Relationships among Landform Elements, Soil Properties, and Crop Yields on Blaine Lake - Hamlin Soils[1]

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Introduction

Soil properties are an important part of the complex framework in the crop production system. Soil properties may vary over short distances, but are related to position within the landscape. This study investigated the relationships among pH, salinity, bulk density, horizon thickness, depth to carbonates, and soil moisture according to landform position. Four catenas were studied under different crop rotations: summerfallow-canola-wheat, summerfallow-wheat-wheat, continuous cereals, and continuous cereals plus a legume. Total plant biomass and crop yields were determined on hand harvested samples from each slope position. Best yields in 1989, generally occurred in back and shoulder slopes and lowest yield in footslope areas that were flooded out by intense summer showers.

Materials and Methods

Site Design

The sites were established 70km north of Saskatoon, just east of the town of Blaine Lake. The soils are thin Black Chernozemic and are mapped as a Blaine Lake- Hamlin complex (lacustrine deposits over till) (Acton and Ellis, 1978). The topography is very gently undulating knoll and depression, with gleyed soils found in the depressional areas.

Each site was a five by six grid of sample locations (30 in total), 10m apart, that included representative landscape elements. Similar grids were set up on four different types of crop rotations. Soil erosion and deposition at each sample location will be influenced by the slope curvature (Pennock and de Jong, 1987). Soil landforms at each sample location were classified using the criteria set out in Pennock et. al., (1987). Modifications were made to the landform elements to include level landscapes that are present on shoulder and footslopes. Since these level locations were still present on shoulder and footslopes, and shared the same general soil properties, moisture and yield as converging and diverging elements, they were modified to include level shoulders (LSH) and level footslopes (LFS) (Fig. 1). Landforms were then grouped for analysis into three categories along the catena into shoulders (SH), backslopes (BS), and footslopes (FS).

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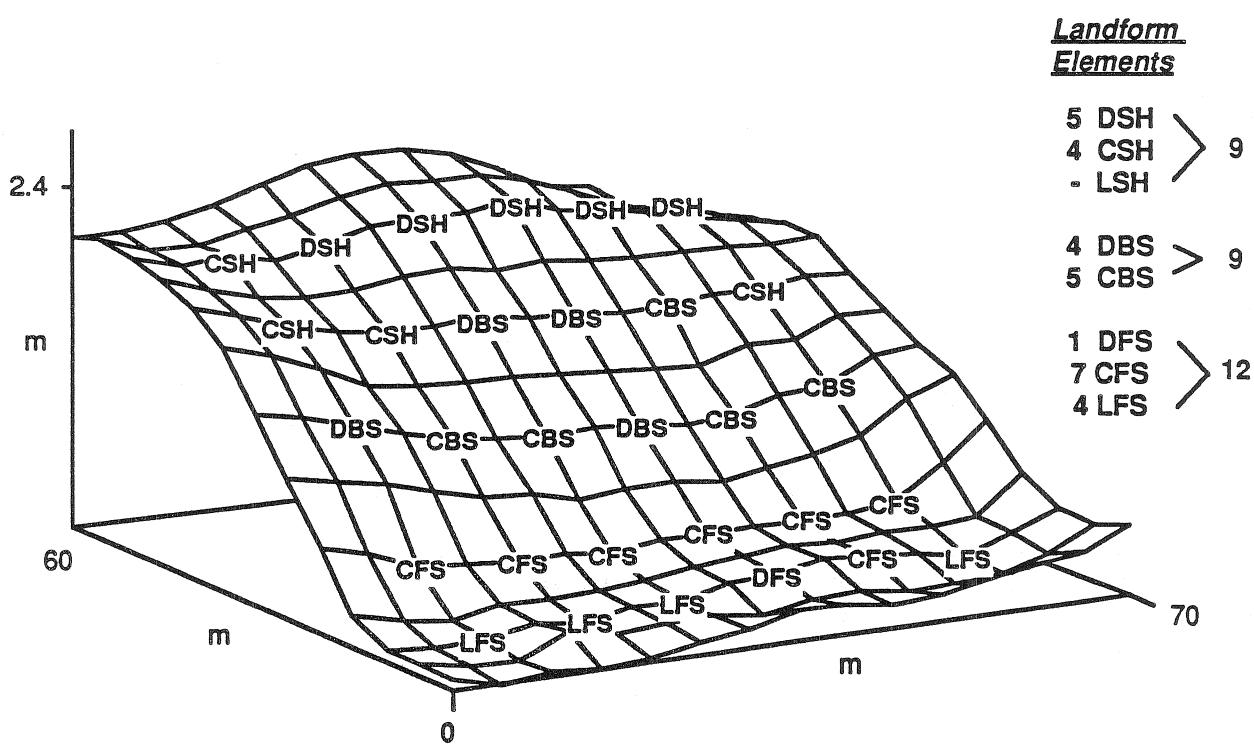
Figure 1. Landform Elements for Site #3



The crop rotation at each site are (with the crop grown in 1989 underlined): Site #1 summerfallow-canola-wheat, Site #2 summerfallow-wheat-wheat, Site #3 continuous cereals (barley), and Site #4 continuous cereals with legumes (peas) once every 3 to 4 years in the rotation. At each site the crop rotation has been followed for at least twenty years.

Measurements

Soil samples were taken in the spring of 1989 at four depths: 0-15, 15-30, 30-60, and 60-90cm. Soil pH and electrical conductivity of these samples were determined using a 1:1 soil water suspension.

Samples for bulk density were collected using a punch truck with a soil corer. Since both the inside diameter of the core and soil weight were known, bulk density was then calculated on a oven dry basis.

Neutron access tubes were installed down one of the center columns of the grid. During the summer, sub-surface soil moisture was monitored every two weeks with the use of neutron moisture meter. Sub-surface soil moisture was determined between 25cm and 125cm depths.

Total plant biomass and crop yield were hand harvested on $1m^2$ areas that were replicated three times at each sample location on the grid. Site #4 was harvested on replicated $3m^2$ because of the nature and variability of the pea crop. Total biomass included any above ground growth of both crop and weeds.

Results and Discussion

Soil Properties

pH General trends for pH were present in all sites. The most consistent trend is the increase of pH with depth, from the increase in carbonates (Fig. 2). Accumulation of carbonates at the 30-60cm depth in a Bmk or Cca horizon resulted in higher pH's than the parent material below.

The trend with slope position is to decrease pH as you move down the slope from the shoulder slope to backslope to footslope (Fig. 2). An interesting case in Site #1 where the backslope position has a higher pH than the shoulder slope (Fig 3). This is mainly from a thinner Ap horizon from cultivation and loss of soil by water erosion, as well as, less infiltration of water on the backslopes.

Salinity The movement of water down the profile and slope can move the soluble salts out of the immediate soil profile and thus not effect crop productivity (Fig. 4). However, if the downward movement of water has not been enough to remove these salts from the parent material, we may see salinity still present underneath the knolls (Fig. 5). These salts generally persisted at the 30-60 and 60-90 cm range, possibly affecting the roots of some crops.

Bulk Density Bulk densities for 0-15cm showed a consistent trend in all sites with the backslope position the highest, compared to the shoulder and footslope positions (Table 1). The depth of the A horizon in the backslope positions are less than those of the shoulder or footslopes, at about 15cm or less. This allows in most cases, that some of the B horizon is being mixed in with the A horizon, thus causing a increase in bulk density with a decrease in the amount of organic matter. Comparing the density of the footslopes with (Sites #1 and #2) and without (Sites #3 and #4) the use of summerfallow, shows that they are significantly different. The continuous addition of crop residues every year may have something to do with increased organic materials and the lower bulk density. The bulk densities for the summerfallow sites in the footslope position were higher

Figure 2.

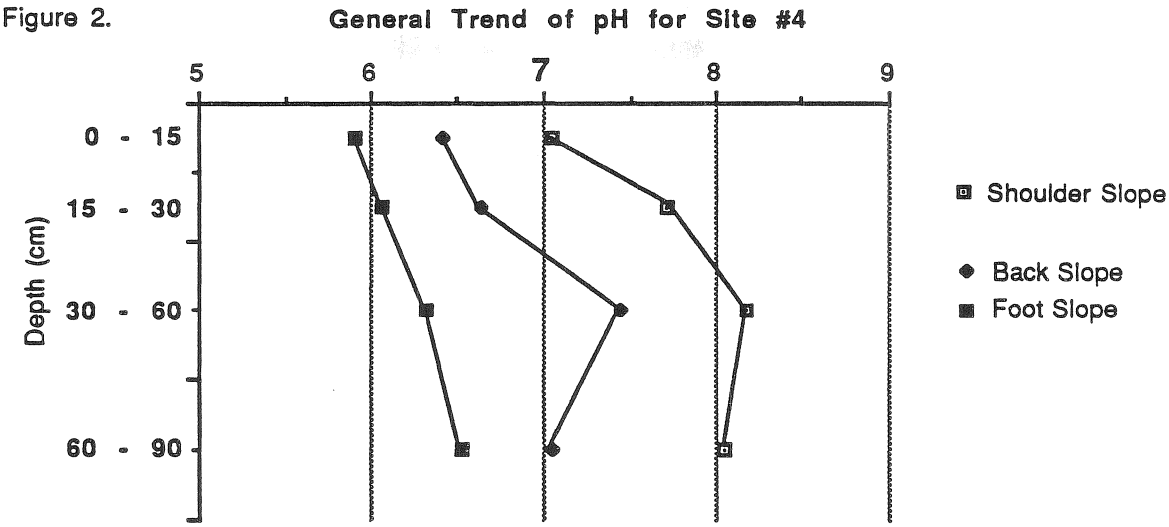


Figure 3.

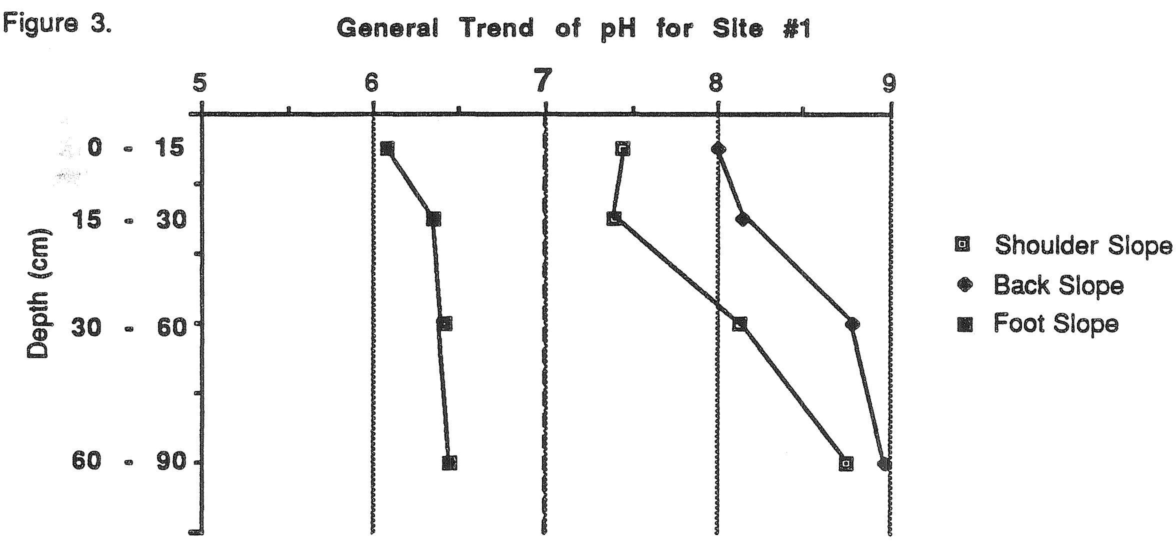


Figure 4. General Trend of Electrical Conductivity for Site #2 (dS/m)

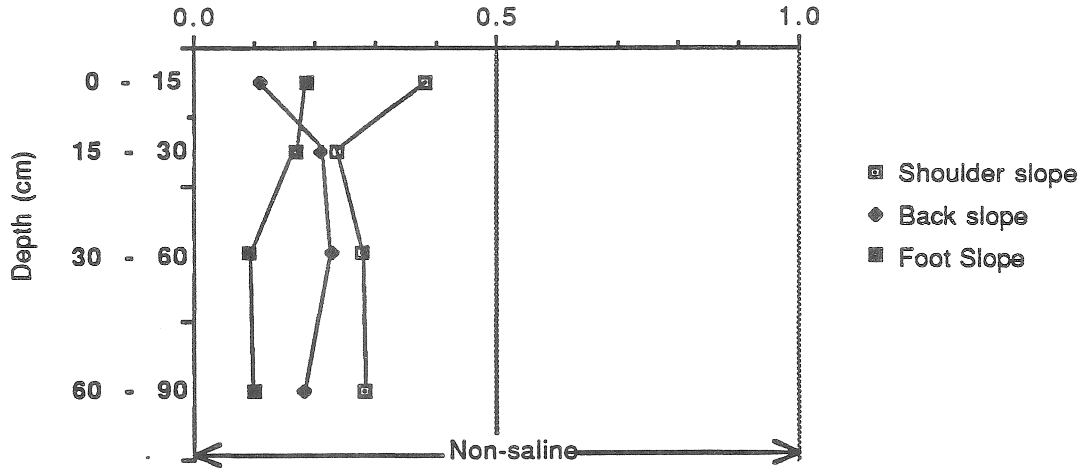
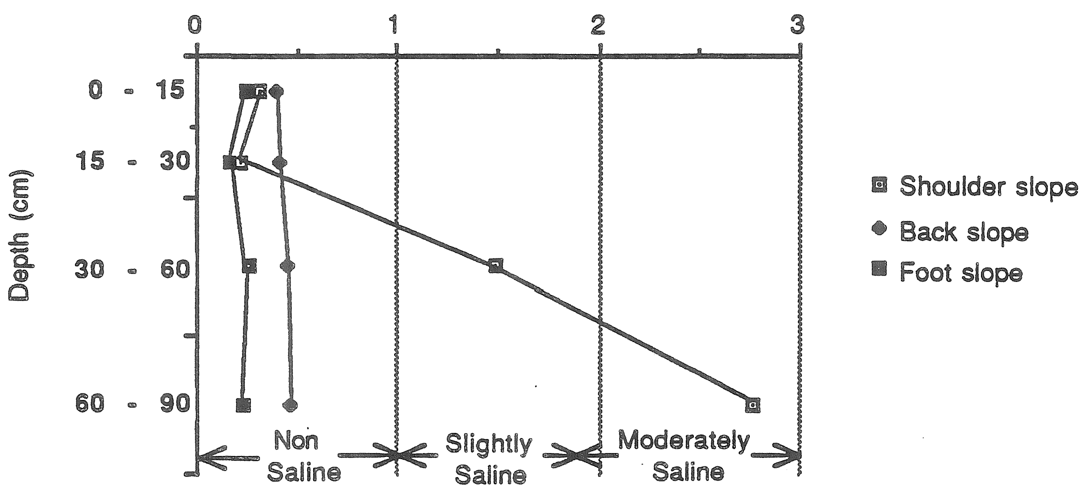


Figure 5. General Trend of Electrical Conductivity for Site #3 (dS/m)



than the shoulder slopes while in the continuous sites the opposite occurred. This again may be attributed to the more complete breakdown of organic materials in the summerfallow year but may also have to do with punching the soil corer in the lower slope positions where some compaction occurred from soil moisture.

Grouped bulk densities for 0-15, 15-30, and 30-45cm followed the general trend of increasing with depth.

Soil Moisture Soil moisture for the growing season in 1989 was generally adequate for the entire growing season. Intense but timely thunderstorms maintained the soil moisture in shoulder and backslopes positions, while flooding out footslope positions a number of times. In the lower slopes crop yields were limited by too much moisture flooding the crop and causing the crop roots to decompose.

Horizon Depth

A horizon The A horizon depth was generally thinner in the steeper backslope positions (Table 1). For all four sites the backslope vs. the footslope positions were significantly different (at significance level of 0.10). The sites that contained summerfallow in the rotation had significantly thinner backslope landforms than did the rotations without summerfallow. This is from the greater movement of top soil from the backslope positions into the footslope positions; probably in the fallow year. This redistribution of the soil also affects other properties such as pH that was mentioned earlier.

Solum Depth Solum depth generally increased from SH to BS to FS and was relatively unaffected by crop rotation (Table 1). Since the B horizon is at a sufficient depth, it is not redistributed within the catena. Site #1 was the only site to have a thinner solum in the backslope than the shoulder slope, again from the greater top soil erosion and redistribution.

Depth to Carbonates The depth to carbonates in the shoulder and backslope positions for all the sites are generally at the same depth as their solum depth (Table 1). The carbonates in these two slope positions had moved down with the development of the profile and were situated at top the C horizon, the parent material. Some of the sample locations in Site #3 backslope positions had a development of an Ae horizon in backslope position suggesting that these converging elements were receiving surface runoff from higher slopes. This was also very evident in the very deep carbonate depth for those sample locations (Table 1.) In the footslope positions of all the sites, water movement had moved these carbonates to a depth of >200cm in most of the sample locations.

All told, there is a consistent relationship between slope position and soil properties that are reflected by soil redistribution and long term soil moisture.

Total Biomass and Crop Yield in 1989

The highest plant biomass and crop yields occurred in the back and shoulder slope positions (Table 2). The soil moisture for most of the growing season was adequate, even in the upper slope positions. The lowest yield that occurred in Site #1 was in the backslope position from poor crop establishment early in the spring, high shattering losses at harvest, and possibly from the thin Ap horizon reducing crop productivity. The crop in Site #2 did the best on the backslope positions and where some of the lower slopes had been flooded out completely. Site #3 interestingly enough had the highest yield on the shoulder slope, attributed to the availability of soil moisture and favorable growing conditions over the season. Site #4 had a higher biomass yield in the backslope due to the infestation of Canada thistle in the pea crop, but a consistent yield across the shoulder and backslopes, with flooding occurred in the footslope positions.

Table 1. Average A Horizon and Solum Depth, Depth to Carbonates, and Bulk Density for Each Slope Position.

Site	A Horizon			Solum			Depth to Carbonates			Bulk Density (0 -15 cm)		
	cm									g/cm^3		
	SH	BS	FS	SH	BS	FS†	SH	BS	FS¥	SH	BS	FS
# 1	17.2	12.2a§	20.7abc	39.2a	28.0ab	>64	37.6ab	25.6a	>155	1.32a	1.46a	1.38ab
# 2	14.9	9.3bc	35.5a	58.0ab	68.3a	>95	60.4ac	141.3abc	>174	1.33b	1.54b	1.38cd
# 3	17.7	18.4ac	37.8b	44.4	62.3b	>111	51.4bd	57.7b	>169	1.29c	1.32abc	1.21ace
# 4	16.3	15.2b	32.1c	34.0b	53.2	>63	31.1cd	69.8c	>180	1.40abc	1.47c	1.31bde

§Elements with the same letter in each column are significantly different at a significance level of 0.10

† Solum depth deeper -ave. does not include the Bg horizon

¥ Carbonate depth in most cases was >200cm

Table 2. Average Total Biomass and Crop Yield for each Slope Position

Site	Crop	Total biomass			Crop Yield		
		kg/ha					
		SH	BS	FS	SH	BS	FS
# 1	Canola	4854	3600	4511	1066	761	1027
# 2	Wheat	6412	6930	6288	2469	2633	2052
# 3	Barley	8918	8429	2490	3664	2775	272
# 4	Peas	5517	7707	1494	1996	1994	0

Note: Comparison among sites can not be done because of different agronomy practices among cooperators (i.e. crop, seeding date, weed control, etc.)

The interaction between climate and slope positions prove to be very significant for total plant biomass and crop yield in any one given year.

References

Acton, D.F. and J.G. Ellis. 1978. The soils of the Saskatoon map area 73-B, Saskatchewan. Saskatchewan Institute of Pedology Publication S4.

Pennock, D.J. and E. deJong. 1987. The influence of slope curvature on soil erosion and deposition in hummock terrain. Soil Science 144:209-217.

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