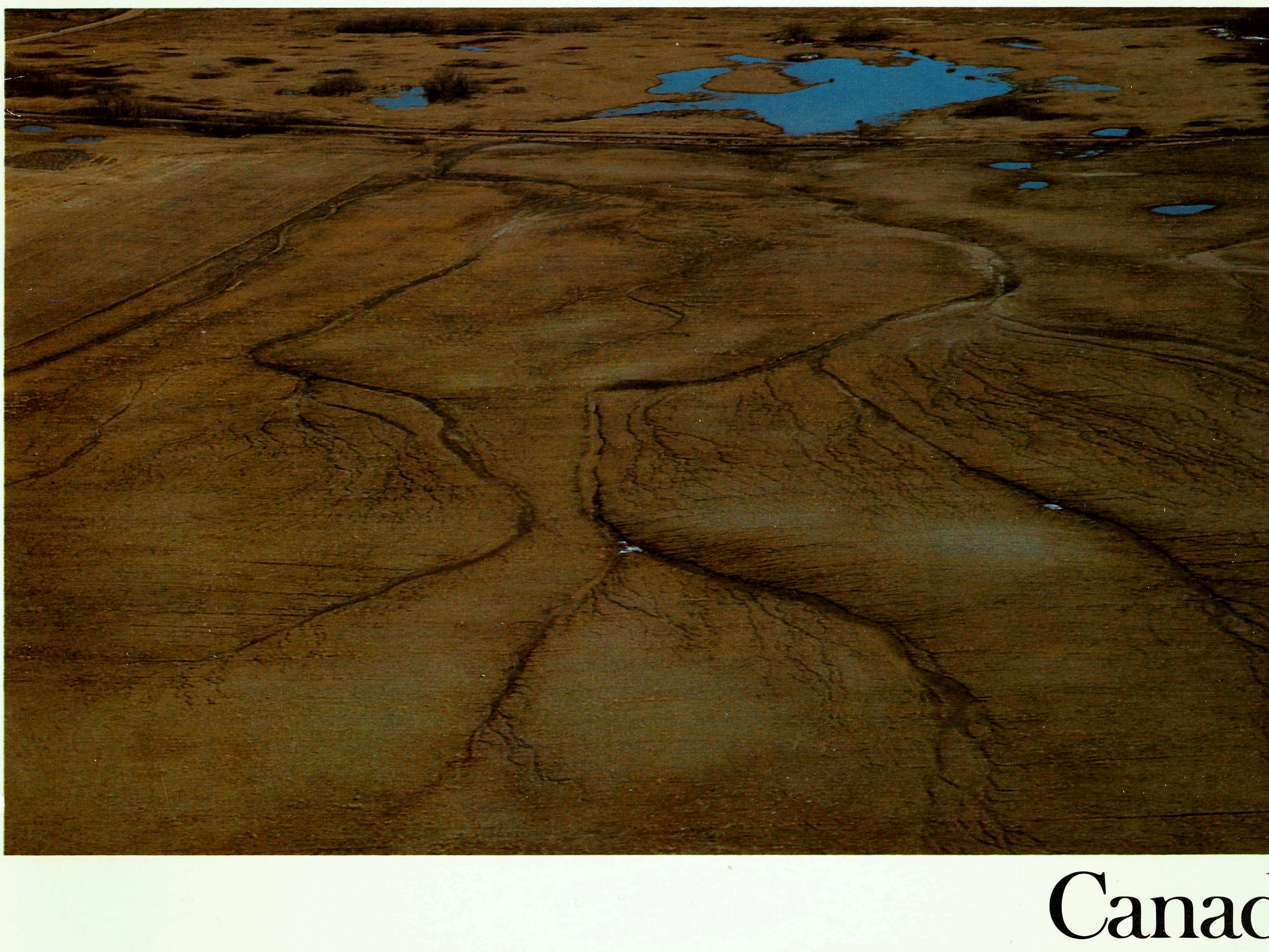
PRAIRIE FARM REHABILITATION ADMINISTRATION SERVING THE PRAIRIE PROVINCES

Soil and Water Conservation Service

Prairie Soils: The Case for Conservation



Canada

Introduction

The Canadian Prairies contain some 37.7 million hectares of developed agricultural land — certainly an impressive figure. Perhaps because of its immense size, farmers have tended to take their land for granted. This has shown up in farming practices, which for decades have stressed short-term returns with little thought to the long-term health and maintenance of the land.

As a result, prairie soils now face a number of serious threats. Salinity, erosion, organic-matter loss and other problems are affecting millions of hectares, although improvements in agricultural technology have masked many of their effects. In all, the cost is staggering. Prairie farmers will lose an additional $100 million in 1984 as a result of soil degradation. This could represent as much as a 10 per cent drop in net farm income from cash crops.

The farmlands of Western Canada are precious — but fragile. Like any natural resource, they must be conserved if they are to keep working for us. To do this, we must understand how soils deteriorate, and how they may be restored. The nature and causes of prairie soil degradation, and the soil conservation methods needed to solve it, are the subjects of this brochure.

Excessive cultivation has left Prairie soils vulnerable to erosion.

Soil Salinity

"Alkali soils". Salinity. Saline Seep. These terms, heard more and more in Western farming circles, all refer to the same problem — the presence of salts in farmland. More than 2 million hectares are affected on the Prairies, and salinity is spreading at about 10 per cent per year. It is estimated that in 1984, the growth of salinity will cost farmers more than $25 million.

What Causes Salinity?

Most of the salts found in prairie soils lie below the root zone, and under natural conditions, do not affect plant growth. However, several factors can cause dissolved salts to rise to the surface, where they prevent crops from taking up water and nutrients. Causes of salinity include features of the geology and climate of the Prairies, and the practice of summerfallowing.

Geology and Climate. Much of the bedrock and subsoil in the region contains high concentrations of salts. When groundwater comes in contact with these layers, salt is dissolved out. Because the bedrock is often shale, the water and dissolved salt cannot go deeper into the ground, and remains in the soil.

The prairie climate increases the risk of salinity. Nearly half the annual rainfall occurs during the spring months, when both evaporation and crop growth are limited. Therefore, the risk of moisture percolating below the root zone is increased. In wet years, the water table under fallow land may rise as much as 3 metres, bringing dissolved salts with it.

Summerfallowing. Summerfallowing has long been used to conserve moisture for crops, but it has recently been shown to be a major cause of soil salinity. Under summerfallow, water which would normally be used by plants percolates below the root zone and dissolves salts from the subsoil. At some depth the water meets a soil or rock layer that it can't penetrate. It then moves along this layer until it emerges as a saline seep, as shown in Figure 1.

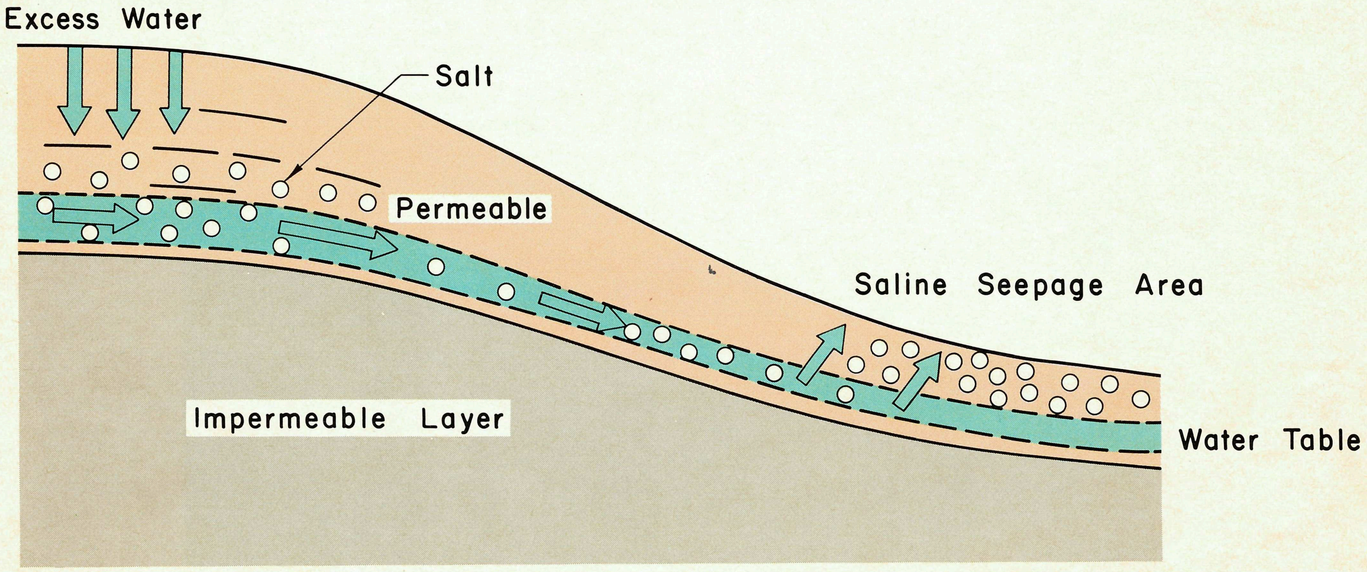


Figure 1. A Generalized Version of Saline Seep Formation.

Encroaching salinity. The green patch shows the invasion of a cereal crop by Kochia, a salt-tolerant weed. (Saskatchewan Agriculture photo).

Detecting Salinity

Early detection of salt-affected areas is critical to preventing the growth of salinity. The following are usually signs of a salinity problem:

- intermittent or continual surface wetness, prolonged wetness after rain, or free flow of water down a slope.
- excessive crop growth that stays green after the surrounding crop has matured.
- invasion of an area by salt-tolerant plants like Kochia, red samphire, sea blite or wild barley.
- formation of a salt crust on the soil surface.

Soil Salinity: What Can Be Done?

Dryland salinity is a complex issue, and more research into its causes and solutions is needed. At present, cropping systems that limit summerfallowing and control soil moisture offer the most promising solution. A number of methods can be used.

Flexible Cropping. Flexible cropping means land is left fallow only when crop prospects are poor because of insufficient moisture in spring. Soil moisture conditions can be improved by trash management, stubble mulching, zero tillage, weed control and snow management.

Deep-Rooting Crops. On soils where excess moisture has caused salinization, the use of deep-rooting crops will dry out the subsoil and lower the water table. Common deep-rooted dryland crops are alfalfa, sainfoin, safflower, Russian wild ryegrass, tall wheatgrass and sweet clover. Of these, alfalfa will use the most moisture.

Salt-Tolerant Crops. Forages are generally more tolerant of salt than grains — with crops such as Bermuda grass, tall and crested wheatgrass, and fescue performing well on saline soils.

Snow Management. Deep snowdrifts provide excess moisture which can cause salinity. Barriers that trap large amounts of snow should be altered; standing stubble should be left to prevent drifts and areas where snow build-up cannot be prevented should be seeded to deep-rooted perennials.

Surface Drainage. Drainage of ponds in a recharge area can prevent the deep percolation of water which leads to saline seeps. The use of open trenches, buried pipe, grassed drainage waterways and adequate culverts will all prevent ponding of water.

Erosion

Unfortunately, erosion on the Prairies didn't end after the "dust bowl" of the 1930's. It continues to be a problem today, to the extent that it has reduced the natural productivity of all farmland in the region by 10 to 15 per cent. The cost to the farmer is massive. Currently, erosion reduces annual net profits by an average of $12 per cropped hectare. Each year, soil loss reduces the value of prairie crop production by an additional $6 million.

Farming Practices And Erosion

One of the major causes of erosion on the Prairies is excess tillage of farmland. Intensive cultivation in the fall to apply herbicides and fertilizers or to speed spring planting makes soil prone to wind and water erosion. Bare summerfallow is another important cause of erosion. Despite the grim experience of the "Dirty Thirties", some 9.5 million hectares of land were in fallow in 1981, an increase of 42 per cent since 1931.

The Impacts of Erosion

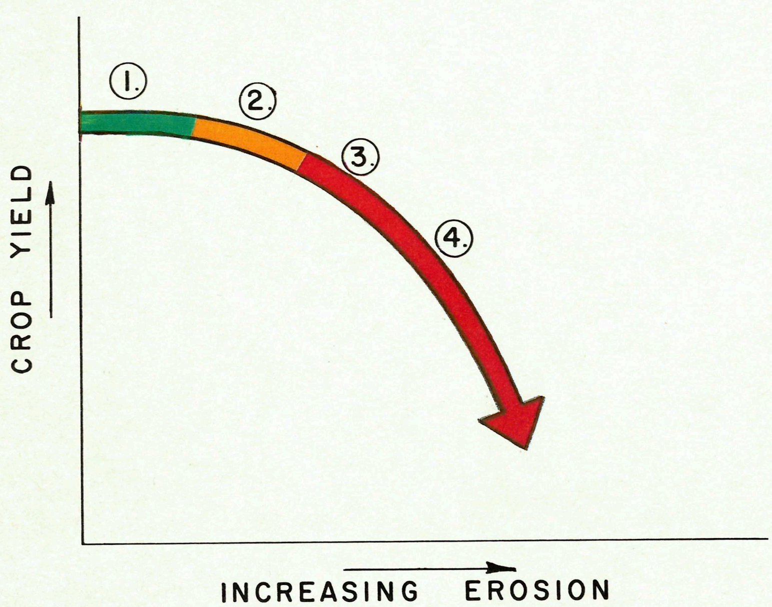
Because most soil nutrients are found in topsoil, erosion losses have a severe effect on soil fertility. As well, with the removal of topsoil, less water penetrates into the soil. Consequently, water ponds up, seeding is delayed, and the seedbed may crust over, resulting in poor seedling emergence and a lack of aeration of the soil. Runoff also increases because less moisture is being absorbed, and so even more soil is carried away. Soil eroded by wind is also more easily damaged as erosion progresses. This "vicious circle" can lead to gullying, "blowouts" and the formation of sand dunes. When this happens, the land becomes useless for farming.

Reducing Erosion Losses

Controlling erosion means protecting soil from the destructive effects of wind and water. To achieve this, a number of conservation-oriented farming methods may be used.

Reducing Summerfallow. Because summerfallow contributes to erosion, soil salinity and organic-matter losses, its use should be greatly reduced on the Prairies and the practice of bare fallowing should be eliminated. Where summerfallow is still necessary, a stubble mulch should be left to protect the soil surface.

Conservation Tillage. Keeping a mulch on the soil surface at all times has a number of benefits. These include less sealing of the soil surface, increased water infiltration, and greatly reduced soil loss. When stubble is left on fallow lands on the Prairies, annual soil loss is much less than if the fallow was kept "black" or bare.



1. **Minor loss of topsoil, yields maintained by increased fertilizer.**
2. **Moderate topsoil loss, fields become patchy due to selective erosion. Overall yields reduced despite increasing fertilizer use.**
3. **Topsoil lost from major portions of the field, serious gullying or blow-outs. Yields decline rapidly.**
4. **Erosion rapidly removing topsoil, field no longer economic to farm. Reclamation urgently required.**

Figure 2. The Effect of Erosion on Crop Yields.

Contour Farming. In contour farming, tillage and crops are run across a slope, creating a ridged surface which traps soil and water. It is not effective on slopes of more than eight per cent.

Strip Cropping. When used to control wind erosion, strip cropping alternates erosion-resistant small grains or forages with erosion-prone row crops or fallow strips. These are run at right angles to the direction of the prevailing winds. Erosion is reduced because the impact of the wind is decreased. The most effective strip widths vary from 6 metres to 130 metres, depending on soil texture.

If used to control water erosion, strips of crop are run on a contour, with the strip width varying with the steepness and length of the slope and the soil texture. On steep slopes or fine soils, wider strips of erosion-resistant crops are needed. When strips of forage are used with this method, soil losses can be cut by as much as 75 per cent.

Cover Crops. Planted to protect the soil when regular crops are off the land, cover crops add fibre, improve the physical condition of the soil, and may be used for grazing. Wind erosion can be prevented by the fall seeding of rye or spring grains into erodible soils.

Grassed Waterways and Gully Control. Grassed waterways are broad, shallow, grass-lined channels designed to carry runoff away with a minimum of erosion. Because the speed of water flow is cut, gully formation is prevented. Where gullying already exists, check dams are needed to slow the flow of water so that soil can be trapped and plant growth can be re-established.

Shelterbelts and Windbreaks. The principle behind shelterbelts and windbreaks is simple — they reduce erosion by cutting windspeed. However, shelterbelts alone will not eliminate erosion from strong winds, and should be used with other soil-conservation methods. Design is very important, as an arrangement of trees that is too dense can create deep snowdrifts, causing excess moisture to build up in the soil.

Recently, crops such as tall wheatgrass, flax and corn have been planted in strips and used as windbreaks. Research has found wheatgrass very effective in controlling erosion when planted on 18-metre centres, and the crop has the further advantage of being a perennial.

Water erosion. Retaining trash cover and practising contour cultivation would prevent this type of soil loss.

Organic Matter and Fertility Loss

The practice of adding manure, green manure or crop residues to soil has been known since ancient times. Intuitively, early farmers knew that soils high in organic matter produced good crops. Today we know that organic matter is the source of key plant nutrients such as carbon, nitrogen, phosphorus and sulfur.

In recent years it has become obvious that organic matter is being lost from our farmland at an alarming rate. It took prairie soils some 10,000 years to form, yet in less than 100 years of farming nearly half of the original organic content has been lost. (See Figure 3). Organic matter lost due to frequent summerfallowing is costing farmers over $70 million per year, just in lost nitrogen.

Causes and Effects of the Problem

Perhaps the most serious effect of lost soil organic matter is the accompanying decline in such crucial minerals as nitrogen. Nitrogen is important because it is the major factor affecting plant growth and the protein level of grains. Large amounts of nitrogen have been lost unnecessarily from prairie soils as a result of erosion and leaching below the root zone. As well, soils with low levels of organic matter have less oxygen, which causes nitrogen to be lost to the air in the form of gas.

The physical structure of soil also suffers when organic matter is depleted. A common result is surface crusting, which slows germination and increases runoff. As well, soils become more prone to erosion. This is because organic matter, when it decomposes, produces natural "glue" that binds soil particles together. When levels of organic matter drop, so does the tilth of the soil. While fertilizer can replace much of the nutrient loss described above, it does not repair the physical damage done to soils.

As with salinity and erosion, summerfallowing is a major cause of organic-matter loss. The reasons for this are twofold. First, the heavy tillage that accompanies fallowing speeds up the decomposition of organic matter. Second, land that is fallow contributes none of the plant matter needed to maintain the strength and productivity of the soil.

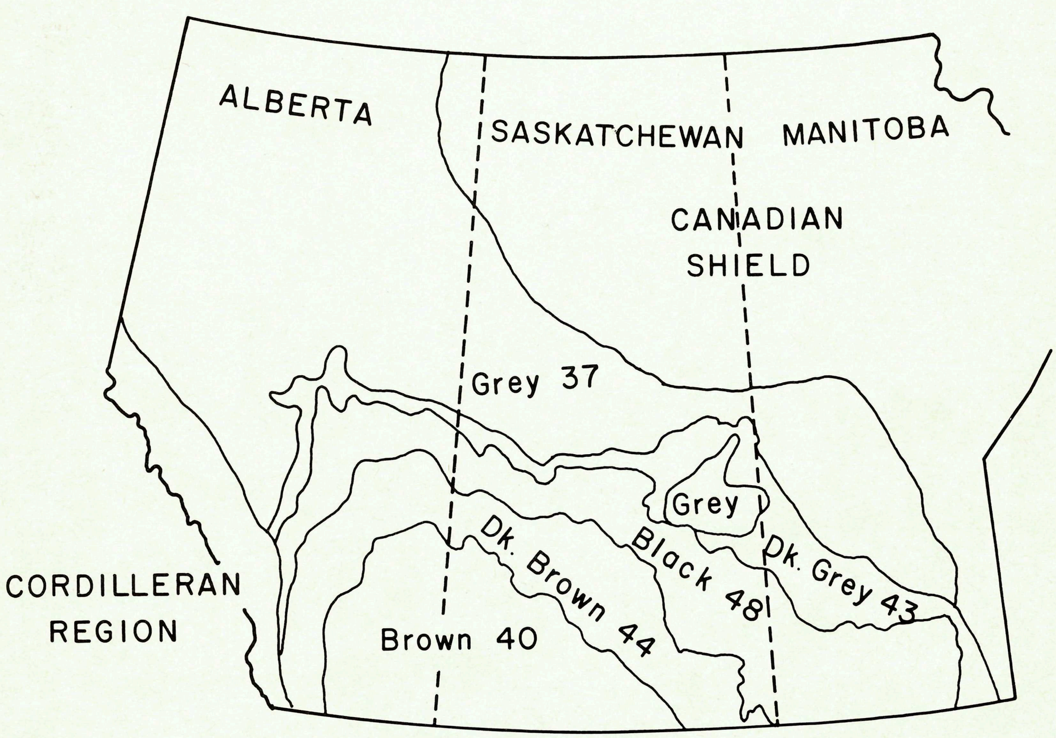


Figure 3. Percentages of Organic Matter Lost from Various Prairie Soils (Source: McGill et al, 1981).

Conserving Soil Organic Matter

At this time, it is not known "how much" organic matter is needed to support crops on the Prairies. Once gone, however, the benefits of soil organic matter may be difficult, expensive, or even impossible to replace. For this reason, a three-point program of conservation is recommended.

Crop Rotations. The periodic use of grasses, grass-legumes or legumes in a crop rotation can add large amounts of organic matter to the soil. A suggested rotation is one-third of the farm in forage, with each field in a forage for three years and cropped for six years. The benefits of forages include reducing salinity and erosion, as already described.

Continuous Cropping. When used with adequate amounts of fertilizer, this method keeps soil organic matter at higher levels than fallow-cropping systems. However, because of prairie moisture conditions, it is better suited to the Gray, Black and Dark Brown soil zones than to the Brown zone. These zones are shown in Figure 3.

Conservation Tillage. Zero or minimum tillage reduces organic matter decomposition because it maintains a mulch on the soil surface. In the process, it also improves the physical structure of the soil.

Soil-Moisture Conservation

Each year, roughly one-third of the more than 31 million hectares under cultivation on the Prairies are left fallow. Apart from the many soil problems which summerfallowing causes, it does not save large amounts of water for crops. Only 20-30 per cent of the precipitation that falls during the 21-month fallow period is conserved for future crop production. By comparison, continuous cropping has been shown to use 70 to 80 per cent of available moisture. Except in the very dry, Brown-soil zones of the region, summerfallowing could be replaced by conservation methods which trap extra moisture through snow and residue management.

Moisture-Conservation Practices

Straw Shaping. By attaching simple deflectors to a swather, strips of taller straw can be left every six to seven metres in stubble. The extra snow trapped by this

Grass barriers. These grass strips conserve moisture by trapping extra snow in winter. They also help reduce erosion.

Stubble is useful for conserving moisture, reducing erosion and increasing soil organic matter.

method has yielded an additional 3.5 to 7.5 centimetres of moisture in experiments in southwest Saskatchewan.

Shelterbelts. Shelterbelts are typically used to control soil erosion. However, if their density is kept low by the pruning of trees or spacing, shelterbelts can produce a higher accumulation and better distribution of snow.

Grass Barriers. Single or double rows of tall wheatgrass spaced on centres of 10 to 20 metres have proved very effective for snow management. Research has shown that this method can yield as much moisture as is saved by a fallow rotation.

Stubble Mulching. On the Prairies, 50 to 75 per cent of all water is lost to farming due to evaporation. Stubble mulching or trash management improves soil water intake and reduces evaporation, thus saving moisture for crops. Blade or sweep implements are used to undercut the stubble, as opposed to turning it under with a disc or plow. Substituting herbicides for tillage conserves even more soil moisture.

Other Soil Conservation Issues

Salinization, erosion damage, organic-matter loss and the efficient use of soil moisture are all highly-publicized issues on the Prairies. Recently, however, *soil acidification and solonetzic soils* have also been recognized as serious soil-management problems. Together, they affect more than 10 million hectares of farmland in the region. In 1981, losses due to soil acidity in Alberta alone were estimated at $85 million.

Soil Acidification

The acidity of soil is measured by the 14-point pH scale illustrated in Figure 4. The lower the pH rating, the more acidic the soil, with soils valued between 6.5 and 7.5 considered to be neutral. Most prairie soils are neutral or even alkaline, but large areas with a pH of 5 to 6 are found in Alberta, which has 70 per cent of Western Canada's acid soils.

Adding lime to restore productivity to acid soils.

Most of the major prairie crops are sensitive to soil acidity, with yields dropping considerably under moderate to strong acidity. Alfalfa and other legumes are least tolerant, followed by grasses, corn and wheat. Oats and rye are the most acid-tolerant prairie crops.

Causes of Soil Acidity

Most soil acidity in Western Canada results from natural causes. When organic materials in the soil break down, a common product is carbonic acid. However, the problem can also be caused by modern farming techniques: specifically fertilization, cropping and tillage practices.

Fertilizers containing ammonium or urea are a major cause of increases in soil acidity on the Prairies. Because acidity is caused by excess fertilization, moderate applications of fertilizer will prevent this type of acidification.

Certain crops such as alfalfa remove considerable amounts of lime from the soil, and over time, can cause acid conditions. Lastly, some soils, such as the Gray Luvisolic, can become acid if they are ploughed deeply or damaged by erosion.

Responses to Soil Acidity

Producers faced with acid soils can either plant **acid-tolerant crops** or apply **lime** to the soil. Oats will grow well on all but the most acidic soils, but the small number of suitable crops means that acid-tolerant cropping on the Prairies is at best a temporary solution.

In British Columbia and Alberta, alfalfa yields on limed soils have increased from 50 to 100 per cent, with increases for wheat and barley being in the 5 to 15 per cent range. Each treatment of lime is effective for about ten years, and the increased returns are much higher than the cost of application.

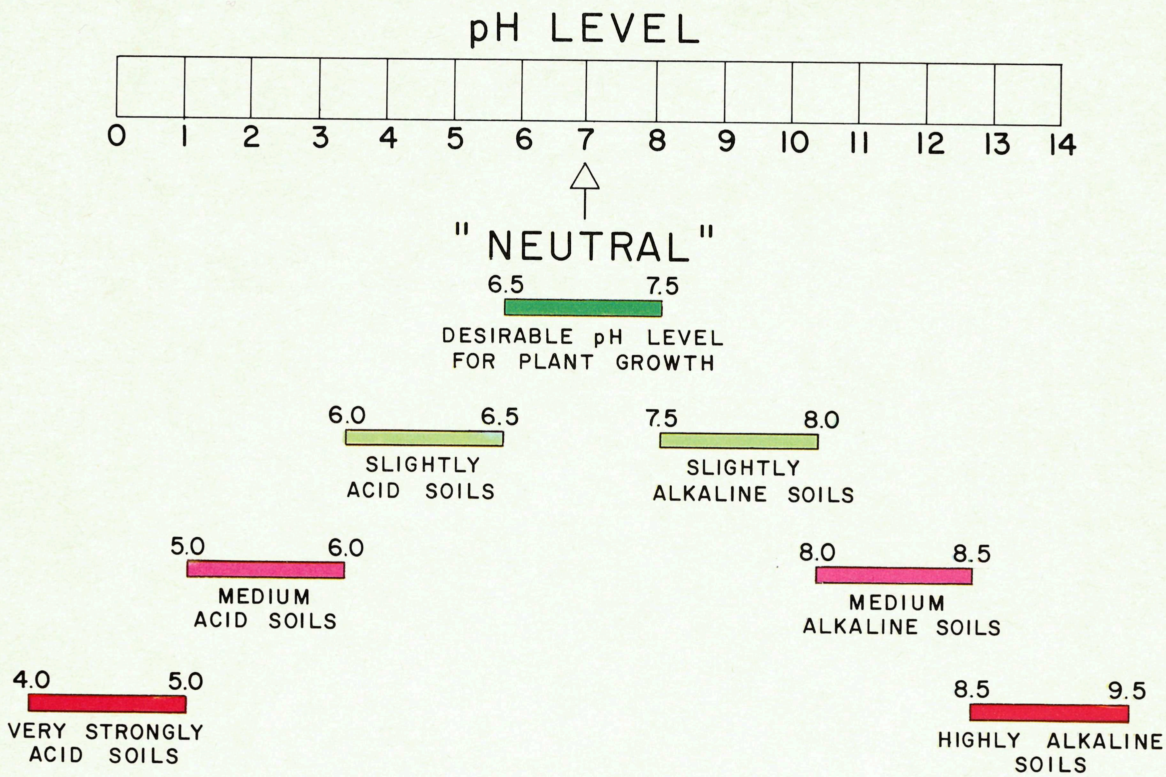


Figure 4. The pH Scale, Used to Measure Soil Reaction.

Solonetzic Soils

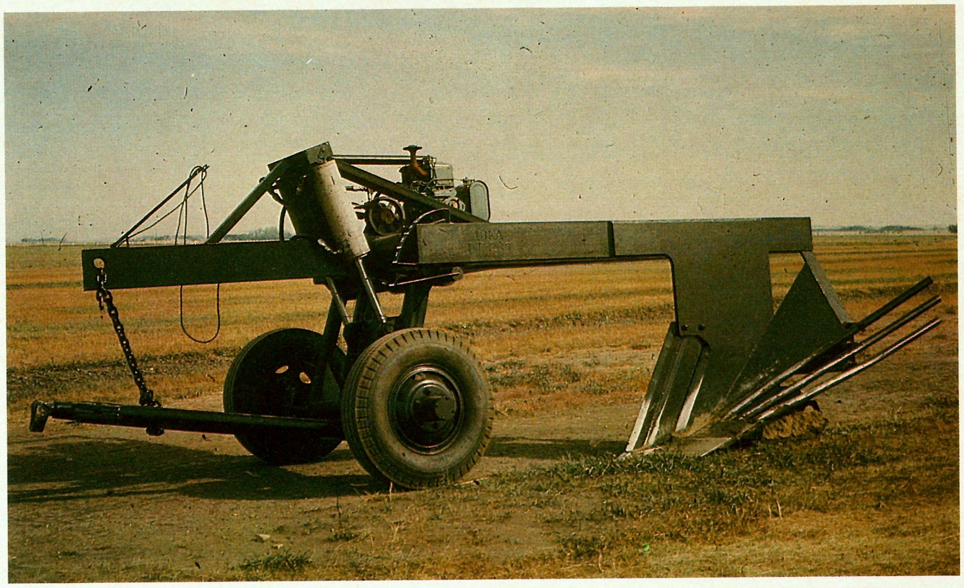
Although both solonetzic and saline soils are caused by salts, they differ in important ways. Typically, the bedrock under solonetzic soils is saline or alkaline and is quite close to the surface. Drainage is or has been restricted, resulting in a high water table. Unlike saline seeps, salts are distributed throughout solonetzic soils and can occur over wide areas.

Originally called "burnout" or "blowout" soils, solonetzics have a layer of hardpan, close to the surface, which restricts root growth and prevents the free flow of water in the soil. (See page 10). Seeding on these soils is delayed because of standing water, and crop emergence is hampered by surface crusting, with the result that yields average only one-third of normal. As of 1977, there were nearly 8 million hectares of solonetzic soils on the Prairies. The majority were in Alberta, where some 30 per cent of the farmland is affected by this problem.

Treatment of Solonetzic Soils

Methods of attacking these soils fall into three categories: **cultivation, chemical application** and **drainage.** Because of the hardpan layer and the fact that lime tends to be leached below the root zone, deep plowing can often restore productivity to solonetzic soils. Using this method, hay crop yields have been boosted by 50-

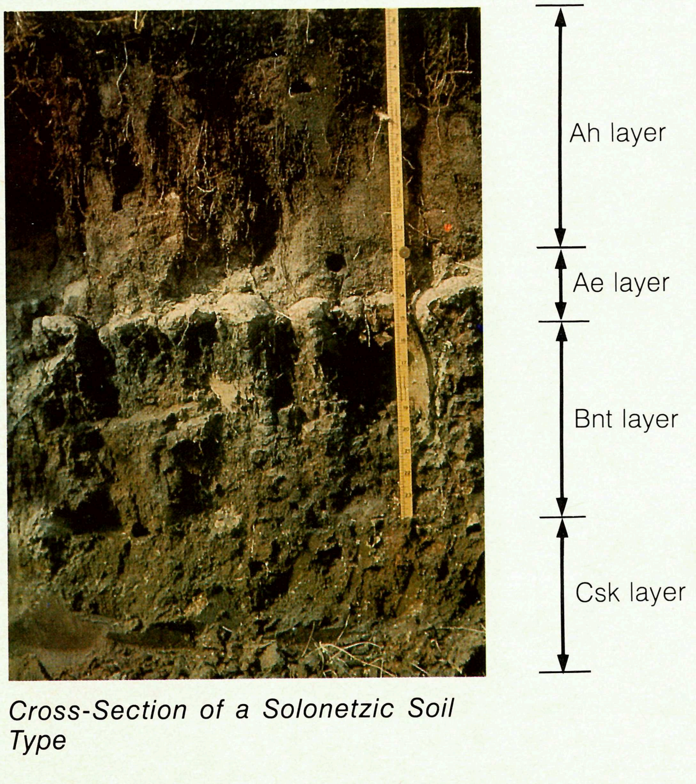
A deep-tillage plough used to break up the hardpan and bring lime up into the root zone of solonetzic soils.



60 per cent. However, not all solonetzic soils can be deep plowed, due to problems with stoniness and the depth and concentration of lime and salt deposits. Disturbing subsoil that is very high in salts may only cause future salinity problems.

Several chemicals can be applied to solonetzic soils, including agricultural limestone, gypsum, ammonium nitrate and ammonium bisulphate. Limits to their use on the Prairies include the high cost of limestone and the risk of acidification when using ammonium fertilizers.

Surface drainage is often beneficial because of the presence of excess water in solonetzic soils. Opening up shallow natural waterways with a one-way discer is often sufficient. The very slow movement of water within these soils means that subsurface drainage is not usually effective.



— The surface layer usually has two levels, the Ah and Ae. The Ah level is high in organic matter, while the Ae is coarse-textured, highly leached and can be acidic.

— The upper subsoil or hardpan layer contains high amounts of clay and sodium and is tough, dense and impermeable. This interferes with the penetration of water and plant roots. The layer has a distinctive, column appearance.

— This usually has a high concentration of soluble salts and lime. In many cases the salts also include gypsum.

Cross-Section of a Solonetzic Soil Type

Economic Benefits of Soil Conservation

Because soil degradation on the Prairies has been such a gradual process, its connection with ongoing practices like summerfallowing has only recently been known. At the same time, the extent and severity of soil problems are not widely appreciated by the region's producers. For this reason, it is worth looking at the dollar value of the present and future effects of soil degradation. Figure 5 shows the annual economic benefits that producers could reap by adopting soil-conservation methods.

As shown in Table 1, the total benefits of soil conservation for the period 1983-2000 are estimated at more than $3.2 billion. This figure is actually conservative. It is based on grain prices remaining stable over time, but even if prices fell by 25 per cent, this figure would still be a massive $2.5 billion. In addition, the benefits of overcoming soil acidity and solonetzic soils have not been included in the above. The value of this will probably approach $100 million in 1984.

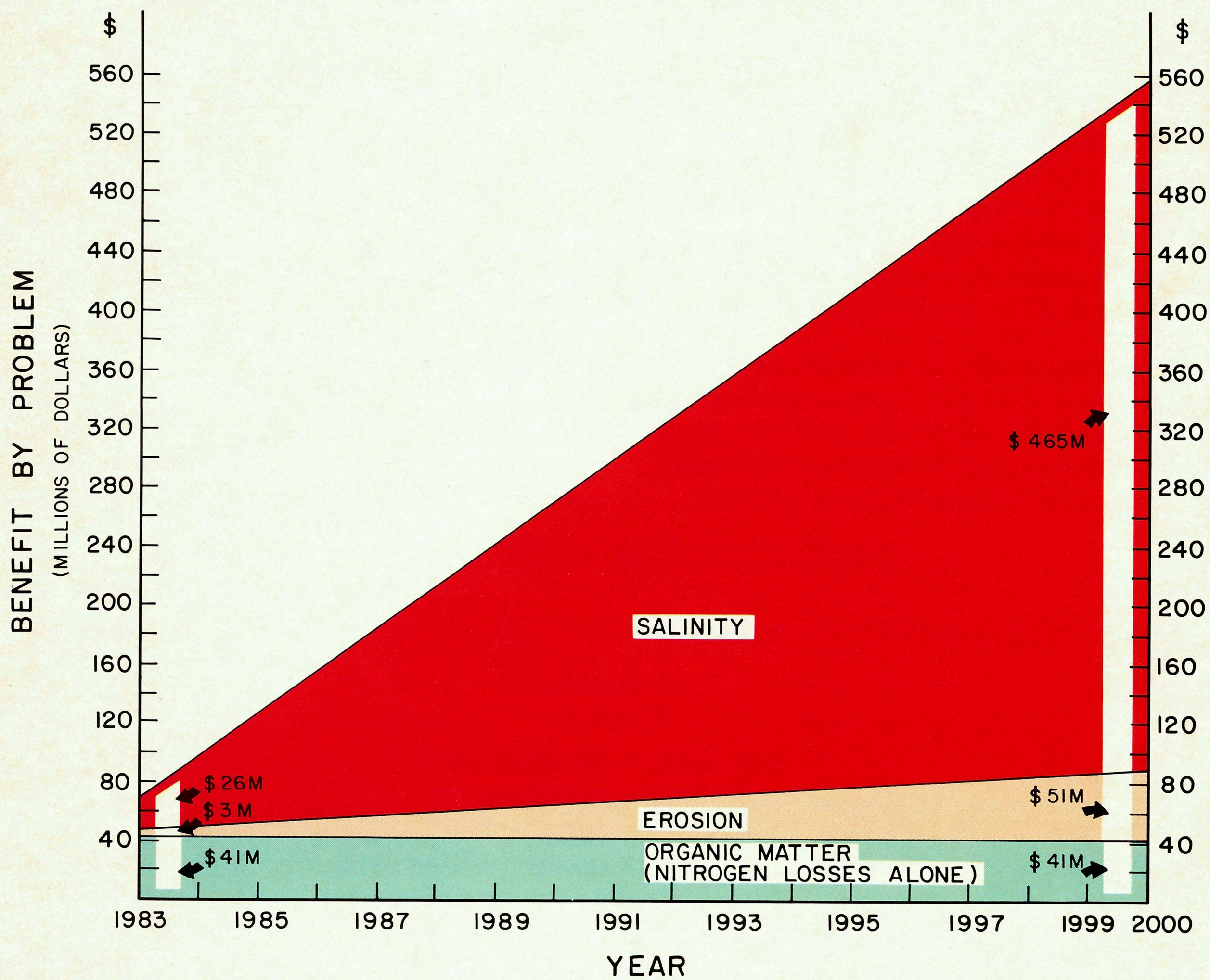


Figure 5. Projected Annual Benefits of Soil Conservation.

Summary

Our knowledge of the major Prairie soil problems leads to one important conclusion: the practice of summerfallowing must be drastically reduced. It has been shown to be a direct cause of soil degradation due to salinity, erosion damage and organic-matter decline. For these reasons, a soil conservation objective should be to reduce fallow land on the Prairies by nearly 5.5 million hectares.

To replace summerfallow, a number of soil conservation practices have been suggested. In addition to offering ways of saving soil moisture, these methods can help solve the soil-degradation problems created by summerfallowing.

Many conservation practices "overlap", in that they can be applied to more than one soil problem. For example, zero or minimum tillage is useful for conserving soil moisture, preventing erosion and increasing levels of organic matter. Similarly, continuous cropping boosts organic-matter levels, while also fighting wind and water erosion and salinity. The profitability of continuous cropping has been shown by recent research where yields on stubble have been as much as 90 per cent of yields on fallow.

Conservation farming holds great potential for overcoming the soil problems of Western Canada. However, existing techniques must be refined, and new ones developed. A great deal of basic research is still needed, in order to answer the following important questions:

* What are the exact causes of salinity?
* What are the precise effects of soil loss on crop yields?
* Which levels of organic matter are ideal for crop growth?

At present, there is no coordinated campaign against soil degradation on the Canadian Prairies. In the American Great Plains states, where soil problems are similar in nature and scale, a better-organized and well-funded program of soil conservation has existed since the 1940's. Clearly, answering the type of questions posed above requires major government commitments.

For individual producers, the variety and extent of soil problems may seem overwhelming. In Alberta's Warner County, more than 100 farmers recently organized to fight soil salinity, with the result that special assistance has been given by the governments of Canada and Alberta. Forming soil conservation associations is another way that producers can help each other learn about the causes and solutions to salinity, erosion, organic-matter loss, and other threats.

Many people believe that a disaster like the "Dirty Thirties" could never occur again. However, soils on the Canadian Prairies are now *more* prone to erosion than they were fifty years ago, the result of years of overtillage and organic-matter depletion. Clearly, we cannot ignore the soil problems of the region, nor can we keep masking their effects with new chemicals, fertilizer and equipment. **The time for conservation is now.**

Table 1
Cumulative Benefits of Soil Conservation
1983-2000
(1982 $ values)

Salinity	Erosion	Organic Matter Decline Nitrogen Loss	Total
$2,478,870,000	$271,370,000	$474,250,000	$3,224,490,000

PFRA, in cooperation with other agencies, is increasing its efforts to solve soil degradation.

For Further Information

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