SOIL DEGRADATION IN SASKATCHEWAN, A PEDOLOGICAL PERSPECTIVE

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INTRODUCTION

Recent evaluations of soil deterioration in Western Canada have acknowledged that there still remains serious problems, but have concluded that many of our soils are in better condition than than some earlier studies suggested. Robertson and Laverty (1988), for example, concluded that "deterioration is probably less severe than it was in pre-World War II days when straw was removed, land was plowed, few nutrients were returned and clean fallowing was more prevalent". McGill et al. (1988) reported on one of the most comprehensive studies of the effects of cultivation on soil organic matter, and noted that actual losses of organic matter were more like 15 to 30%, rather than 50%. Their study did identify the frequency of bare summerfallow as the factor most strongly related to organic matter decline. de Jong (1988) pointed out that soil erosion is not a recent phenomenon on the prairies, occurring even prior to cultivation when the land was overgrazed by bison, but concluded that erosion remains a serious problem that must be solved in order to sustain land quality. Flaten and Hedlin (1988) observed that productivity has increased substantially over the past several decades, and pointed to the difficulty of assessing the effects of soil deterioration because of the masking effect of improved technology.

These statements appear to be at variance with earlier reports that concluded, or at least appeared to conclude, that soil deterioration is a crisis that affects nearly all the cultivated land in Western Canada, and that extreme measures to alter the basic methods of production are required in order to sustain agriculture (Rennie 1979; Senate Committee on Agriculture, Fisheries and Forestry 1984; Science Council of Canada 1986). In fairness, it was pointed out in several of the reports that conclusions were based on an inadequate data base (Rennie 1979). In some cases, recent reports that have pointed out that much of the farmland that is being managed with conservation-oriented cropping strategies is of better quality than earlier reports suggested have been interpreted to mean that soil deterioration is not a serious problem. This too is not correct. Soil deterioration, particularly the serious soil erosion that has occurred in recent years, is still a serious problem that requires our attention.

This paper has two objectives: one is to suggest a framework for examining and understanding the complex system that is the agricultural land of Saskatchewan within a hierarchical framework based on soil survey; the second objective is to report briefly on recent findings on soil quality, particularly those concerning soil organic matter and erosion, and soil salinity.

A PEDOLOGIST'S VIEW OF LAND

Pedology integrates knowledge of the geology, geomorphology and hydrology of an area, into the study and explanation of soils (Daniels 1988). Pedology is essentially a field science by which soil scientists are able to relate findings obtained by studying samples in the laboratory back to that portion of the real world that the sample represents. This is accomplished by knowing the nature of the soil horizon sampled, the place of the horizon in a soil profile, and the relationship of the profile to the landscapes of which it is a component (Fig. 1). A soil sample in the laboratory is nothing more than a bag of dirt, becoming a research sample only when the field relations are known (Daniels 1988).

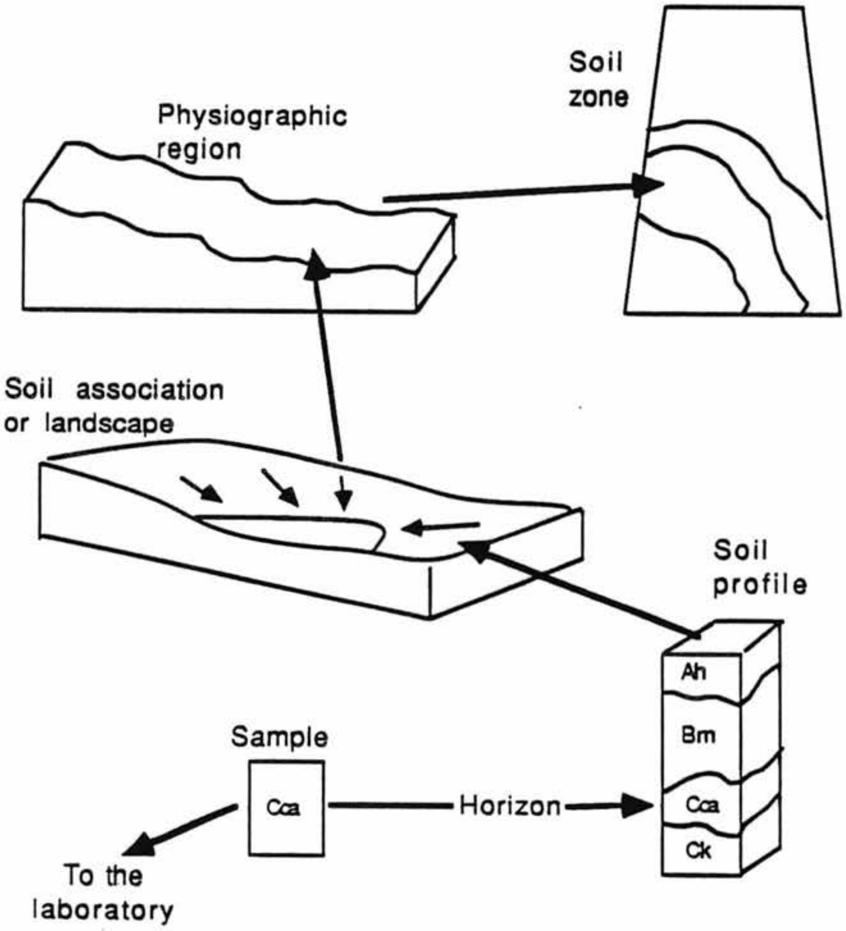


Figure 1. Schematic diagram illustrating the relationship between soil horizons, profiles, associations, physiographic regions and soil zones.

The agricultural land of Saskatchewan is a complex assemblage of different geological materials, climates, landforms, past and present vegetation, and land uses. We understand or bring order to this system by organizing the complexity at different levels of detail, using attributes of the land as differentiating criteria. The basic structure for this organization was first suggested by Ellis (1931). Pedologists have made good use of Ellis' ideas in setting up soil surveys, particularly in Saskatchewan. Ellis considered that the basic unit to be used in developing a classification for soil survey was the soil associate. A soil associate is a particular kind of soil profile that has developed on a specified parent material. Related associates were aggregated into soil associations, with associates differing mainly in their drainage or moisture status as indicated by the characteristics of the soil profile. Associations were basically groups of related soils within a hillslope or toposequence, and included, physically as well as conceptually, all the soil that occurred there. Associations could be grouped together to form combinations, or related groups of associates within the same physiographic division. The most general grouping was the soil zone, which was defined by general climate and vegetation of a region as represented by important soil characteristics, particularly colour of the surface horizons.

The present soil survey in Saskatchewan is based largely on the classification proposed by Ellis (1931), with some minor differences that are significant. One difference is the absence of one level, the combination. Physiographic regions are not an integral part of the soil survey classification, although physiography is used in a descriptive way. In retrospect, this may be a deficiency in our classification in that the environment for soil formation is considerably different in lowlands than in uplands, as discussed later. The agricultural resource area maps now being prepared for the prairie provinces delineate areas of related groups of soils based on landscape and physiography. These maps are to be used for land evaluation on a regional scale, mainly to interact with dynamic models and assess large-scale phenomena such as climate change.

Many soil survey maps in Saskatchewan appear to be overly complex because of rigorous use of the soil taxonomy in defining classes, particularly map units. The result can be a large number of map units, many of which differ only in having some minor soils with a different subgroup classification that may involve differences in only one horizon. Witty and Arnold (1987) consider that a too rigid application of soil taxonomy, especially where the result is soil boundaries that do not coincide with obvious changes in the landscape, is a problem with many soil surveys. Research in Saskatchewan has indicated that a more functional division of the soil landscape is to separate convex areas with thin soils, concave areas with thicker soils that contain more organic matter, and poorly drained soils (King et al. 1983). These divisions may not only be more realistic in defining the soils that actually occur within a landscape, but lead to map unit descriptions that are easier for non-pedologists to understand. Recent soil surveys in Saskatchewan describe map units by using ordinary language, rather than the more obscure terms of the soil taxonomy. This appears to be an important change to enhance the useful of reports.

One of the main uses of a soil and landscape map is to enable the appropriate extrapolation of findings from a point or local area to larger areas that have similar characteristics. This is a common problem in all sciences where complex systems are involved--how far can a set of observations that are limited in space and time be extrapolated to more general systems (O'Neill et al 1986)? It appears to me that many of the different perceptions of the seriousness of soil deterioration relate to this problem, in that very limited data were available and those data that were available may have been applied much beyond the soil and landscape areas where the data were valid. For example, observations on the organic matter content of cultivated Ap horizons in comparison to native Ah horizons were used to characterize the organic matter content of soils at a zonal scale. These comparisons did not consider intermediate levels, namely profiles, soil series and associations or landscapes, nor the inherently different character of Ap and Ah horizons. Ap horizons are not a natural feature of the soil, in that their thickness is determined by the depth of cultivation. Incorporation of soil from lower horizons dilutes the organic matter present and alters the density of the horizon. Later work that has focused on horizons, profiles, and profiles within hillslopes has resulted in significantly different ideas about the loss of organic matter from prairie soils (Anderson et al. 1985; Gregorich and Anderson 1985; de Jong and Kachanoski 1988; McGill et al. 1988).

It is important that future research to monitor changes in soil quality under different management pay attention to the kind of horizon, profile and association being sampled and the location of the profile within a landscape in order to obtain data that are able to be extrapolated to more general but appropriate situations.

SASKATCHEWAN SOILS AT DIFFERENT LEVELS OF DETAIL

The hierarchical approach for a classification to be used for soil survey that was proposed by Ellis (1931), and adapted for use in the present Saskatchewan soil surveys will be discussed, with particular attention to process, mainly processes involving water (Table 1). Processes that are driven or mediated by water are important to soil deterioration, especially changes in soil salinity, erosion, and organic matter losses.

Table 1. Hierarchical classification for Soil Survey (Ellis,1931) related to soil survey in Saskatchewan.

Level of detail	Differentiating characteristics	Sask. Research Emphasis
Soil zone	Regional climate, vegetation	General relationships
Combination	Physiography	Soil salinity
Association	Landscape	Soil erosion
Associate (series)	Parent material, nature of the profile	Yield response
Profile	Typical volume of soil	Process studies
Horizon	Functioning part of soil	Basic unit for sampling

Soil Profile and Series

The soil profile is the basic unit of soil and should be the object of study regardless of the final level of detail to which the findings may be extrapolated. Field experiments such as small field plots can sometimes be located on one kind of profile, whereas other experiments that are more extensive may group sample locations based on the kind of profile. This was the basic approach in many field-scale fertilizer trials in Saskatchewan, and in experiments that evaluated the productivity of Solonetzic soils (Anderson and Wilkinson 1976). Profiles are studied by sampling at the next more detailed level, the soil horizon. Natural soil horizons have acquired a particular character because of performing a particular function over time (Nikiforoff 1959). The processes within horizons are mediated mainly by water and can be viewed as a balance between downward flows or leaching, and upward fluxes such as capillary rise (Fig. 2). Quality soils have a balance between leaching and counteracting influences such as capillary rise, and it is when this balance is too much one way that problem soils develop. Saline and sodic soils occur where upward, fluxes driven by evaporation in arid climates or by strong artesian pressure, are greater than leaching potential. Acidic soils occur where leaching is strong and upward fluxes due to capillary rise are minimal, although the biocycling of base cations and retention of base cations on exchange sites both act to sustain natural soil productivity over time in strongly leached soils.

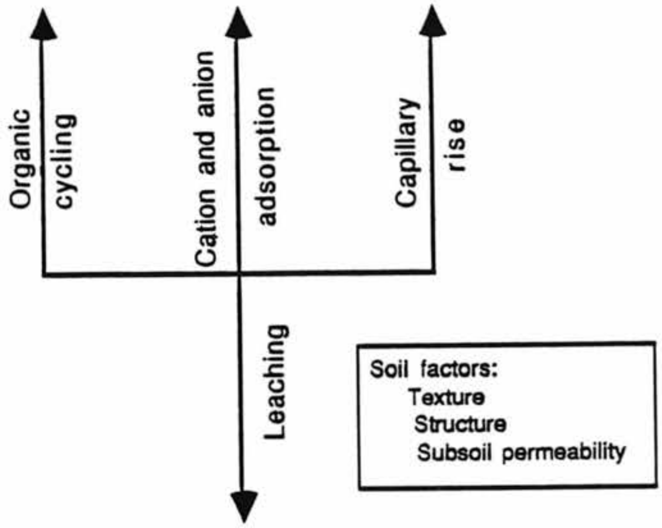


Figure 2. Processes and factors in soil that affect the degree of leaching.

Attention to the nature of soil horizons can give clues of the response of soils to change. Increases in artesian pressure that raised water tables and increased upward fluxes of water and solutes first affected Solonetzic soils, because the dynamic balance between leaching and capillary rise had maintained naturally high salt loads in the subsoil (Anderson 1989). The salts simply moved upward with the increase in artesian pressure. Another group of soils in the same study area that became more saline were those with strong Cca or carbonate-enriched C horizons, particularly those soils that occurred in lower areas. Strong Cca horizons in lower slope soils indicate, at least to me, that leaching is restricted by capillary rise, and any change to raise the water table will move water and solutes back to the surface. The presence of soluble salts in the well developed B horizons of soils is good evidence that the salts have re-salinized a soil that formerly was well drained.

The geological material that a soil has developed from is recognized as a differentiating characteristic in soil classification at the level of the profile or series, although it is recognized that lithology or composition has considerable effect at more general levels. Parent material has considerable effect on processes and resulting soil quality, particularly in areas like Saskatchewan where the soils are relatively young and still retain mainly properties of the original geological deposit. Soil texture is one attribute that is determined mainly by original composition, and is a property that relates strongly to soil quality because of the critical importance of moisture holding capacity. Texture has considerable importance to the nature of soil profiles because of its effect on infiltration and permeability, therefore on leaching. Clayey soils tend to take in water slowly, and depths of leaching are generally less because of the high moisture holding capacity of surface layers, whereas sandy soils are leached to much greater depths. Texture affects, as well, the susceptibility of soils to erosion, with soils made up primarily of one dominant size class (sandy, silty and clayey soils) all considered more erodible than those of medium texture.

Soil Association and Catenas-Soils at the Landscape Level

Soil profiles occur in landscapes or catenas, and are strongly affected by the shape of the land surface and by interactions between relative differences in elevation between the surface and the surface of the water table. Ellis (1931) recognized differences in soils in different portions of landscapes and ascribed them mainly to differences in drainage, although it is evident in his writings that he recognized the critical importance of surface form on runoff and runon, and therefore the moisture available for soil development (Fig. 3). Later work, mainly in Saskatchewan, has reinforced the earlier ideas and provided more quantitative data relating surface form to characteristics of the soil profile and to yield. King et al. (1983) presented cross sectional diagrams of landscapes that indicated the critical influence of degree of concaveness or convexness on the resulting thickness and nature of soil horizons, with soil thickness increasing markedly at inflection points where surface form goes from slightly convex to slightly concave. This work indicated the strong relations between profile development and pH, clay content and exchangeable potassium. Soils within landscapes could be divided functionally into thin soils on upland convexities, much thicker soils on concave areas, and imperfectly drained or gleyed soils in depressions, as noted earlier.

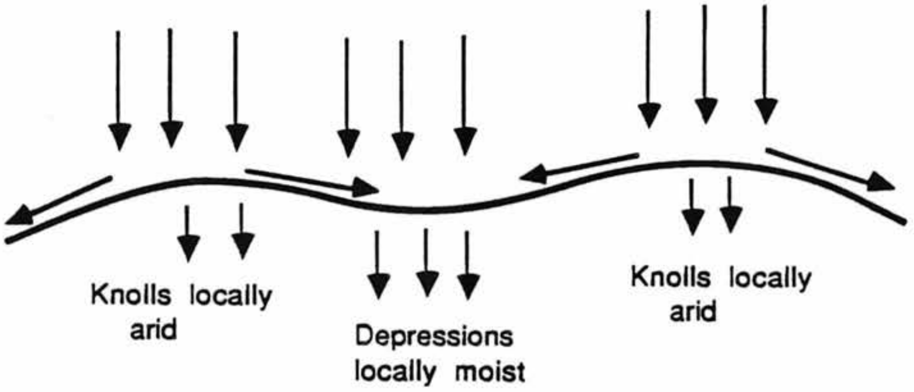


Figure 3. The effect of relief on water penetration on soils (Ellis 1931).

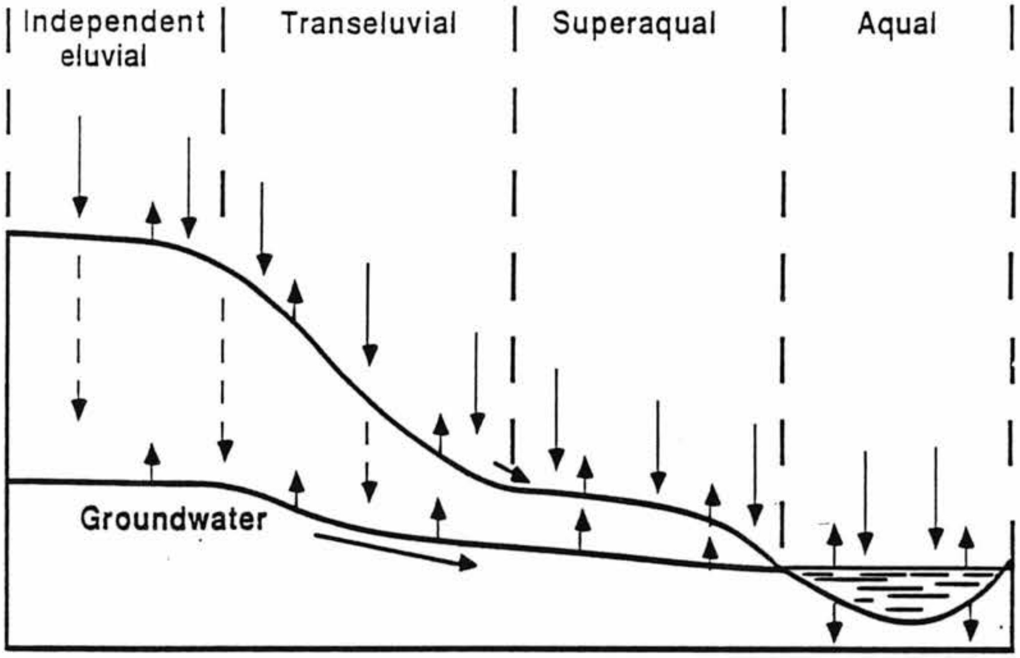
Recent work relating surface form to soil profile has been based on three-dimensional landscape elements (Pennock et al. 1987). The landscape elements were based on three important features: gradient or steepness of slope, profile (downslope) curvature, and plan (across-slope) curvature. Seven landform elements were recognized, with a primary division based on whether flow lines, as indicated by contours, flowed together (convergent), or flowed away from each other (divergent). Differences in soil properties among the landform elements can be largely explained by differences in water movement and distribution in hillslope systems. The thicknesses of A horizons and depths to calcium carbonate (depth of leaching) were consistently greater in convergent versus divergent elements, and increased in the sequence shoulders < backslopes < level < footslope elements.

Research by St. Arnaud (1979) and by Eilers (1982), albeit in two dimensions only, considered the importance of surface form and near surface stratigraphy on soil profiles, particularly the distribution of carbonates and more soluble salts. Cross sections indicate the strong influence of surface form on not only the depth of A and B horizons, but on the depth of leaching of salts and carbonates (St. Arnaud 1979). Carbonate minerals were leached to much greater depths and soluble salts completely removed to 10 to 12 meters depth, from under even relatively minor concavities or depressions, with little leaching of salts or carbonates under convex landscape portions. Salt concentrations were highest in some subsoils at about two to three meters depth under level to convex lands, and adjacent to some strongly leached depressions where they appear to have been concentrated by lateral movement. Lateral movement could occur as temporary groundwater mounds under the depressions are dissipated by mainly downward but some lateral flow. Eilers (1982) research further pointed to the importance of surface form and its influence on surface flow on carbonates and salts. Cross-sections illustrate that weakly leached soils with carbonates at or near the surface, and gypsum accumulations in the subsoil occur under convex slope elements with reduced leaching, whereas even minor concave portions have both minerals completely removed from the soil to a depth of three to four meters. Strong accumulations of carbonates, gypsum and more soluble salts occur in soils on very gently sloping land adjacent to depressions, and appear to be the result of the lateral dissipation of high water tables that occur under the depressions early in the growing season. The lateral movement of water results in high water tables under the sloping land adjacent to the depression. Water carrying salts and carbonates wicks upward due to capillary rise, with the salt accumulating on the soil surface during dry periods.

Physiographic Sections and Subsections

Soil survey in Saskatchewan does not use physiography directly in differentiating map units for mapping. The physiographic divisions of all of Saskatchewan (Acton et al. 1960) and physiographic descriptions and the small-scale maps that are provided in reports for specific areas provides a setting or framework for the actual soil mapping. Physiography refers to the general classification of land based on its physical attributes, namely elevation, landform, topography or surface form and geological composition. Physiography is important to soil formation because of its influence on local climate, as on uplands such as the Cypress Hills that form an effectively more moist and cooler region within the Brown soil zone, and because of interactions between elevation and groundwater. The basic ideas relating depth and influence of groundwater on soil development were presented by Polynov (1951), as shown in Figure 4, and are similar to more refined concepts based on studies that related hydrogeology to soil salinity (Henry et al. 1985). Soil formation on uplands with deep water tables occurs on eluvial landscape elements, with the water table having little or no effect on soil development. The soils of lowlands, within the landscape element designated as superaqual, will generally have soils that are strongly influenced by groundwater. Saline and sodic soils occur where upward fluxes of water plus dissolved ions, usually abetted by strong evaporation from the soil surface under dry climates, are much stronger than leaching. Solonetzic soils occur in the superaqual and transitional landscape elements where a dynamic balance between upward fluxes from groundwater and leaching maintains high salt concentrations, particularly sodium salts, in subsoils (Anderson 1987; Luba 1987).

Strongly developed, calcium carbonate-enriched (Cca) horizons are typical of lowlands where calcium salts rather than sodium salts are dominant. The soils mapped as Ryerson Association in Soil Survey Report Number 12 occur in the lowland east of Moose Mountain. Soils within this area have strong Cca horizons, a large proportion of calcareous profiles and a higher than usual occurrence of saline soils that appear to relate to the influence of regional and local groundwater flows.



Characteristic Soils of Each Landscape Element in Different Soil Zones

Eluvial	Transeluvial	Superaqual
Brown, Dark Brown Chernozemic with some solonetzic where subsoils less permeable	Chernozemic, solonetzic, saline	Saline and solonetzic
Black Black, Dark Gray and Gray Luvisol	Black, often calcareous, saline	Saline and calcareous
Gray Gray Luvisol	Gleyed Gray Luvisol, Wooded Calcareous, occasional saline	Organic soils

Figure 4. The importance of physiography to landscape elements as described by Polynov (1951), and soil formation.

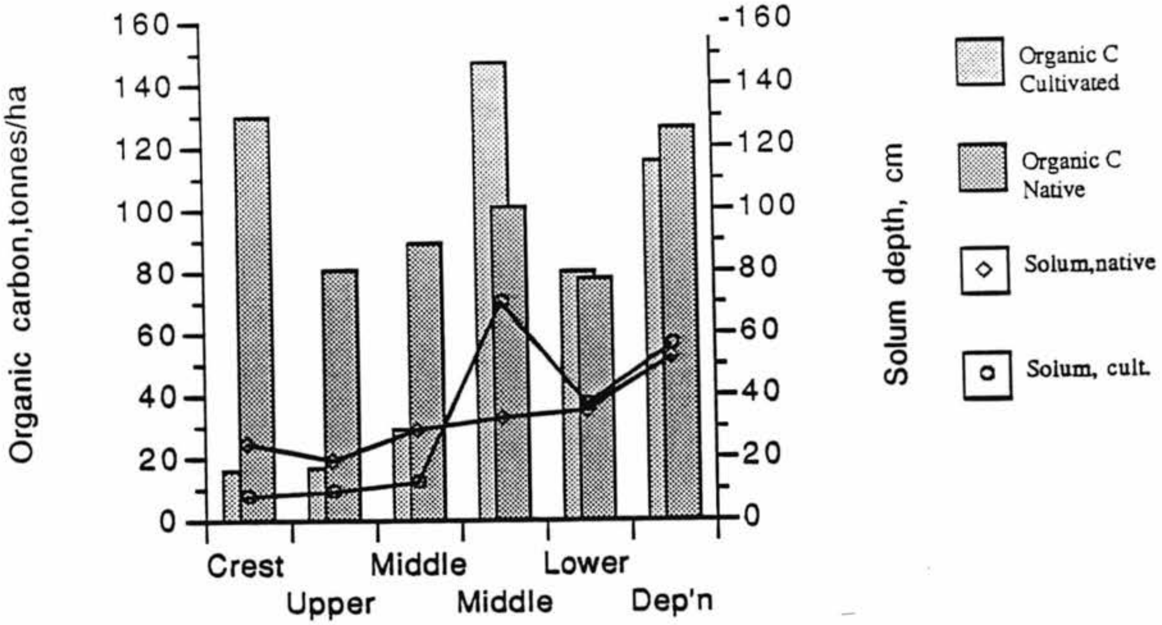


Figure 5. Organic carbon and solum depth in paired cultivated and native Dark Brown soils on hummocky terrain.

Table 2. Amounts of organic C and cesium in paired native and cultivated soil profiles of the Brown, Dark Brown and Black soil zones.

Zone	Native		Cultivated	
	Organic C (t/ha)	Cesium (Beq/m^2)	Organic C (t/ha)	Cesium (Beq/m^2)
Brown (21)	105.4±12.9	2570±181	108.5±17.8	2501±490
Dark Brown (23)	101.0±11.7	2555±81	57.8±9.6	1784±168
Black (22)	115.0±11.2	2472±131	101.4±15.9	2738±473
All (66)	107.0±6.8	2533±78	88.7±8.8	2332±232

four cultivated hillslopes were open systems with no gains of soil in lower slopes. This study is one of the larger data sets that deal with erosion and organic matter loss, but evidently is not adequate to adequately assess the current situation. The large gains of cesium and organic carbon in some of the lower slope soils in the Brown zone may have resulted from the deposition of soil eroded from adjacent slopes and is, therefore, an overestimation of deposition within the hillslope in question. The amount of cesium present in the cultivated Black soils was higher than the native soils, probably because of a similar gain of cesium and soil from other slopes within complex landscapes. This accentuates the need for studies that consider the landscape in three-dimensions, as suggested by Pennock and de Jong (1987). Considering all 67 pairs of native and cultivated profiles indicates a reduction of organic carbon from 107 tonnes per hectare in the native to 89 tonnes per hectare in the cultivated soils, or a 17% loss of organic carbon or organic matter overall. Despite the reservations of the adequacy of the data set, I think that this represents a reasonable estimate of total organic matter losses, and is consistent with the detailed studies reported by McGill et al. (1988).

This redistribution of topsoil and organic matter by erosion is still a serious problem because it results in increasingly less fertile upper slopes. The extra topsoil that is deposited in lower areas appears to have little beneficial effect on production, in that lower slope soils already are deep and well supplied with organic matter and nutrients. Redistribution of soil within hillslopes adds to soil variability making it difficult to apply appropriate rates of fertilizer on a field basis. Another recent study at the University of Saskatchewan has concluded that erosion was the main process accounting for differences in the organic matter content of soils sampled in the 1960s and re-sampled in the 1980s (de Jong and Kachanoski 1988).

Most studies of organic matter losses have compared virgin soils with lands broken 50 to 90 years ago, with only limited knowledge of the effects of current soil-conserving management practices and different rotations on organic matter. Both comparisons of farmers' fields and experimental plot studies have shown that the more frequently a field is summerfallowed, the lower the organic matter content, other factors being equal (McGill et al. 1988; Campbell et al. 1989). This is because little or no organic residues are returned to the soil during fallow years, rates of organic matter breakdown by the soil micro-organisms are increased in the moist and warm fallow soils, and erosion may be more severe where fields are not protected by a crop.

A comparison of soils in North Dakota where farmers had practised stubble mulch tillage since the early 1950s with soils not managed with so much attention to conservation, showed that organic matter levels under stubble mulch tillage today were about the same as those measured on similar fields in 1947 (Bauer and Black 1981). Good stubble mulch tillage to limit erosion had the greatest positive effect on organic matter on sandy and, to lesser degree, clayey soils that are easily eroded. Differences between conservation tillage and conventional tillage were least on the heavy loam and clay loam soils that are not easily eroded. This study has two important conclusions. One is that currently available tillage and cropping practices can be effective in reducing erosion and maintaining organic matter, and the second is that attention must be given to erosion-susceptible soils, particularly clayey and sandy soils.

Work at the Agriculture Canada Research Stations at Swift Current and Lethbridge indicate that farming systems that use stubble mulch tillage, provide adequate fertilizer so that yields are not limited by shortages of nutrients (resulting in greater production of grain, and more straw to be returned to the soil), and reduce the frequency of summerfallow can maintain or even slightly increase organic matter (Biederbeck et al. 1984; Janzen 1987). In addition, minimizing the frequency of summerfallow and enhancing production with fertilizers resulted an organic fraction with an enhanced capacity to supply nutrients by mineralization. A current study at the Indian Head Experimental Farm shows similar trends for wheat- fallow rotations, and a considerably increased supply of nitrogen where forage crops are part of the rotation (Greer and Anderson 1989).

Erosion

Discussions on organic matter have pointed to the importance of erosion to changes in organic matter, and indicated that erosion is a serious problem on sandy and clayey soils, and on upper slopes in areas with hummocky or strongly sloping lands (Anderson et al. 1985; Pennock and de Jong 1987). There appears to be little actual data to indicate the magnitude of the problem on sandy soils, but general observations of the past few years, and the blow-banks or fence-row dunes still remaining from the 1930s indicate that most sandy soils should not be under annual cultivation. Many of these lands were put under grass decades ago, and only cultivated again in the 1970s and early 1980s when grain land was bringing high prices and livestock returns were low. The best management strategy for the fragile and low capability lands is to remove them from annual crop production, and use them for the production of forage or, in some cases, forest and wildlife lands.

Clayey soils lose their stable granular structure and are easily eroded by wind during winters with little or no snow cover. These soils, however, are generally quite productive and are well suited to large-scale cereal production. Particular attention must be given to clayey soils on rolling topography, in that water erosion can be severe (Mermut et al. 1983). These lands should remain in annual crops, but conservation measures such as conservation tillage, strip-cropping to reduce field widths, and grassed runways where water erosion is a problem must be implemented. Interestingly, early work at Swift Current showed that clayey soils are as easily eroded by wind as sandy soils, and recommended very narrow strips (32 strips per half-mile) to adequately protect fallow lands against wind erosion.

Salinity

Comprehensive studies of the geological and hydrological processes that cause salinity have shown that much of the most serious salinity results from the upward movement of water and salts in lowlands that are affected by artesian pressure. Henry (1988) has estimated that about two-thirds of the salinity in Saskatchewan is related directly to discharge from aquifers of either glacial or bedrock origin. Salinity of this nature is a natural occurrence and appears to be affected minimally by current agricultural practices. Some of these lands may be improved by pumping aquifers to reduce artesian pressure, perhaps using the water to reclaim saline land where the water is of adequate quality, that is, containing calcium and magnesium rather than sodium salts. Possibilities for reclaiming these saline lands are limited and most should be taken out of cereal production and used for forages and grazing where practicable.

Several studies have examined the effect of agriculture on the areal extent and severity of saline soils. Ballantyne (1963), in assessing an apparent increase in saline land during a wet period, the 1950s, in sub-humid southeastern Saskatchewan, presented evidence for increasing salinity in lower slope soils. The most strongly affected soils occurred on planar, very gentle slopes slightly above and adjacent to depressions that held temporary ponds during wet periods. The saline land had no growth of the intended wheat crop, and salt concentrations that increased towards the soil surface. Ballantyne (1963) considered that the build up of salts in lower slopes represented a downslope movement of salts within the soil, resulting from the saturation of the upper slope soils. The extra water entering the upper slope soils was considered a result of four years of much above average precipitation.

A study in the semi-arid region of southern Alberta reported increasing salinity in agricultural regions (Greenlee et al. 1968). Solonetzic soils in lower areas were affected most strongly in that salts had moved upwards from a normally saline C horizon to resalinize B and A horizons. Formerly non-saline Dark Brown soils on gentle slopes had also become more saline. The increase in salinity that was evident in comparing aerial photographs taken 1951 and 1962 was attributed to an increased incidence of wet years with greater than the mean precipitation, but implicated the practice of bare fallow, and land use changes on adjacent rangeland.

A more comprehensive assessment involving annual sampling of 64 sites in Saskatchewan (Ballantyne 1978) indicated the highly variable and dynamic nature of soil salinity. There were always changes in salt concentration for individual soil profiles that were opposite to the average change in the area. Yearly variations were not related to any single factor such as cropping practice, topography or type of soil profile. The largest annual changes in salinity (30% increase in soluble salts) occurred in soils under low knolls in bare fallow fields.

The salt level in soils can change rapidly. A change in the water table or artesian pressure that enhances upward flows by capillary rise can make surface horizons saline in a matter of years, and salts may leach from a freely drained soil in a similarly short period (Table 3). Recently salinized soils have particular characteristics that include high concentrations of soluble sodium, and total salt concentrations in surface layers, coupled with low salt concentrations in the subsoil. The net result is that many salinized soils have low readings with the portable salinity meters such as the EM38. Care must be taken when establishing relations between EM38 readings and salt concentrations in the soil.

Table 3. Two soil profiles that show the dynamic nature of soil salinity.

Horizon	Previously non-saline soil subject to increased artesian pressure			Saline glacial till placed in a mine-spoil in 1947, sampled in 1975		
	Depth (cm)	EC (mS/cm)	SAR	Depth (cm)	EC (mS/cm)	SAR
Aps	0-15	14.7	15.1	0-15	0.4	0.2
Bms	15-30	5.8	9.8	15-50	3.3	1.2
Cca	30-45	1.9	5.9	50-100	7.2	9.2
Cca 2	45-50	1.1	3.7			
Ck 1	60-90	0.8	2.8			
Ck 2	90-120	0.7	2.1			

Despite these studies that indicate the complexity and dynamic nature of soil salinity, the most often quoted estimates of increases in salinity due to agriculture were based on comparisons of aerial photographs of the same areas taken ten years apart (van der Pluym et al. 1981). Estimates of soil salinity were based on visible evidence (light-colored areas) or restricted vegetative growth, and indicated that salinity was increasing at a rate of 10% annually. It appears that this estimate of rate of increase of salinity has been extrapolated beyond the area for which it is applicable. Hedlin and Kraft (1984) question the contention that the area of salt-affected land in the Prairie region is growing at an alarming rate, but do point to the need for knowing the severity of the problem. The variable nature of soil salinity, and assessments that are based mainly on proxy data such as the severity of crop growth restriction or the appearance of light-coloured soil on aerial photographs, makes accurate assessments of areal extent difficult and generally unreliable. It appears to be important to know if soil salinity is increasing and at what rate, in order to direct soil conservation incentives to where the incentives will be most effective. It appears to me that limited programs to monitor soil salinity and the contributing factors such as levels of artesian pressure and water tables that may be contributing are still required. It is important that the monitoring programs measure a number of properties and be pedologically based as much as possible. These studies should work towards an integration of findings into conceptual models and then simulation models that can be used to extrapolate findings to longer time periods and related soil landscapes.

There are, however, many areas where salinity has been affected by current farming practices and other activities such as road construction, and the impoundment of water in dugouts and lagoons. Bodies of water that are placed where no or less water occurred before, such as highway ditches that impound water, dugouts and sewage lagoons, appear to have contributed to induced salinity. The development of salinity adjacent to drainage ditches and lagoons has been documented in North Dakota (Skarie et al 1986; Griffin et al. 1985). Preliminary studies of saline soils adjacent to a highway borrow pit in southeastern Saskatchewan indicate that similar, localized salinity problems are occurring there (Fig. 6).

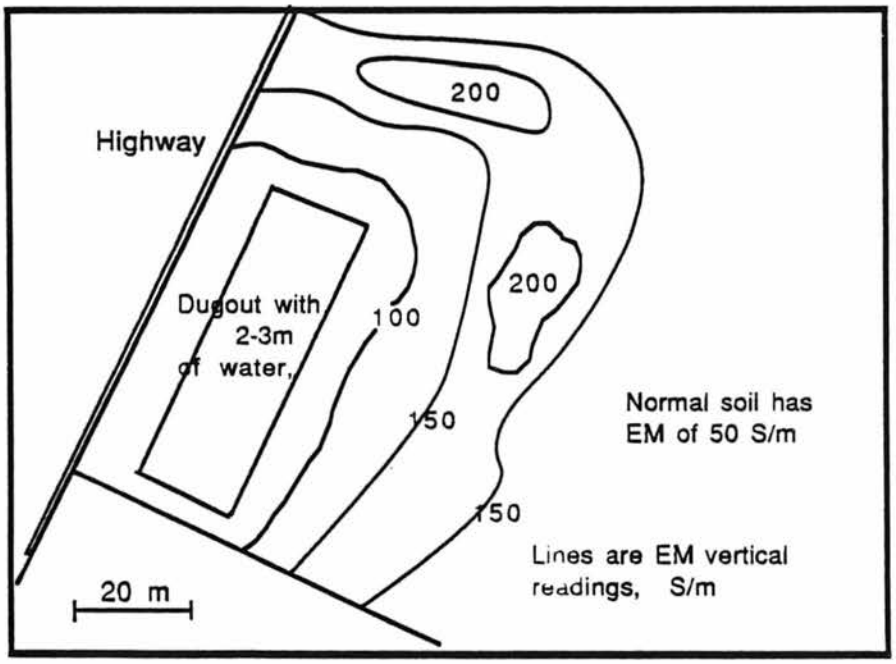


Figure 6. Diagram illustrating the salinization of soils adjacent to a water-filled dugout resulting from highway construction.

The borrow pit was located in an area where soil profiles indicate no natural salinity in surface horizons, and saline subsoils of silty texture. The locally raised water table near the water-filled pit has resulted in the movement of the salts towards the surface, and strong concentrations of salts, particularly sodium salts, in surface layers. Salinity is most severe and salts are concentrated in surface horizons in soils 20 to 30 meters from the pit, presumably where moderate depths to the water table coincide with increasingly saline groundwater. The groundwater becomes more saline because of the solubilization of subsoil salts by the laterally moving water, and the upward movement of salts by capillary rise.

Salinity resulting from extra water in ditches, pits or lagoons appears to be made more serious by summerfallow, because of high rates of evaporation from bare soils and the resulting build up of salts in the surface soil. It is difficult to obtain good estimates of the area of this kind of salinity, because of its occurrence in small patches and year-to-year variability in salinity and its effect on crop growth. Saline soils show up much more in dry years, because of stronger effects on plants, and the absence of rain to wash salts back down into the soil.

SUMMARY

Recent studies in Saskatchewan have shown that the severity of soil degradation in Saskatchewan varies substantially with form of the landscape, hydrogeology, nature of the soil material and land use practices over time. Observations on the severity and extent of soil degradation will be always limited in number. The limited data are best extrapolated to appropriate parts of the agricultural land area within the hierarchical system of land classification available through soil survey. Soil survey can be used at various levels of detail. Evaluations at general levels can influence policy and direct limited conservation funds to where the funds can be used most effectively. Conservation planning at a farm-scale is a possibility resulting from more detailed soil survey maps, improved interpretations and better data management systems with computers. Geographical information systems that make available all pertinent soil, landscape, climatic and land use data for planning are important. The data are best used as input variables for simulation models that will permit predictions based on the data and on in-depth or fundamental knowledge of the processes affecting soil quality. Computer simulation models are the most effective means of extrapolating data over time, and can reduce the need for long-term experiments.

Despite the large number of studies assessing historical soil degradation, some systematic monitoring of soil quality over time should be carried out. Monitoring can provide basic information to test and validate models, and will become a resource for future scientists who will be assessing the effect of current practices on soil quality and the sustainability of the agricultural land resource.

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