SOIL CONSERVATION IN SASKATCHEWAN

A Research Perspective

by

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Abstract

Next to the economic plight of agricultural producers, soil degradation is the most topical subject among agriculturalists today. Soil degradation involves the destruction of soil resources by erosion, organic matter loss, salinization and soil acidification, usually as a result of agricultural mismanagement. This paper has attempted to highlight some of the current areas of research that are specifically designed to address these problems and has suggested specific areas that the author believes require immediate attention. Summerfallowing has been, and still remains the major cause of soil degradation in Saskatchewan. And, although farmers have made a significant effort to reduce this practice in recent years, we still have scenes remindful of the "Dirty Thirties" every few years. Thus we need to move to even more extended cropping systems. This can only be done by adopting new technology such as snow trapping in the Brown and Dark Brown soil zones, zero and minimum tillage, chemical fallow where we must fallow, and so on. In the long run, the farmer will only adopt these changes if they are economical and not too risky; thus the need for an accelerated research effort to provide farmers with answers as soon as possible. Such government-funded programs as FarmLab and ERDA are steps in the right direction.

Introduction

Next to the economic plight of agricultural producers, soil degradation is probably the single most important subject of interest to agriculturalists in Canada. This subject has spawned a whole series of symposia (Agricultural Land - Our Disappearing Heritage (see McGill et al., 1981); Soil Erosion and Land Degradation (see deJong 1983)), books and reports ("Soil at Risk" and "Will the Bounty End?"). As well, Agriculture Canada and PFRA are presently giving this subject considerable attention, thus it is not surprising that we find ourselves here today dealing with this topic once again.

The Problem

Soils are degraded as a result of processes that destroy their productivity. Usually, inadequate management is involved. Four main processes are recognized as contributing to soil degradation, namely: soil erosion, organic matter decline, soil salinization, and soil acidification. The first two processes are closely interrelated and the fourth process is not yet a widespread problem in Saskatchewan. To rationalize my thoughts regarding this
subject I have divided my talk into two sections -- the first part deals with related research presently in progress or in the planning stage, and the second part deals with future research that I think we need to do to address soil degradation.

Research Presently in Progress
To Address Soil Conservation Problems

Erosion

Some of the basic mechanisms of erosion, the reasons for continued erosion and methods of reducing erosion have already been established and are well known (deJong, 1983). Scientists such as Chepil, Bisal, Tracy and Hank Anderson, to name a few of the ones in the past, and deJong of the present, have done much work to establish a wealth of information on this subject.

In general, most producers know what needs to be done -- REDUCE FALLOW ACREAGE! Or, when producers feel they must fallow, they should reduce the number of mechanical tillage operations by using appropriate herbicides to assist with weed control. Use strip cropping. Use tillage implements that leave stubble standing. Use crop rotations where possible. The latest statistics (Statistics Canada, 1985) indicate that prairie producers are in fact heeding the preachings of Rennie and others because fallow acreage is now down by 5M acres to 20.6M ac since 1980 (Statistics Canada Report No. 22-002 -- not yet published). Still, in the spring of 1981 and 1984, soil was blowing across our land and highways almost like the "Dirty 30's". Why is erosion occurring to such an extent today? Is it because too little research is being done? Or, is it that we need a more effective technology transfer? Or, perhaps it is just that economic pressures and lack of proper incentives prevent the producer from adopting a more rational management of our soils.

To my knowledge, Dr. Eltje deJong and his students at the University of Saskatchewan are the only people that are actively and consciously doing research on erosion in this province. Their work centers around the use of radioactive cesium to estimate how much erosion, and the mechanism of erosion that has occurred in past years. To my knowledge, none of the Agriculture Canada Research Stations are doing this type of research. Such studies as Swift Current's long-term crop rotation study and tillage research do contribute valuable information in this regard, but this is not the prime objective of these studies. The PFRA will not be involved in research per se but will be very active in initiating demonstration plots and projects at selected Prairie locations.

Organic Matter Decline

Here again I am not aware of any research that is in progress at the Research Stations that is designed specifically to look at this problem. Valuable information on changes in amount and quality of organic matter has emanated from the Swift Current long-term crop rotation study. In Alberta there is a comprehensive study being done by Dr. Bill McGill and his students at the University of Alberta, in which they are attempting to do a thorough
survey and characterization of changes in soil organic matter that have occurred since the land was broken and cropped. No similar work is ongoing in Saskatchewan. However, this subject has been much researched and modelled (McGill et al. 1984; Campbell et al. 1976). In general, we know what will happen to the organic matter in soils when they are cropped in the conventional manner. But we are not certain how the soils will behave if the cultural practices are markedly changed (e.g., if snow trapping, minimum tillage, chemical fallow, green manuring, organic farming, and various other new techniques are adopted). This uncertainty is because soil changes occur slowly and the effects of these agronomic practices take many years to become evident. Such systems can be modelled mathematically but we need at least a few long-term studies to allow us to check the answers provided by such models.

Soil Salinity

It is estimated that about 2.2 million hectares of cultivated and rangeland in western Canada are affected by salinity to varying degrees. Soil surveys seem to indicate an increase in the area of land affected by soil salinity in western Canada (some argue that this is more apparent than real). The rate of increase is partially related to the long-term increase in groundwater. It should also be noted that due to the nature of the parent material of many prairie soils and the tillage and cropping practices used by farmers, many cultivated soils are at risk to increasing salinity. Thus, cropping and tillage practices need to be implemented that reduce the risk of increasing salinity.

Research on salinity is mainly being done by the Saskatchewan Institute of Pedology at the University of Saskatchewan, while a small program has just been initiated at Swift Current by Dr. Steppuhn. As with erosion, PFRA's Soil and Water Conservation Service is actively involved in technology transfer. In the past, soil surveys by Ballantyne and others at the Saskatchewan Institute of Pedology have estimated the extent of the land affected. Some agronomic work to determine the feasibility of growing various salt-tolerant crops on saline areas has also been done at the University of Saskatchewan by John Peters, by the Saskatchewan Research Council and in the past by Chris Holm of Saskatchewan Agriculture. But, by far the biggest and most current research program is that of the Saskatchewan Institute of Pedology.

At present the concepts governing salinity in Saskatchewan are not well defined. Consequently, there appear to be various schools of thought on the major source of origin of salinity, the degree to which it is or is not spreading, and the required treatment. In general, two views seem prevalent. The first view considers a soil to be salinized when ionic concentrations of its matric solution reach levels detrimental to crop growth and maturity. These ionic enrichments are primarily caused by an invasion of water into lower root zones. This invasion permits evapotranspiration flow to move the solution upward and transfer the water to the atmosphere while concentrating the salts in the remaining soil solution. Cultural, climatic, geological, chemical and hydrological factors strongly influence the salinization process as does, of course, the degree to which excess soluble salts are present. The influence exerted by each of these factors varies considerably with location. As a result, the primary flow-path for waters moving into and out of each individual saline site is unique. Thus, a site-specific diagnostic investigation
within a regional groundwater context serves to indicate probable causes and possible remedies.

Any technique or practice that removes water from the subsurface system or suppresses its recharge reduces the opportunity for salinization. Besides drainage and groundwater pumping, various agronomic practices, such as growing deep-rooted perennials, seeding winter crops, and reducing summerfallow aided by flex-cropping, snow management, etc., in the drier areas, will reduce the accumulation of subsurface water and hence help decrease the danger of salinization. Each remedy should fit the specific problem, the specific cause (if known), and the economic reality. Two approaches should be considered — preventive and remedial. Prevention involves subsurface water removal or entry denial, while remedial efforts require both lowering of groundwater levels and reduction of root zone salt concentrations. All remedies classed as reclamation consist of leaching the offending salts out of the root zone using less saline water. The reclaiming water may either be precipitation or irrigation. Probably the most universally viable remedy utilizes all available precipitation to grow crops, thereby reducing additions to the groundwater. Thus, the call for a reduction in summerfallow acreage.

However, a second view of the problem does not appear to agree with the latter theory. In this view the main cause of salinity in Saskatchewan is attributed to groundwater flow; not the classical sidehill seep as was once believed. Furthermore, it is suggested that summerfallowing probably has had little influence on the problem, and the use of interceptor strips and crop rotations probably have little influence on salinity in Saskatchewan in most cases, because of the nature of our problem. This school of thought suggests that the salinity problem has always been with us — it merely goes and comes depending on the weather conditions of the most recent years. Thus, it is suggested that since the concepts governing salinity in Saskatchewan are not well established, hydrogeologic investigation is required with the treatment, where possible, being made to fit the cause identified.

These two viewpoints only vary in a matter of degree. As I see it, the divergence in opinion is mainly due to our limited knowledge on this subject at present. Thus, most of us are theorizing, guessing, and putting forward our "gut feelings" as accepted facts. This then underscores the need for immediate research to help us resolve the problem. Even if summerfallow is not greatly involved in encouraging salinity (and I believe it is), we must indict the practice on several other counts anyhow and thus we must endeavour to limit its use wherever feasible.

Soil Acidification

This is not as big a problem as the other three areas already discussed. Most of the research being done on this topic is carried out by Dr. Rostad at the University of Saskatchewan. He has produced excellent documentation of Saskatchewan soil pH.

From a slightly different viewpoint, limited work is being done on the effect of crop rotations and fertilizer use on soil pH, using data from the Swift Current long-term crop rotations. Recent published results from this study (Campbell & Zentner, 1984) show that continued application of even moder-
ate rates of N fertilizers may lead to soil acidification (Fig. 1). This tendency to soil acidification could be of increasing importance as we move to more intensive cropping and greater use of N fertilizer applications.

Research Required to Address Soil Degradation

If we accept the premise that too much unnecessary summerfallowing and poor execution of the summerfallow procedure are the main causes of much of the soil degradation we experience in Saskatchewan, then, obviously, to rectify the problem we need to focus on how to correct this misuse of the land.

In the Brown soil zone this might mean (a) extending the rotation to four or five years rather than two years; (b) using more snow trap techniques to help in achieving goal (a); (c) adopting more minimum or zero tillage techniques; (d) including more winter annuals such as winter wheat in the rotations; (e) finding suitable annual legume green manure crops for inclusion in cereal rotations; and (f) leaving the Class 4 and 5 land in forages, where it belongs, rather than plowing it up and seeding it to row crops. One other speculative suggestion is to leave snow trap strips on fields that are to be summerfallowed.

In the Black soil zone, moisture is not usually limiting to crop production. Here then one should strive for: (a) continuous cropping; (b) proper crop rotations to reduce insect and other pests, maximize economic returns and reduce the risk of poor net returns; (c) finding suitable equipment to facilitate spreading of straw and direct seeding into heavy trash; (d) methods of circumventing phytotoxic effects of fresh straw and chaff on succeeding crops; and (e) trying to fit the high yielding triple M wheats into the cropping system.

Research requirements for the Dark Brown soil zone lie somewhere between those for the Brown and for the Black soil zones.

Any sizeable shift in cropping practices adopted by Saskatchewan producers will depend on their ability to survive in these tough economic times. Thus, net returns and low risk will be the basic criteria that will impress our farmers the most. If better soil conservation can be achieved along with these latter two criteria, then farmers will gladly adopt the changes. However, they are not fools and they certainly won't be saving the farm for posterity while losing it for themselves. I believe that with proper research and extension, soil conservation and economic stability both on the short- and long-term can be quite compatible and achievable.

Brown Soil Zone and Drier Parts of Dark Brown Soils

The key to greater economic viability in this region will involve the use of snow trap strips combined with zero or minimum tillage. The increase in water conserved, both over winter and by reduced in-crop evapotranspiration, should in most years make more intensive cropping feasible. Limited research at Swift Current (Campbell et al, 1983; 1984) and FarmLab studies (Rennie et al. 1983; 1984) provide good preliminary evidence in support of this theory (Figs. 2, 3, 4 & 5). The spinoff here is that adoption of these
techniques will stop the decline and may also expedite buildup of soil organic matter, reduce soil erosion and leaching losses of mineral N, and reduce soil salinity (Figs. 6, 7 & 8).

However, this type of agronomic package may present numerous other problems that will require immediate research. For example, although progress is being made, a suitable all-purpose swather attachment for creating tall stubble strips is not yet available to the producer. Lodged grain or short stubble still presents a problem. Another problem involves proper spreading of the straw and chaff so as to facilitate direct seeding into stubble. Associated with the latter is the need to design adequate seeding equipment that can be used in heavy trash without hairpinning or, on the other hand, stubble bunching and plugging up the system. Yet another problem facing the design engineers (and soil fertility experts) is seeding equipment that will allow placement of the fertilizer in any required position, whether it be broadcast, side-band, deep band, mid-row band, or whatever, while perhaps allowing variable rates to be applied easily throughout the field, depending on topography. There is also need to develop seeding equipment that minimizes soil moisture loss during seeding and tillage operations since soil moisture is the most limiting factor to production in this region.

If winter wheat becomes an integral part of the crop rotation (as it should), it should help in reducing deep leaching of soluble salts, thereby reducing salinity and it should reduce erosion. But there are numerous other problems requiring researching before this crop will be efficiently grown in Saskatchewan. Some of these will involve diseases, such as midge and root rot, and insects, which I will not elaborate on further. There is also the likely problem (already being experienced in some cases) of phytotoxic effects caused by fresh straw when winter wheat is stubbled-in (Fig. 9). Some good research is being done in the U.S.A. to determine how certain bacteria, called pseudomonads, can grow on and inhibit root growth of cereals, especially when conditions are cool, moist and the straw is fresh. These organisms produce phytotoxic chemicals (Elliott & Lynch, 1984) and are more specific to some cereal genotypes than others. Perhaps we will require the assistance of plant breeders in this part of the research program.

Whether stubble cropping into minimum or zero till, or chemical fallowing, farmers will need to have access to effective but modestly-priced herbicides -- herbicides that will preferably work in-crop, not soil applied to increase erosion. The price is the key. Zentner and Lindwall (1983) showed that the use of chemicals in minimum till systems was not economical (at least not at the prices paid for chemicals in the 1970's, when the study was done). Thus, both agronomists and chemical companies will have their share of work to do to meet this challenge. Another problem that will no doubt arise if the minimum till route is taken will be the requirement for more research to determine the long-term effects on soil biochemical and biological properties caused by the various chemicals that will be used. As well, we need to determine the residual effects of these chemicals in the soil-plant-air-water system. This requires the input of soil microbiologists -- Agriculture Canada has only one in Saskatchewan.

Many of the studies required to assess the aforementioned problems would take many years in operation before meaningful information can be obtained. We can't afford to wait! One possible short cut to solutions may be to find
producers who live near each other, and who have used contrasting methods of farming on similar soil types. We could use their farms as the experimental units. This technique would apply for most of the assessments required. They would have the advantage of being assessed on large fields under producer scenarios rather than under the small, much criticized research plot scenario. Such things as zero tillage vs. conventional tillage, organic farming vs. conventional fertilizer farming, and so on, could be assessed in this manner. There are also many long-term rotation and agronomic studies located on some Agriculture Canada Research Stations (e.g., at Scott, Melfort, Indian Head) where only yield and grain quality have been assessed and economics is now being assessed. Some of these have provided excellent and relevant information (Biederbeck & Campbell, 1983; Biederbeck et al., 1984) and could provide much more useful information.

Monoculture is known to be generally bad for our soils. Fertilizer N prices will continue to increase in future. These two problems can be attacked by finding a suitable legume green manure crop that can be used as a partial fallow substitute. This crop should be an annual and must be a very efficient user of water, fix much N for soil incorporation and have adequate stand height to allow leave strips for overwinter snow trapping. Research to provide such a crop is now ongoing at several Agriculture Canada Research Stations and at the University of Saskatchewan. I hear that Austrian winter peas and Tangier flat peas both look promising for this purpose. More research of this nature is essential because there are numerous potential problems still to be worked out with this type of system.

One last point for this soil zone. There is no doubt that some summer-fallowing will sometimes be required. The optimum frequency of such occurrences has still to be worked out (maybe one out of three, or one out of four years). A flexible cropping system using spring soil moisture as a criterion is a possibility but it could present headaches for the farmer. When forced to fallow, producers should try to make use of the well established techniques that will reduce soil degradation. They might also want to try a new "wrinkle" such as leaving inexpensive snow trap strips on fields to be summer-fallowed. This might enhance moisture storage during the first winter, especially on clay soils. If combined with chemical fallow, it might enhance water storage even more. The merits of such practises need to be researched.

There will no doubt be a great temptation to try the new triple M wheats such as HY320. On summerfallow, these should present no problem but I fear that on stubble the lack of crop height might present a problem if snow trap techniques were to be tried. Here, however, it might be possible to use direct combining and leave the stubble as tall as possible to help solve this problem. Research is needed to investigate the feasibility of including triple M wheats in the agronomic package for the Brown soil zone and on the advantage of using direct combining techniques with this variety.

The Black and Dark Brown Soil Zones

In some areas of the Dark Brown soil zone, the trap strip approach is feasible. But, in the wetter areas of the Dark Brown and in the Black soil zone this might present a problem of too much water in spring delaying seeding as well as possible deep leaching of soluble salts. In any event, the extra
water is not usually required and there should be little need for summerfallowing. Most of the other research requirements listed for the Brown soil zone are relevant to some degree in the Dark Brown and Black soil zones. In this region the triple M wheat option should be a good one, especially because the straw is short. However, the later maturity of these wheats could be a problem. Here then we will require more research to determine the feasibility of fitting this high yielding wheat into the agronomic package.

Regarding the possibility of including forage crops in the cereal rotations, this is not possible in the Brown soil zone but it might be a viable alternative in the Black and wetter parts of the Dark Brown soil zones. We know that forage crops do not produce much dry matter during the establishment year and, after two or more years of forages the following cereal crop is usually deleteriously affected for at least a year due to severe soil moisture depletion by the forage. It might be possible to underseed cereals with the biennial sweet clover and then plow down the clover the following year for green manure (a fallow substitute); this would supply added N to the soil. However, this system is only applicable to the Dark Brown and Black soil zones where I question the need for fallow anyhow.

As I have stated earlier, it is the economics of the available systems that will decide the one adopted by the producer. At present, red meat production is not a rosy situation. Further, when we consider all the other headaches involved in mixed farming (e.g., more demanding management, more year-round work, more varied equipment, etc.), it is unlikely that too many cereal farmers will opt for this alternative. Perhaps when the economic analysis of the long-term rotations that have been carried out at Melfort, Scott and Indian Head Research Stations have been worked out by Dr. Zentner, we will have a better idea of the feasibility of adopting the mixed farming option. One further point -- the soils in these rotations also require biochemical, biological and physical analysis and could provide a wealth of information just like the Swift Current study has done.

Salinity Research

Since salinity is directly related to the occurrence of periodic excesses of water in the soil, the methods proposed above to reduce summerfallow should assist the reduction of this problem. There are, as well, some other areas that require specific research to help us solve this problem. These are as follows:

1. We need to more adequately identify the areas that are salinized or have the potential to be salt affected so as to keep track of what changes are occurring. This calls for soil surveys to be done periodically.

2. We need diagnostic studies to define the influences of soil, climate, vegetation, topography and agronomy on the total hydrology operating at individual saline sites.

3. We need regional groundwater studies.

4. We must determine the major hydrologic mechanisms that permit recharge of water to subsurface systems.
5. We need to determine more precisely crop and variety tolerances to saline environments.

6. We also need to determine the water use characteristics of the desired crops and varieties associated with preventive and remedial techniques designed to ameliorate the problem.

7. Perhaps plant breeding or gene-splicing techniques can provide salt tolerant crops or varieties (e.g., a new flax cultivar developed at the University of Saskatchewan that I hear is quite promising).

Soil Acidity Research

Most Saskatchewan soils are well buffered and should generally resist changes in pH. However, results from Swift Current's long-term rotations indicate a need for us to keep a close eye on changes in pH that can be caused by additions of high N sources, be they fertilizers or legumes. This is especially true if we go to more intensive cropping systems in the future. At this point the problem is not serious but we need to periodically monitor soil pH in long-term studies or in production systems where fertilizer use is being intensified.

One other possible problem that may require close monitoring and some future research is concerned with the possibility that increased activity in the processing of heavy oil in our province could lead to soil and water acidification, especially in the more fragile soils of northern Saskatchewan.

Conclusions

The latest Statistics Canada report (#22-002) shows that summerfallow acreage on the Prairies dropped by 5 million acres between 1980-1984. This change occurred without any monetary incentives to encourage it. Although there are other factors that may have contributed to this dramatic change, there is no doubt that we may have underestimated the number of producers out there who are concerned with conserving the land for posterity. If researchers can now quickly find answers to some of the questions that I have raised (e.g., such things as snow trap, minimum till, equipment design, appropriate legume green manures, including fall-seeded crops in rotations, using triple M wheats, and so on) then this should expedite the trend to conservation cropping even more. The research should be geared to produce a management package based on actual conditions of soil moisture and fertility, the probabilities of precipitation, prices for product and cost of major inputs (herbicides, fertilizers, and fuel) so as to allow the producer to choose between several management alternatives based on the expected net farm income and the risk in adopting each package. I believe that suitable models already exist to do this. They only need to be updated to fit some of the newer technologies mentioned earlier. Funds now being provided by such programs as FarmLab and ERDA should greatly assist the achievement of our research goals.
References


Fig. 1. Soil pH changes in the 0- to 2.5-cm depth of continuous wheat rotations during the 1983 growing season. The LSD values for pH (P < 0.05) for comparing sampling time means is 0.50 and for comparing fertilizer effects 0.24.

Fig. 2. Effect of N rate, P rate and stubble height on spring wheat yields (1983).
Fig. 3. Effect of trap strips and N fertilizer rate on yield of spring wheat grown on zero-till in 1984. Data from Swift Current long-term crop rotations on conventional tillage included for comparison.

Fig. 4. Effect of fertilizer rate and stubble height on net farm income in the 1983 study year.
Fig. 5. Effect of fertilizer rate and stubble height on net farm income in the 1984 study year.

Fig. 6. Comparison of trash conserved and soil erodibility for various crop rotations and fertilizer treatments (average for first 12 yr). * Based on percent of soil diameter 0.84 mm; samples taken from top 5 cm of soil. ** Based on averages of five, 1-m² samples per plot.
Fig. 7. Subsoil $\text{NO}_3^-\text{N}$ as affected by rotation and N fertilizer (data averaged over the three sampling times).

Fig. 8. Changes in soil organic N in 0- to 15-cm depth during 15 yr of cropping to various rotations.
Fig. 9. Phytotoxic effects of chaff on winter wheat seeded into zero till at Swift Current, Fall 1981.