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LANDSCAPE-BASED VARIABLE RATE FERTILIZATION

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ABSTRACT

Fertilizer responses were measured on management units determined by landscape analysis. Yield variability was greatest at the sites which had been broken in the early 1900s. Yields tended to be higher on footslope and level complexes than on shoulder complexes. Shoulders also exhibited slightly different fertilizer responses than footslope complexes.

INTRODUCTION

Crop yield varies within the landscape: knolls which are generally drier and infertile yield less than footslopes which receive runoff water and additional nutrients in soil eroded from higher elevations. Such differences make variable rate fertilization an attractive management option.

From the standpoint of soil conservation, additional fertilizer could be applied to knolls to improve crop growth and reduce the potential for further erosion (Hamm 1985). However if water is the yield-limiting factor on knolls, the extra fertilizer may be redundant. From an economic standpoint, resources should be concentrated on the lower slope positions where yield potential is greatest (Kachanoski et al. 1985).

This research was undertaken to clarify the effect of fertilizer addition on yield on different parts of the landscape. The objectives were to identify easily recognizable landscape units which could be fertilized uniformly and to establish fertilizer responses within each of the units.

MATERIALS AND METHODS

Yield experiments were carried out at three sites with strongly rolling topography near Saskatoon, Saskatchewan in 1991. The Cutbank site was located on a Dark Brown Chernozem (Typic Boroll) classified as a Weyburn loam (Ellis et al. 1970). The land at the site was broken in the early 1900s and for the past 20 years a two-year wheat-fallow rotation had been in place. The other two sites were located one mile apart on a Black Chernozem (Udic Boroll) classified as an Oxbow loam (Mitchell et al. 1962). The Kresse site was broken around 1910 and had recently been cropped to canola, wheat, and barley with summerfallow every third or fourth year. The Termuende site had been continuously cropped to wheat or barley since it was broken in 1977. In 1990 a wheat crop had been grown on summerfallow at the Kresse site and barley was grown at the Termuende site.

Spring wheat was grown on all the sites: var. Neepawa at Cutbank and var. Laura at Kresse and Termuende. Fertilizer treatments were seeded in strips 1.87 m wide (one seeder width) and

500m long so that each treatment was applied on all elements of the landscape. Treatments were randomly allocated to the strips. At each site there were nine fertilizer treatments which combined three rates of nitrogen and phosphorus fertilizer (0, 20, and 40 kg/ha of N as ammonium nitrate and 0, 20, and 40 kg/ha of P_2O_5 as ammonium phosphate). Where N was applied as ammonium phosphate, the rate of ammonium nitrate was correspondingly reduced and two extra check strips with 4 and 8 kg/ha N were included for comparison with the N:0 P:20 and N:0 P:40 strips respectively.

Prior to seeding soil samples were taken at 0-15, 15-30, 30-60, 60-90 and 90-120 cm depth every 10m along the N:0 P:0 and the N:40 P:40 strips. These samples were used to determine profile moisture at seeding, nitrate-N (Keeney and Nelson 1982), bicarbonate extractable P (Olsen and Sommers 1982), and Cesium content (de Jong et al. 1982). The distribution of Cs in the landscape is an indicator of soil redistribution which has occured since 1961. A horizon depth and depth to $CaCO_3$ were recorded at the sampling positions. Topographic surveys were used to obtain elevation data for the area of the plots at a 5 m grid spacing. Temperature and precipitation were measured at each site. Harvest yield samples were taken every 10 m along each fertilizer strip. Both total (grain and straw) and grain yield were recorded.

RESULTS AND DISCUSSION

Identification of Landform Complexes

The elevation data was used to determine the downslope and cross-slope curvature at each yield sampling position. The sampling positions were then assigned to a landform element using the classification developed by Pennock et al. (1987). Five landscape elements were identified on each of the three study sites: diverging and converging shoulders and footslopes and level elements. Although these landform elements could be easily recognized in the field, their distribution was too complex to be considered as a pattern for the application of different fertilizer rates.

A more useful classification was achieved by grouping the landform elements using a progressive smoothing proceedure. The five landform elements were reduced to three landform element complexes: shoulder, footslope, and level complexes. Level complexes could occur either in depressions or on top of knolls. Depending on its neighbours a landform element could be assigned to any of the complexes (ie. a converging shoulder element could be found in a footslope complex). The landform element complexes are visually identifiable and are sufficiently large to be field management units. A significant amount of the land area fell into each landform element complex (LFC) at each site. Nearly half of the land area at the Kresse site was in level complexes, while shoulder complexes dominated at the Cutbank site, and at the Termuende site there was not a dominant complex.

Variation in Soil Properties between Landforms

Differences in soil properties between the landform element complexes are shown in Table 1. Significant differences in soil properties between landscape elements were found at all three sites. There were significant differences between the LECs for all properties except spring profile moisture at the Cutbank site, nitrate and depth to $CaCO_3$ did not vary significantly between LEC at the Kresse site, and at the Termuende site cesium was the only soil property which varied significantly between LECs. The lack of significant differences in soil properties between LECs at Termuende reflects the relatively recent breaking of the land and the continous cropping system that has been in place since the land was brought into production. Long-term crop production, summer-fallow, and soil erosion have strengthened the differences in soil properties across the landscape at the other two sites.

Table 1. Mean values for the soil properties on the landform element complexes at the three sites.

Soil Property	LFC	Cutbank	Kresse	Termuende
Nitrate kgN/ha 0-60 cm	Shoulder	6.3 a	6.9	8.4
	Footslope	8.1 b	9.7	11.6
	Level	8.3 b	9.1	11.1
Phosphorus kgP/ha 0-60 cm	Shoulder	17.0 a	47.4 a	68.6
	Footslope	27.2 a	116.0 b	94.9
	Level	44.5 b	80.9 ab	67.3
Profile Moisture cm	Shoulder	32.2	25.5 a	24.8
	Footslope	30.6	27.6 ab	27.4
	Level	31.5	28.6 b	24.8
A horizon Thickness cm	Shoulder	5.3 a	10.2 a	15.2
	Footslope	11.7 b	18.0 b	16.1
	Level	8.3 b	18.1 b	16.2
Depth to $CaCO_3$ cm	Shoulder	7.3 a	9.9	36.8
	Footslope	38.0 b	26.5	46.3
	Level	16.5 a	17.2	42.6
Cs conc. Bq/kg 0-15 cm	Shoulder	7.0 a	-	10.0 a
	Footslope	9.8 b	-	13.2 b
	Level	10.9 b	-	11.9 ab

Values for all of the soil properties were generally higher on the footslope and level complexes than on the shoulder complexes, with most of the significant differences being between shoulder and footslope complexes. Differences between footslope and level complexes tended to be slight and were only significant for P and depth to $CaCO_3$ at the Cutbank site. The P level was greater on the level complex than the footslope complex but $CaCO_3$ was found deeper in the profile on the footslope complex.

Yield Variability in the Landscape

Differences in total and grain yield between landscape element complexes on the control strips are shown in Table 2. The only significant differences in grain yield were found at the Cutbank site where footslope and level complexes significantly outyielded shoulder complexes. At the Kresse and Termuende sites moisture stress resulted in very low grain yields and harvest indices, and masked the effect of landscape position on yield. Soil moisture in the spring was very low on the stubble fields (Table 1) and although exceptional precipitation in May and June (171 mm) gave rise to substantial dry matter production, hot dry weather in July and August resulted in low grain yields. At the Kresse site significantly higher total yields were measured on footslope and level complexes than on the shoulder complexes. The absence of significant differences in total yield at Termuende reflected the uniformity of soil properties at the site.

Table 2. Average yields for the unfertilized strips on the landform element complexes at the three sites.

	LEC	Cutbank	Kresse	Termuende
Grain Yield kg/ha	Shoulder	1641 a	1496	1297
	Footslope	2097 b	1531	1252
	Level	1911 ab	1519	1284
Total Yield kg/ha	Shoulder	3692 a	3464 a	3884
	Footslope	4942 b	4317 b	3971
	Level	4310 b	4393 b	4019

Fertilizer Responses on the Landform Units

Fertilizer responses for the two landform element complexes which showed the greatest contrast are shown in Figure 1. Grain yield is plotted for the Cutbank site but total yields were used for the Kresse and Termuende sites to avoid the leveling effect of late season moisture stress on grain yield.

There was a significant response in yield to most of the fertilizer treatments at the Cutbank site. On the shoulder complexes 20 kg/ha of N or P did not produce a significant response if the other nutrient was missing. Only the N:20 P:0 treatment failed produce a yield response on the footslope complexes. The shoulder complexes responded more strongly to N fertilizer than the footslopes but the effect of P was greatest on the footslope complexes although responses were good throughout the landscape.

At the Kresse site, fertilizer responses were generally better on the footslope complexes than the shoulder complexes. On all three landform element complexes the only treatments which significantly increased total yield above that on the check strips were N:40 P:40, N:40 P:20 and N:20 P:40.

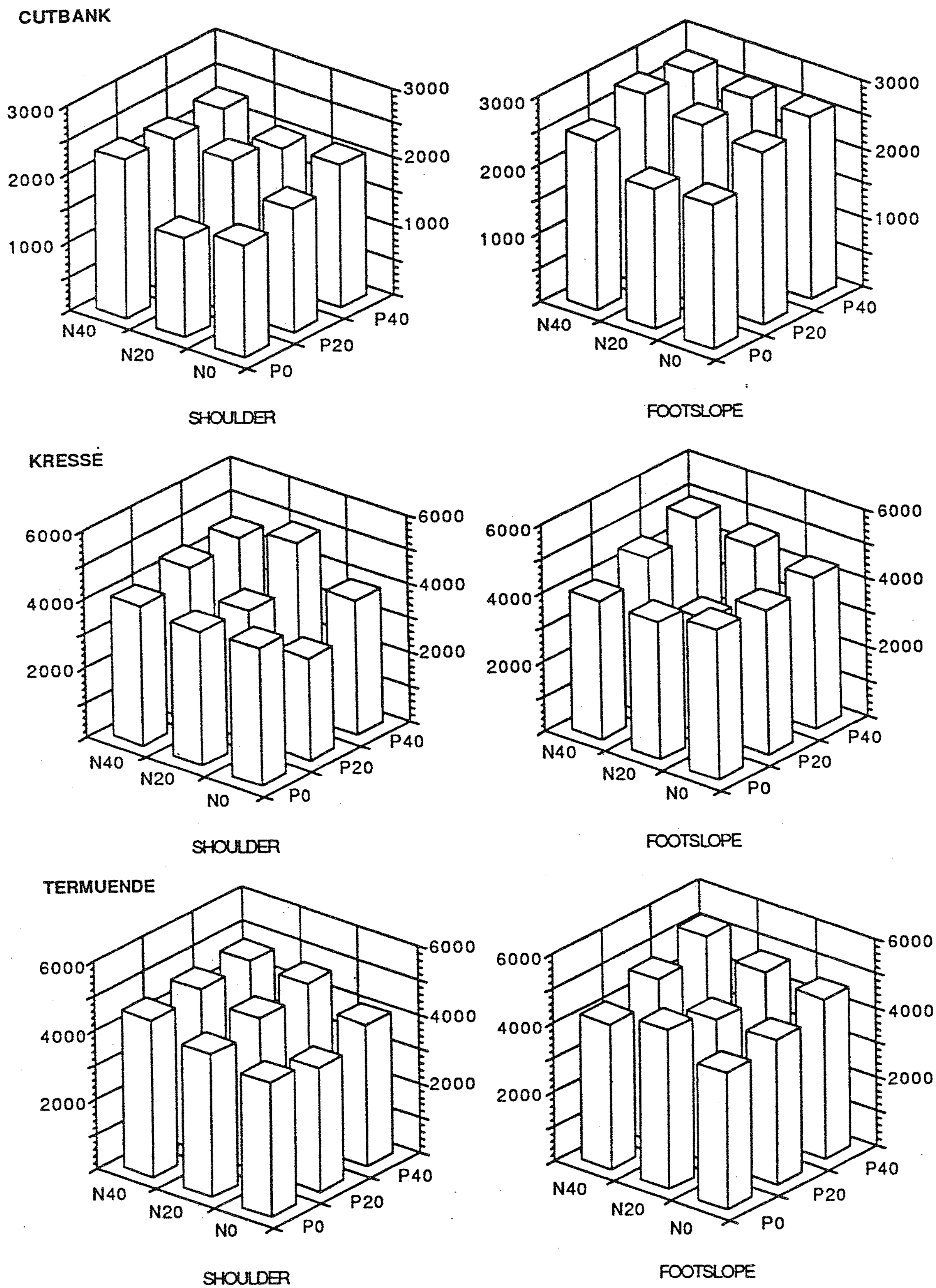

Figure 1. Yield responses on shoulder and footslope complexes.

There were no significant differences in total yield due to fertilizer addition at the Tremuende site. Trends in total yield were similar on all landscape element complexes but P responses appeared stronger on the footslopes than the shoulders.

CONCLUSIONS

Landform element complexes are a useful tool for subdividing a field into management units as they seem group soils with similar properties. The benefits of variable rate fertilization were more apparent on the Cutbank and Kresse sites where there was greater variability in soil properties. Results were inconclusive but shoulders appear to benefit more if both nitrogen and phosphorus fertilizers are applied whilst yield responses (especially to phosphorus) appear to be greatest on footslope complexes.

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