Assessing Nutrient Availability Variations in Landscapes

P. Qian, J.J. Schoenau, L.E. Cowell and L. Dennis
Department of Soil Science, University of Saskatchewan

Key word: landscape variability, nutrient availability, ion exchange resin, residual NO_3-N, N mineralization

ABSTRACT

A simple method was developed to assess the variability in nutrient availability in undulating landscapes using anion exchange resin strip burial. Resin strips were buried in ten farm fields along transects at points in the landscape representing different landform elements present within the field. In all ten fields, strips were buried for one hour. In two of the fields, in addition to a one hour burial, another set of resin strips was buried and allowed to remain in the soil for two weeks. After burial, resin strips were removed and the nitrate accumulated on the strips was measured. Large variations in nutrient availability as predicted by resin strip burial were observed in the landscapes. The differences were closely related to the landscape position and landform element with the highest levels of available nitrate observed at lower slope positions where deposition of eroded soil has occurred. Two week burials revealed that mineralization contributes significantly to available nitrate in the soil. Resin strip burial appears to be a suitable tool for evaluating variations in nutrient availability in different landscape positions of a field.

INTRODUCTION

In rolling landscapes, soil properties vary among positions in the landscape (Pennock et al. 1987). Fields in Saskatchewan often cover 80 acres or more. To that end, soil properties within a field will vary with undulating topography. However, conventional fertilizer recommendations are based on a small number of soil samples taken from the field. Fertilizer is then usually applied uniformly over the field despite varying nutrient levels. This can result in an unbalanced nutrient supply within a field. With technology to apply fertilizer at variable rates from the tractor cab, fertilizer may be applied and used more efficiently, thereby reducing nutrient losses and nutrient deficiencies within a field. Carr et al. (1991) reported that a larger return would be achieved from variable rate fertilization compared to fertilizing the field as one unit. Accurate variable rate fertilization partly depends on the rapid determination of available soil nutrients at different landscape positions. The objective of this study is to determine the nature and extent of variability in nitrate availability in several undulating landscapes, and to examine the potential for using buried ion resin strips to provide an index of relative NO_3-N availability in different slope positions.

MATERIALS AND METHODS

The study was conducted at 5 locations in Saskatchewan: Perdue, Prince Albert (Conservation Learning Center Farm), Bradwell, Aberdeen and Waitville.

At each location, two transects were sampled. The transects at Perdue were sampled in July 1992. The transects at the other locations were sampled in October 1993. The basic soil information for the 5 locations is in Table 1.

Table 1. Some soil properties of the tested fields.

Transect Slope	Soil zone	Texture	Sequence in rotation	Transect length (m)	(%)
Perdue I	Dark brown	fine sandy loam	ChemFallow	60	5
Perdue II	Dark brown	fine sandy loam	ChemFallow	60	5
P.A.-CLC* I	Black	loam	Canola stubble	70	4
P.A.-CLC* II	Black	loam	Wheat stubble	70	4
Bradwell I	Dark brown	sandy loam	Fallow	70	4
Bradwell II	Dark brown	sandy loam	Wheat stubble	70	4
Aberdeen I	Dark brown	loam	Canola stubble	150	7
Aberdeen II	Dark brown	loam	Fallow	150	7
Waitville I	Grey	loam	Oat stubble	80	4
Waitville II	Grey	loam	Fallow	80	4

* P.A.-CLC, Conservation Learning Center Farm at Prince Albert

Anion exchange resin strip burial was used to provide an index of relative NO_3-N availability among slope positions. It is considered an index because resin strip burial does not provide a quantitative measure of NO_3-N concentration in the soil as does $CaCl_2$ extraction of a soil sample. Instead, concentration is expressed as weight of nutrient per strip surface area. The basic technique used was as reported in Schoenau et al (1993). Two strips of anion exchange membrane were buried at each of 10 sites along a transect. After burial, sufficient deionized water was added to ensure the soil in the vicinity of the strips was nearly saturated. Strips were removed after one hour burial and washed off with deionized water. At Perdue, additional membranes were buried in the soil for two weeks to estimate N mineralization. Resin strip extractable soil nitrate is reported as μg NO_3-N per 10 cm^2 of strip surface.

Near each membrane burial site, soil cores were sampled for the measurement of nitrate using conventional $CaCl_2$ extraction. Twenty-five g of soil sample was extracted in 50 ml of 0.01 M $CaCl_2$ solution for 30 minutes. The nitrate in the filtrate was determined colorimetrically using an autoanlyzer.

The landscape elements were assigned visually, according to descriptions given by Pennock et al (1987).

RESULTS AND DISCUSSION

Distribution of nitrate

Malo and Worcester (1975) reported that soil nitrate is lowest at the shoulder positions of slopes where erosion is the highest and increases at the

lower slopes where soil deposition occurs. This was corroborated by our study in both resin strip burial and $CaCl_2$ extractable nitrate (see Table 2 and Table 3).
Table 2. Resin strip extractable soil nitrate at different slope positions.

Transect (rotation)	NO_3-N index (µg/10 cm^2)				
	Upper level	Shoulder	Back slope	Foot slope	Depression
Perdue A (Chemfallow)	10.8	9.7	10.9	25.9	
Perdue B (Chemfallow)	16.4	8.4	13.1	33.2	
P.A.-CLC.* (Canola stubble)		7.8		9.0	40.1
P.A.-CLC* (Wheat stubble)		4.6		78.2	111.3
Bradwell (Fallow stubble)	27.2	9.0	6.3	11.6	
Bradwell (Wheat stubble)	4.7	7.6	7.0	5.3	
Aberdeen (Canola stubble)		4.0	9.2	12.9	
Aberdeen (Fallow stubble)		57.6	19.6	197.6	
Waitville (Oat stubble)	2.7	2.3	2.4	4.2	
Waitville (Fallow stubble)	101.8	34.7	31.8	89.5	

* At P.A.-CLC, the two testing transects were 1 km apart. At Perdue, testing transects were in the same field. At all the other locations, the transects were in adjacent fields.

Table 3. $CaCl_2$ extractable soil nitrate in different slope positions.

Transect (rotation)	NO_3-N concentration (µg/g)				
	Upper level	Shoulder	Back slope	Foot slope	Depression
P.A.-CLC* (Canola)		7.0		24.8	24.1
P.A.-CLC* (Wheat)		3.6		18.6	22.2
Bradwell (Fallow)	6.5	9.0	8.6	7.2	
Bradwell (Wheat)	3.9	5.3	6.2	5.7	
Aberdeen (Canola)		2.3	3.2	6.7	
Aberdeen (Fallow)		23.2	8.9	21.5	
Waitville (Oat)	4.3	2.4	3.0	5.1	
Waitville (Fallow)	3.6	9.5	10.6	13.6	

* see Table two

Nitrate distribution was significantly influenced by slope position. Figure 1 shows a typical example of how soil nitrate progressively changes with slope position across a field. Higher availability of NO_3-N in footslope and depressional areas of the fields, as indicated by the two methods, likely reflects greater organic N mineralization rates due to a higher organic N content and greater moisture availability. Higher organic matter levels in the lower slope positions of the landscape (Table 4) suggest a greater N mineralization potential. However, at Bradwell transect, NO_3- N availability was low across all slope positions. This may be attributed to the sandy texture and overall higher leaching potential in this soil, particularly in 1993 with above normal rainfall.

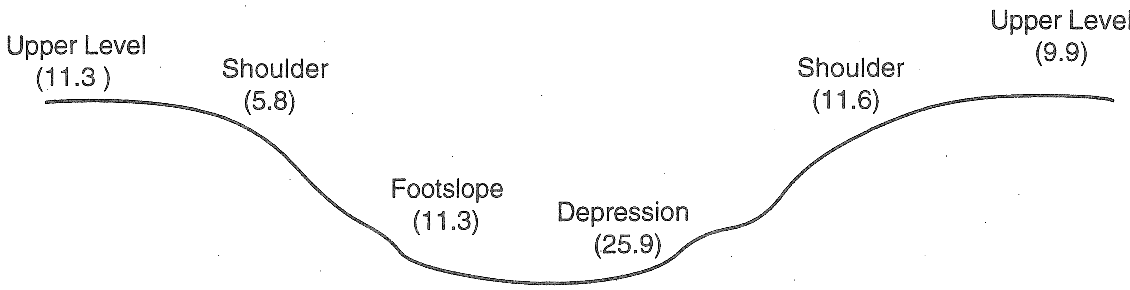

Figure 1. Distribution of resin extractable soil nitrate ($\mu g/10\ cm^2$) along the Perdue A transect.

Table 4. Organic carbon contents at the sampling locations.

Transect (rotation)	Organic C (%)		
	Shoulder	Back slope	Footslope
P.A. -CLC (Canola)	3.3		4.7
P.A.-CLC (Wheat)	3.2		5.1
Bradwell (Fallow)	2.0	1.9	2.3
Bradwell (Wheat)	2.6	3.4	3.8
Aberdeen (Canola)	2.3	2.6	3.1
Aberdeen (Fallow)	2.7	2.5	3.5
Waitville (Oat)	3.4	2.0	4.3
Waitville (Fallow)	1.5	2.1	2.6

Table 2 and 3 also show the effect of rotation on nitrate distribution. The nitrate concentration as given by $CaCl_2$ extraction and the relative availability as indicated by resin strip is consistently higher in fallow soil than in cropped soil. Nitrates produced from mineralization have accumulated in the fallow soil.

The effect of topography on the distribution of nitrate was apparent even within the same general slope region. For example, at Aberdeen, the soil nitrate availability on the even shoulder positions was consistently higher than on the convex shoulder positions (Table 5). This may be explained by greater runoff and erosion on the convex shoulders.

Table 5. Soil nitrate in even and convex shoulder slope positions at Aberdeen transect .

Position	Nitrate concentration			
	Resin strip ($\mu g/10cm^2$)		$CaCl_2$ extraction ($\mu g/g$)	
	Canola stubble	Fallow	Canola stubble	Fallow
Shoulder even	4.7	70.1	2.6	28.4
Shoulder convex	1.7	20.2	1.5	9.0

N mineralization

An index of N mineralization over a two week period at different landscape positions at Perdue (Table 6) was provided using NO_3-N accumulated on buried ion exchange resin strip (Qian et al., 1993). An index of mineralized NO_3-N obtained by subtracting 1 hour NO_3-N from 2 week NO_3-N showed that mineralization significantly contributed to nitrate availability in the soil over the two week period in July, with the mineralization index highest in the footslopes where the greatest residual nitrate was also observed.

Table 6. Resin extractable soil nitrate from 1 hour and from 2 week burial.

Transect	Burial time	NO_3-N concentration ($\mu g/10cm2$)			
		Upper level	Shoulder	Back slope	Foot slope
Perdue A	1 hr	10.8	9.7	10.9	25.9
Perdue A	2 wks	53.2	26.4	32.9	88.8
Perdue A	M. I.*	42.3	16.7	21.6	62.4
Perdue B	1 hr	16.4	8.4	13.1	33.2
Perdue B	2 wks	68.2	43.2	56.5	121.2
Perdue B	M. I.*	45.9	34.8	43.4	88.0

* M. I. = mineralization index (2 wks - 1 hr).

CONCLUSION

Large variations in nitrate availability were observed in undulating landscapes as measured by both resin strip and $CaCl_2$ extractions. The largest accumulations of residual nitrate were observed in lower slope (footslope) and depressional areas of the landscapes. These were the same slope positions where mineralization rates appear to be the highest. Greater mineralization of organic N in the low slope positions of the landscape due to greater organic matter levels and moisture availability my explain the variability in NO_3-N that is observed in the undulating landscapes. The relative index of NO_3-N availability provided by resin strip burial appears to be comparable to the conventional $CaCl_2$ extraction. Owing to its simplicity, the direct burial of resin strips in the field appears to be an attractive means of evaluating the variations in nutrient availability in different landscape positions of a field.

ACKNOWLEDGEMENTS

The authors thank the Imperial Oil Chemical Division and Natural Science and Engineering Research Council for financial support.

LITERATURE

Carr, P. M., G. R. Carlson, G. A. Nielson and E. O. Skogley. 1991. Farming soils, not field: a strategy for increasing fertilizer profitability. J. Prod. Agric. 4:57-61

Malo, D. D., B. K. Worcester. 1975. Soil fertility and crop responses at selected landscape positions. Agron. J. 67:397-401.

Pennock, D. J. , B. J. Zebarth and E. de Jong. 1987. Landform classification and soil distribution in hummocky terrain, Saskatchewan, Canada. Geoderma 40: 297-315.

Qian, P., J. J. Schoenau and A. Braul. 1993. Estimating nutrient release from soil organic matter using ion exchange membranes. Soils and Crop Workshop. University of Saskatchewan, Saskatoon, Saskatchewan. pp. 436-451.

Schoenau, J. J., P. Qian and W. Z. Huang. 1993. Ion exchange resin strips as plant root simulators. Soils and Crop Workshop. University of Saskatchewan, Saskatoon, Saskatchewan. pp. 392-400.