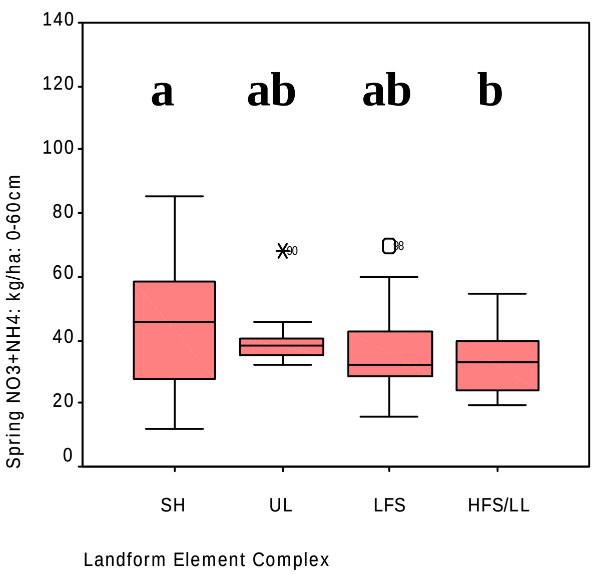


Figure 1: Yield data vs landform. Figure 2: Cumulative N min. vs landform.

Landform positions with same letter are not significantly different at 0.20 sig.



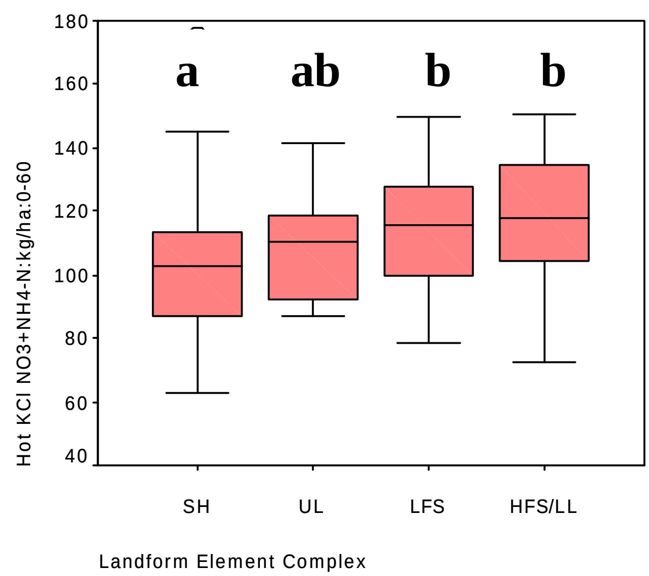


Figure 3: Spring Soil N vs landform Figure 4: Hot KCl extractable N vs landform

Landform positions with same letter are not significantly different at 0.20 sig.

Spring N did not exhibit the same relationship with landform as did other variables. A weak, negative relationship, existed between spring N and landform, with SH highest in spring N and generally decreasing downslope (Figure 3). This was confirmed by Spearman's rank correlation which shows a moderate negative correlation with landform (Table 1). However, the only significantly different positions were SH and HFS/LL. According to Ebdon (1985) a negative correlation in a one tailed test is not an indicator of a significant correlation. The value of r_s must be positive and greater than the critical value before it can be concluded that a significant rank correlation exists.

Hot KCl extractable N had a similar trend as cumulative N mineralization save that HFS/LL positions ranked highest for hot KCl as compared to cumulative N mineralization (Figure 4). This is likely due to the available N being extracted under chemical conditions, such as with hot KCl, as compared to biological indices, as in the 16 week incubation. SH positions were significantly different from LFS and HFS/LL, but not from UL positions. No other positions were significantly different from each other. Hot KCl extractable N was poorly correlated with cumulative N mineralization, weakly correlated with spring moisture, moderately correlated with spring N and well correlated with yield.

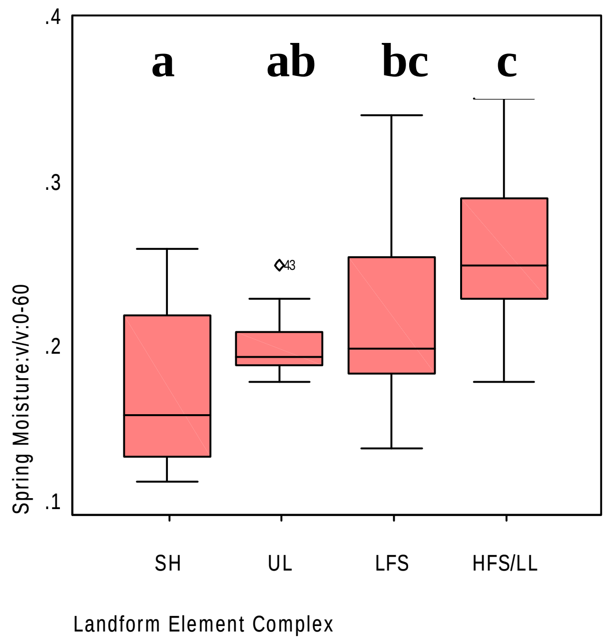


Figure 5: Spring Soil Moisture vs landform

Landform positions with same letter are not significantly different at 0.20 sig.

Spring soil moisture conditions had the best relation to landscape position out of all of the variables reported. Figure 5 shows a clear increase in moisture content from SH to HFS/LL positions. SH were significantly different from all positions except UL. Upper levels were significantly different from HFS/LL. Spring moisture was well correlated with yield, cumulative N mineralization, and landform. There was a moderate correlation with hot KCl extractable N, and a poor correlation with spring soil N.

Table 1: Spearman's rank correlation coefficients (one tailed significance)

	Cumulative N	Spring θ v/v	Spring N	Hot KCl	Landform
Yield 0 N	.315 **	.301 **	-.131	.391 **	.467 **
Yield 1XN	.321 **	.486 **	-.135	.414 **	.685 **
Cumulative N	X	.384 **	.171 *	.160	.351 **
Spring θ v/v	.384 **	X	.058	.207 *	.535 **
Spring N	.074	-.208*	X	.251 **	-.285 **
Hot KCl	.160	.207 *	.250 *	X	.302 **

** Significant to p (.01). Critical value for n=100: .234

* Significant to p (.05). Critical value for n=100: .165

Discussion

The expectations of this research were that yield would vary in a field according to landscape position and that a significant portion of this variability would be explained through differences in N mineralization, as determined through 16 week incubation, between landscape positions. Using a laboratory incubation removed the landscape control on water availability and exposed differences in the ability of the soil to supply plant available N between landscape positions. The data shows a definite trend with increasing cumulative N as one goes downslope from SH to HFS/LL positions; however, this trend was not strong as only two management units were apparent, i.e., SH and UL-LFS-HFS/LL. Estimates of cumulative N mineralization and hot KCl extractable N indicate that SH-UL positions were distinct from the other landscape complexes. Spring moisture defined similar units where as UL positions were split between SH and LFS-HFS/LL. The correlation between cumulative N mineralization and yield was significant; however, it did not explain as much of the variability in grain yield as did spring moisture which suggests that moisture content is as much or more of a control on yield as soil quality. The fertilized treatment demonstrates that where N availability is not a limiting factor, water distribution determines the differences in yield between landscape positions.

According to the results at this research site, spring soil N did not correlate well with grain yield on a point by point basis. The poor correlation between spring soil N and landform and related variables such as moisture indicates soil N is strongly influenced by other variables not definable in this data set. The significant correlation between spring nitrate and hot KCl extractable N, although not strong, is unexplainable at this point.

The lack of correlation between hot KCl and cumulative N mineralization was somewhat surprising, and suggests that this test may not always simulate the ability of a soil to mineralize N. Estimates of hot KCl extractable N It were better correlated with yield than was cumulative N mineralization. These results are encouraging in terms of identifying potential alternative soil N testing methods. However, according to the hot KCl extractable N estimates, the HFS/LL positions would produce more plant available N, whereas the cumulative N mineralization data suggest that this is not the case. The fact that these positions were the highest yielding can likely be be attributed to their ability to collect and retain moisture by virtue of their position in the landscape.

Summary

It appears that yield varied according to landscape position and that this variation, to a large extent, is influenced by the distribution of moisture in the landscape. The ability of a soil to produce plant available N also varied according to landscape, but the influence of this variation on yield was dependant on moisture, for both mineralization of N and N transport to the plant.   Therefore, one can speculate that although N mineralization is important to fertilizer recommendations, soil moisture also must be accounted for. Spring soil N did not relate well to other variables, suggesting it had been complicated by another factor yet unidentified. Hot KCl extractable N may offer an alternative to current soil testing methods. SH positions appeared as a distinct field unit, in terms of precision farming, either alone or with UL positions. This supports the need for precision farming applications, but suggests division of a field into more than two units may be not be necessary in certain situations.

Acknowledgements

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