Topographic Position Effects on Soil Water and Wheat Yields on Reclaimed Minelands

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In a semi-arid area such as North Dakota, agricultural production is very dependent upon the amount of water available to a growing plant. Bauer (1972) showed that available soil water at planting time plus growing season precipitation are well correlated with yields of small grains.

Several studies have also indicated that landscape position influences crop yields (Ciha, 1984; Stone et al., 1985; and Douglas et al., 1985). Hanna et al. (1982) documented how topography redistributed water among landscape positions. Runon-runoff of precipitation among landscape positions as well as differences in saturated and unsaturated flow in the soil profiles resulted in an uneven distribution of water in the landscape.

Regulations in North Dakota require land disturbed by mining activities be reclaimed to productivity levels "equal to or better than" levels prior to mining. However, since the landscape is severely disrupted during mining and reclamation, the reclaimed landscape may be similar in appearance to the undisturbed state but differences in the depths of replaced soil materials generally are not similar (Figure 1).

This study was undertaken to determine the relationship of landscape position to water distribution and crop yields on reclaimed mineland soils. To simplify the discussion, the classical position terms shown in Figure 1 will be used although they are not entirely applicable by definition to reclaimed landscapes.

METHODS AND MATERIALS

This study was initiated in 1986 at two mining locations. Discrete plots (100 by 100 feet) located on four topographic positions (summit, shoulder, backslope, and footslope) were established on the BNI mind near Center. A continuous plot was established on the Falkirk Mining Company mine near Underwood utilizing seven topographic positions (summit; shoulder; top, middle, and low backslope; footslope; and toeslope).

All tillage (fall chisel, spring disk) and planting operations were conducted up and down the slope gradient. Application of fertilizer for a 40 bushel per acre wheat yield (based upon soil tests) was accomplished by broadcasting and/or drill placement. Stoa wheat was seeded each year except 1988 when oats was seeded (data not reported).

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Two neutron access tubes for monitoring soil water by depth were installed in each position. Rainfall was measured daily with a recording rain gauge. Total water use (TWU) was calculated by adding growing-season rainfall (GSP) to the changes in soil water (0-4 foot profile depth) from planting to harvest assuming no runon/runoff.

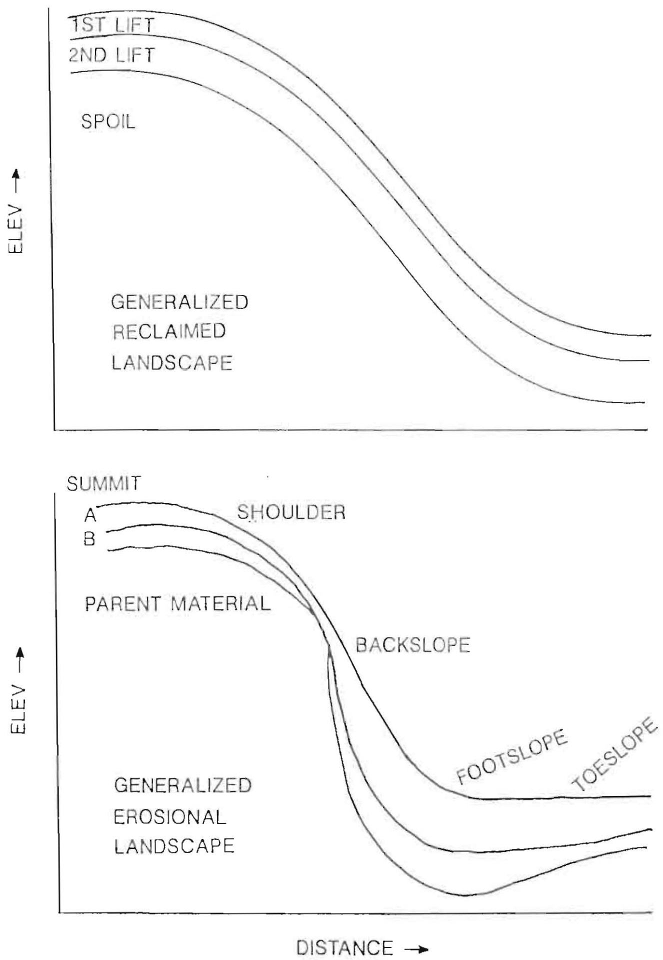

Figure 1. Comparison of differences between generalized undisturbed and reclaimed mineland landscapes.

Available water at planting (AWP) and wheat yields were analyzed using a modified randomized block design. Yields were based on a 4 square yard sample (four 1 square yard samples combined) per access tube (two replications per topographic position per year). Regression/correlation analyses were used to relate wheat yields to TWU.

RESULTS AND DISCUSSION

Available water at planting (AWP) shows significant differences among years at both locations (Tables 1 and 2). Values have generally decreased over years due to recropping and to poor overwinter/spring soil water recharge from below normal precipitation.

Lower topographic positions have generally had higher AWP amounts than upslope positions but differences have not always been significant. AWP at both locations was

Table 1. Topographic position and year effects on available soil water at planting and wheat yields at the Center reclaimed mineland location (oats planted in 1988).

Year of Data	Position[1]		Available water at planting[2]	Wheat Yield	GSP[3]
			(inches)	(bu/A)	(inches)
			Year Effects (averaged over positions)		
1986			6.7	21.0	6.9
1987			6.2	9.6	7.6
1989			4.6	12.0	4.9
1990			2.5	17.0	8.0
		LSD(0.10)[4]	0.4	2.1	
			Position Effects (averaged over years)		
	Su		4.4	12.6	
	Sh		5.1	12.3	
	Bs		5.3	13.2	
	Fs		5.3	21.6	
		LSD(0.10)	0.5	2.1	
			Year by Position Effects		
1986	Su		5.4	19.4	
	Sh		9.1	20.4	
	Bs		5.0	18.5	
	Fs		7.3	25.9	
1987	Su		6.7	7.6	
	Sh		4.8	6.0	
	Bs		7.8	5.4	
	Fs		5.6	19.5	
1989	Su		3.0	8.7	
	Sh		3.7	8.4	
	Bs		5.1	9.2	
	Fs		6.4	21.6	
1990	Su		2.3	14.8	
	Sh		2.6	14.2	
	Bs		3.2	19.6	
	Fs		1.9	19.5	
		LSD(0.10)	1.0	4.1	

[1]Su = summit, Sh = shoulder, Bs = backslope, Fs = footslope.
[2]0-4 foot profile depth.
[3]Growing-season precipitation from planting to harvest.
[4]Least significant difference at the P = 0.10 level.

Table 2. Topographic position and year effects on available soil water at planting and wheat yields at the Falkirk reclaimed mineland location (oats planted in 1988).

Year of Data	Position[1]		Available water at planting[2]	Wheat Yield	GSP[3]
			(inches)	(bu/A)	(inches)
			Year Effects (averaged over positions)		
1986			5.2	26.1	8.9
1987			5.6	19.6	11.1
1989			2.0	12.4	4.6
1990			1.3	34.9	9.9
		LSD(0.10)[4]	0.8	2.0	
			Position Effects (averaged over years)		
	Su		3.5	19.0	
	Sh		1.9	19.0	
	TBs		3.8	22.4	
	MBs		3.2	25.6	
	LBs		3.5	23.2	
	Fs		4.4	28.2	
	Ts		4.4	25.4	
		LSD(0.10)	1.0	2.7	
			Year by Position Effects		
1986	Su		5.1	22.1	
	Sh		3.0	16.8	
	TBs		5.8	23.6	
	MBs		4.0	27.9	
	LBs		5.4	24.3	
	Fs		6.6	34.6	
	Ts		6.6	33.3	
1987	Su		5.8	16.8	
	Sh		3.6	16.9	
	TBs		5.7	18.2	
	MBs		54.	24.8	
	LBs		5.9	20.9	
	Fs		6.3	26.2	
	Ts		6.3	13.5	
1989	Su		1.7	9.3	
	Sh		0.6	7.9	
	TBs		2.0	12.8	
	MBs		1.9	11.7	
	LBs		1.9	14.0	
	Fs		2.9	15.3	
	Ts		3.2	16.2	
1990	Su		1.4	22.7	
	Sh		0.4	34.3	
	TBs		1.7	35.2	
	MBs		1.6	38.2	
	LBs		0.6	33.6	
	Fs		1.8	36.9	
	Ts		1.5	38.6	
		LSD(0.10)	NS	5.4	

[1]Su = summit, Sh = shoulder, TBs, MBs and Lbs = top, middle, and low backslope; Fs = footslope; and Ts = toeslope.
[2]0-4 foot profile depth.
[3]Growing-season precipitation from planting to harvest.
[4]Least significant difference at the P = 0.10 level. NS indicates no significant differences among means.

highly variable not only between but also within topographic positions. Some of the variability over years by positions can be seen in the data listed in Tables 1 and 2. While significant year by position AWP differences were found at Center where the range was 7.2 inches, no significant differences were found at Falkirk where the range was almost as large (6.2 inches). These year-by-position AWP values at both locations also show the decline measured over years.

The amount of growing-season precipitation received over the years of this experiment at these two locations was also highly variable as indicated in Tables 1 and 2. Distribution during the various years was also highly variable. For example, at Falkirk in 1987 nearly 50 percent of the precipitation occurred during the four weeks prior to harvest while only about 8 percent occurred in the same time period in 1990. Similarly at Center, over 50 percent occurred during the four weeks prior to harvest in 1987 as compared to about 19 percent in 1990. Both locations suffered from hot, droughty conditions in 1989.

Average wheat yields at both locations showed significant differences among years. This was due to the significant differences present in AWP and/or the amount/distribution of precipitation received. For example, at Center where AWP in 1990 was an average of 3.7 inches less than 1987, the average yields were 77 percent greater with only 0.5 inches more precipitation. At Falkirk in 1990 average AWP was 4.3 inches less than 1987 but average yields were 78 percent greater with 1.2 inches less rainfall due to better distribution of GSP.

When averaged over years, significant wheat yield differences were present from upslope to downslope topographic positions. This trend was more readily apparent for the discrete plots at Center than the continuous plot at Falkirk and may partially be due to microtopographic differences in the plot.

The year-by-position data in Tables 1 and 2 show some of the variability that was present from year to year among positions at the two locations. Wheat yields generally increased from upslope to downslope positions at both locations although yield differences within any one year for year by position may or may not be significant. The discrete footslope position plot at Center consistently had the highest (or nearly so) yield while at Falkirk the footslope or toeslope had the highest wheat yields in all four years (toeslope was mistakenly double seeded in 1987).

Results of regressing total water use to wheat yields at these two locations with four years of data are listed in Table 3. All equations have a positive regression slope value indicating increasing yields with increasing values for TWU. Coefficient of determination (r^2) values are poor due to variability in wheat yields and TWU values within positions at each location within each year. Other factors affecting these regression equations not included in the analyses were the distribution of rainfall during the growing season, weed infestation, insect damage, and possible runon/runoff among landscape positions.

Table 3. Regression/correlation analyses from the two reclaimed mineland locations relating wheat yields to total water use.

	Regression Coefficients			
Location	a	b	N	r^2
Falkirk	2.77	−1.66	56	0.44
Center	2.09	−0.60	32	0.47
Combined	2.83	−3.64	88	0.50

WHERE: Yield (bu/A) = (a*TWU) + b
TWU = total water use (inches)
N = number of samples

CONCLUSIONS

The two reclaimed mineland locations show significant topographic position effects on available water at planting and wheat yields. Both parameters are generally higher on downslope as compared to upslope topographic positions although actual values vary among years by positions. Although the yield and total water use values are highly variable, wheat yields increase with increasing total water use. Modelling efforts are now underway to try to determine a topographic position factor (most likely using slope gradient) to adjust total water use among positions to account for the variability found in the yield data.

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