ONTARIO SOILS
their USE
MANAGEMENT
and IMPROVEMENT

by
L. R. Webber, F. F. Morwick, T. J. Heeg,
N. J. Thomas and N. R. Richards

ONTARIO AGRICULTURAL COLLEGE
DEPARTMENT OF SOILS

ONTARIO DEPARTMENT OF AGRICULTURE
Statistics and Publications Branch, Toronto, Ontario.

BULLETIN 492 MAY 1952.
This bulletin was written for the farmer and others interested in the Use, Management and Improvement of Ontario soils. Many farmers are already using sound soil management practices which are basic to good land use and soil conservation. Some of our soils are now in a high state of productivity. Others, because of exhaustive cropping practices, damage from erosion, or inherently low content of plant food have been depleted of fertility. 

The many factors influencing fertility depletion and erosion are discussed in the bulletin. Practices that will reduce erosion and assist in maintaining a highly productive soil are recommended. Most unproductive soils can be made useful by intelligent management. The suggested land use practices herein contained are made to assist farmers and farmers-to-be to devise means and ways of using land according to its capability, to culture and manage each acre according to its needs and to sustain its maximum productivity.

Whether we own land or not, we are dependent upon the products of the soil for the necessities of life. Each of us has a vital concern in the use, management and improvement of our soil resources to maintain or increase productivity.

All photographs used in this bulletin were taken on farms in Ontario.
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ONTARIO SOILS
their
USE, MANAGEMENT and IMPROVEMENT

Down through the ages an adequate supply of food has been one of man's important problems. There has been a constant struggle to provide enough food for all people. In many nations man's very existence has been, and still is, blighted by the lack of food.

Many authorities agree that soil deterioration is preceded by a deterioration of man's ability to understand and manage a soil according to its capability. Archaeological investigations in foreign lands have revealed ancient cities that once stood in the midst of flourishing agricultural regions. These findings support the assumption that soil erosion and soil exhaustion forced the people to abandon the land. With the primitive modes of transportation, these great cities could not exist far from a supply of food. They were surrounded by fertile fields; today many of these are deserts.

Abandoned Farm Buildings.
This land once grew mighty beech and maples. Early settlers selected land, the productivity of which was indicated by a shovel or by the growth of trees. Excellent tree growth was not a true value of this land for farming.

When man first cultivated the soil, he upset the balance that Nature had established between the soil and the vegetative cover. It is fully realized that the balance must be disturbed in order that man may eat. He is not content to live as an animal. As a custodian of a great natural resource, the soil, man has not always been a faithful steward. On many occasions and in many places he has exploited the soil.
In Ontario we are fortunate in having a supply of food that has generally been adequate for a relatively high standard of living. We have no deserts nor mass abandonment of land through previous exploitation of the soil, but we do have soil depletion problems. Erosion has become serious in parts of the Province.

**FACTORS INFLUENCING OUR SOIL PROBLEMS**

Many factors have contributed to our current soil problems. This is not the place to discuss such topics as: man's desire to get rich quick; the economic effect of prices, wages or subsidies; the impact on Ontario agriculture of war, peace and exports; the contributions and obligations of industry; the security of sharecroppers or of those who rent farms and those who farm on a part-time basis.

Factors such as climate and soil variation have an effect on soil depletion and soil erosion. These factors often determine the type of farming peculiar to areas of Ontario, which in turn affect our soil problems. Ontario soils vary widely in topography, natural reserves of plant food, soil reaction, organic matter, texture and drainage. Some soils are deep, rich, naturally well drained; others are shallow with rock outcrops; others are smooth undulating clays, and others sands and gravel.

It is over a thousand miles from the extreme southern point to the northern limits of the Province. From north to south there are extremes in climate. Parts of Northern Ontario may expect frost any month of the year while in the southern part the frost-free period averages 167 days. The annual precipitation, rain plus snow, in Ontario ranges from 25 to 40 inches. The soils in most of the southern counties are frozen for several months of the year.

In addition to soil variations and climatic differences, we have in Ontario over 22 million acres of farm land subdivided into 178,000 occupied farms. Many and varied are the land use problems and the ways of managing a soil when there are so many individual farmers.

No overall planning of the settlement and utilization of soils prevailed at the time of clearing and establishment. The pioneer's chief desire was freedom, independence and security in exchange for hard work, hardship, and for some, adventure. The settlers were largely self-sufficient and built around themselves self-supporting communities. Many and varied were the reasons why people settled in different parts of this Province. From past experience many were soil conscious and selected land whose productivity was indicated by a shovel or by tree growth. Others opened tracts of land where they could maintain family or racial clannishness and gave little thought to the quality of the soil.

In Ontario, farms were usually surveyed into square or rectangular hundred-acre lots. A lane was established through the middle of the farm, and fields, square or rectangular, were fenced on either side of the lane. Regardless of topography or soil type, tillage and cropping operations were generally conducted parallel with a road, lane or fence. Tradition has contributed to practices that are hard to change and has hampered the introduction of improved land use practices.

While many factors have contributed to our problems in the use and management of soils, investigational work already conducted in Ontario indicates that our problems may be associated with one or a combination of fertility, drainage and erosion.
A prosperous Ontario farm.
This farm is one of many in Ontario where soil depletion is not evident. Level and gently rolling land remain productive when the farm operator practices good soil management.

The ability of a soil to provide plant nutrients for crop growth is closely related to soil texture. A sandy soil is characteristically low in organic matter and clay. These are necessary in the storage of water and plant nutrients. Water moves readily through sandy soils and by a process of leaching depletes the soil of nutrients. Clay soils retain more plant nutrients and are subject to less leaching than the lighter textured soils (sands and sandy loams).

Inadequate drainage interferes with the growing of those crops that require good drainage. Indeed, unsatisfactory drainage may preclude the possibility of including such crops as alfalfa and red clover in a crop rotation, thereby greatly reducing the nutritive value of the forage produced. There are large and extensive areas in Ontario where inadequate drainage is the number one land use problem. Usually mechanical means of some form are necessary to remove the excess water. Once a soil has been drained the improved aeration encourages a more rapid depletion of the organic matter. Maintaining adequate fertility levels is often a greater problem in artificially drained soils than in soils with good natural drainage. Soils are drained to increase the number of crops that can be successfully grown and to create a more satisfactory moisture environment for those already growing.

The physical character of the land is the most significant aspect in determining the susceptibility of soil to erosion. There is a tendency for
people to be much slower in becoming conscious of the menacing effects of erosion than in recognizing either fertility or drainage needs. This is due, in no small part, to the slow insidious manner with which erosion depletes our soil resources. Because of the type of topography common to a large part of Ontario, millions of acres are susceptible to sheet erosion. The degree to which soils have suffered from erosion depends on soil texture, length and per cent slope, and the cropping practices. Large areas of sandy soils have suffered from or are susceptible to wind erosion. Often subsoil and parent materials become exposed through prolonged wind or water erosion.

SOIL FERTILITY

Soil fertility is the ability of a soil to supply plant nutrients. In the soil will be found organic matter, plant nutrients, air and water. As these nutrients increase in available amounts and maintain an optimum ratio among themselves, the fertility of the soil is said to be improved.

A highly fertile soil may not be a productive soil if one or more factors are not favourable to crop growth. Soil productivity is a very broad term encompassing fertility, physical condition, drainage, climatic and seasonal conditions, and cultural practices.

This bulletin mentions but a few factors involved in the management of soils to keep them productive. It is widely recognized that soil fertility maintenance is perhaps the dominant conservation problem associated with Ontario soils.

SOIL ORGANIC MATTER

Soil organic matter refers to the remains of all plant and animal life in various stages of decomposition in the soil. Humus is a product from the decomposition of fresh organic matter. Fresh organic matter is subject to relatively rapid decomposition under favourable conditions. Humus, on the other hand, is comparatively stable, but is nevertheless also subject to destruction. Because the term organic matter covers all forms of organic material, it will be used here almost entirely.

THE FUNCTIONS OF ORGANIC MATTER

Organic matter is made up chiefly of the elements carbon, hydrogen, oxygen and nitrogen. There is no mineral which supplies nitrogen naturally to soils. Practically all nitrogen in the soil is in, or was supplied by, the organic matter, with the exception of that which might have been supplied by manure, fertilizers, rain and snow.

Organic matter in adequate amounts:

- promotes the formation of granules
- assists the infiltration of rainfall
- encourages deeper rooting
- increases resistance to erosion
- imparts good soil aeration

A feature of good structure in heavier soils is the presence of granules. Heavy soils, on drying, frequently become excessively hard and form wide deep cracks, because clay shrinks considerably as it dries. When a clay soil is well supplied with organic matter, each clay particle is lightly smeared with it, thus reducing the baking action and the cracking.
On sandy soils organic matter improves the infiltration of rainfall and the water-holding capacity, enabling them to supply moisture to plants over a longer period of dry weather.

Organic matter is the chief source of food and energy for a great variety of organisms. One of the products of this breakdown of organic matter is the gas carbon dioxide, a part of which is dissolved in the soil moisture to form a weak acid. This weak acid plays an important role in slowly releasing nutrients from the mineral matter.

Of the larger organisms, earthworms are probably the most important. They pass large amounts of soil through their bodies, digesting the organic matter and leaving it in a state favourable for easy decomposition by the micro-organisms. Their burrowing leaves channels in the soil for air and water penetration. The number is small in soils low in organic matter, but the population of earthworms increases when fresh organic material is added.

**Depletion of Organic Matter**

The decomposition of organic matter in a soil may be compared to burning coal in a furnace. If three-inch lumps of coal are placed on a fire they tend to burn more quickly than lumps of a half-inch size. When very small coal particles are used, forced air from a blower is almost necessary to induce combustion. The larger lumps of coal have larger air spaces between them than the smaller pieces, allowing combustion to take place more rapidly.

Particles making up a sandy soil are large in size with consequent big pore spaces between them. Clay soil particles are very small in size, and it follows that their pore spaces are small. Well drained sandy soils are lower in organic matter than clay soils of similar good drainage, because there is more air present for rapid decomposition. Fresh organic material added to a sandy soil soon decomposes, reaching a low organic matter equilibrium. The same fresh organic material applied to a clay soil will also decompose until the balance for this soil is reached, but the decomposition rate will be slower. In general it is not economically possible to maintain as much organic matter in a sandy soil as in a clay.

Any tillage operation incorporates air into a soil. When the drafts of a furnace are opened, more air is supplied to the burning coal, increasing combustion. Cultivation increases the draft or air supply in the soil, causing more rapid decomposition of organic matter. While cultivation hastens destruction of organic matter, it nevertheless is essential. If plants are to grow, air must be supplied to the roots. Certain crops, for example the grasses and legumes, require no further cultivation than the preparation of a seed bed. Others, like corn, potatoes and vegetables, usually receive one or more cultivations during their growth period. In the destruction of organic matter through cultivation, microbiological activity is increased, and valuable nutrients are released. Cultivation speeds up the tempo in the soil factory to produce more available nutrients and thereby to increase yields. Some cultivation is required if crops are to be grown successfully, but because organic matter destruction is hastened, it should be kept at the minimum necessary for optimum yields.

**Effect of Cropping on Organic Matter Losses**

The amount and the kind of residue which a crop leaves in a soil are all important. Good soil humus has an approximate ratio of twelve parts of
Crop residues to be turned under.
If straw, corn stalks or other non-leguminous crop residues are turned under, a nitrogenuous fertilizer should be broadcast on top of the hay or straw before discing or plowing.

carbon to one part of nitrogen. The closer the fresh organic material is to this ratio, the more chance there will be for its accumulation in the soil as humus. If grain straw is turned under, the carbon addition is large but the nitrogen content is low. The ultimate effect in all probability is nitrogen starvation in the following crop, and little increase in organic matter. The straw stubble and roots contain a large amount of carbon with little nitrogen. The micro-organisms have a large supply of energy at their disposal, in the form of carbon. If they are to grow and multiply, they must have nitrogen to form the protein of their bodies. The rate of decomposition of the straw will be dependent upon the amount of nitrogen the soil humus can supply. Thus all of the nitrogen released by the soil humus is used by the micro-organisms to build their body tissue with little left for the crop. Plowing down straw and other carbonaceous residues causes a shortage of available nitrogen for the succeeding crop which may last over the whole season. To overcome this situation, a nitrogen fertilizer should be applied at the time of plowing under the residue to give the equivalent rate of 75 pounds of ammonium nitrate per ton of residue. This supplies the nitrogen for the micro-organisms, instead of depending on that released from the soil humus. In this way more residual humus may result, and the succeeding crop will be less likely to show a nitrogen deficiency.

Poorly handled manure or manure with excess straw may cause nitrogen starvation when applied to a field. What has been said for straw is also true of corn stalks and old grass sods in which there are few legumes.

Legumes when properly inoculated need little soil nitrogen. They fix nitrogen from the air in excess of their needs. If the soil itself has a high nitrogen content, the bacteria on roots of legumes will use it instead of
### Average Daily Amount and Composition of Solid and Liquid Excrement of Mature Animals

<table>
<thead>
<tr>
<th>Kind of Animal</th>
<th>Daily Production per Animal</th>
<th>Composition of Fresh Excrement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Solid</td>
<td>Liquid</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>Horses</td>
<td>35.5 Pounds</td>
<td>8.0</td>
</tr>
<tr>
<td>Cattle</td>
<td>52.0 Pounds</td>
<td>20.0</td>
</tr>
<tr>
<td>Sheep</td>
<td>2.5 Pounds</td>
<td>1.5</td>
</tr>
<tr>
<td>Hogs</td>
<td>6.0 Pounds</td>
<td>3.5</td>
</tr>
<tr>
<td>Hens</td>
<td>0.1 Pounds</td>
<td>..</td>
</tr>
</tbody>
</table>

Table from Salter and Schollenberger: Yearbook of Agriculture, 1938.
fixing nitrogen from the air. However, a little nitrogen fertilizer at seeding time often assists the young plants to establish themselves, without interfering with nitrogen fixation.

ORGANIC MATTER

- natural source of nitrogen
- storehouse for essential nutrients
- makes fertilizer and lime more effective
- improves the physical condition
- reduces erosion losses

FARM MANURES

VALUE OF FARM MANURE

Manure contains valuable nutrient elements necessary for the growth of plants. On a percentage basis, manure has an average composition of 0.5 per cent total nitrogen, 0.25 per cent phosphoric acid (P₂O₅), and 0.5 per cent potash (K₂O). A five-ton application of manure per acre would be approximately equivalent to a fertilizer application of about 500 pounds of 10-5-10.

Every farmer knows the beneficial results accruing from the use of manure. It supplies a large amount of organic matter in a form easily decomposed by micro-organisms. This increases microbial action. It improves the physical condition of a soil, tending to knit the loose sand particles together and opening up heavy clay soils. It improves the water-holding capacity of sandy soils and assists in the infiltration of rainfall in both light and heavy soils. Fields top-dressed with manure are afforded protection from beating rains.

LOSSES IN THE HANDLING OF MANURE

Manure is an ideal food for micro-organisms; they commence to decompose it immediately. Decomposition of the manure is desirable in the soil but when manure decomposes in the pile, nitrogen is lost to the air and the soluble minerals are leached out by rain.

The first losses may occur in the stable if insufficient bedding is used to hold the moisture, because 40-75 per cent of the fertilizing value of manure is in the liquid portion.

Manure spread on the surface of the soil will lose as much as one-third of the total nitrogen within a week at ordinary summer temperatures.

When manure is placed in shallow piles, and not compacted, conditions are perfect for heavy losses. Heating in the pile assists in the loss of ammonia. Forking over a pile of manure is not advisable because it allows air to enter, and further assists in decomposition.

Rainfall tends to leach manure. When it is considered that a one-inch rainfall is equivalent to about two quarts of water per square foot, it is not difficult to visualize the amount of loss which can take place in this manner.

PROPER HANDLING OF MANURE

It is almost impossible to entirely avoid losses in manure handling; perhaps the nearest approach to complete avoidance of loss is to haul
Spreading manure on pasture.
Pastures and new seedings give excellent response to light or moderate applications of manure. It is important to spread manure evenly and avoid smothering the small plants.

Loosely piled manure is leached by rain.
When manure cannot be spread and must be stored outside, it should be packed tightly in large, straight-sided piles.
**Spreading manure on snow.**

Winter spreading of manure should be confined to nearly level land. Some losses will occur but the practice allows a more efficient use of farm labour.

Manure daily to the field and to plow it in immediately. This is not always possible, but the closer the approach to this practice the better will be the returns.

**Losses of Fertilizing Constituents in the Rotting of Manure**

Central Experimental Farm, Ottawa.

<table>
<thead>
<tr>
<th></th>
<th>Rotted for 6 months</th>
<th>Rotted for 12 months</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>Organic Matter</td>
<td>58</td>
<td>65</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>19</td>
<td>30</td>
</tr>
<tr>
<td>Phosphoric Acid</td>
<td>None</td>
<td>12</td>
</tr>
<tr>
<td>Potash</td>
<td>3</td>
<td>29</td>
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</table>

This experiment indicated that fresh manure when rotted for six months lost one-half to two-thirds of its original weight.

If manure is to be stored, it should be stacked in a pile of small base and tightly packed. Covered manure pits are a recommended means of storage.

Manure should not be spread on frozen or snow-covered rolling land. In such cases most of the soluble matter may be leached out by snow or rain to be lost in the runoff.
Spreading phosphate in the stable gutter.

Ontario soils and manure are generally low in phosphate. Adding phosphate in the stable absorbs the liquid and increases the fertilizing value of manure.

**Preserving Manure with Chemicals**

There are two reasons why preservatives have been proposed:

1. to reduce odour,
2. to prevent the loss of ammonia.

The most widely used preservative is superphosphate. Ammonia in the manure combines with the superphosphate so that it cannot escape as gas. The ammonia, however, is still susceptible to loss by leaching. Soils treated with phosphated manure frequently show a high phosphorus test. The present recommendation advocates the use of 50 pounds of superphosphate per ton of manure, applied to the gutters in the stable. This is equivalent to 2-2½ pounds for each mature animal per day.

Gypsum and limestone are of little use in preserving the nitrogen in manure. Burned lime and slaked lime assist in the loss of ammonia.

**Where to Apply Manure**

Manure should be applied for any crops having a high nitrogen requirement. Corn responds well to manure applications of 5-10 tons per acre. Potato yields are also increased with the use of manure. Vegetable
crops and small fruits in general respond to manure. Manure has proved beneficial when applied at seeding time or as a top dressing on established pastures.

If manure contains an excess of straw, it may induce nitrogen deficiency in the crop. In such cases, apply about 50 pounds of ammonium nitrate or a corresponding amount of any other available nitrogen fertilizer per acre to correct this situation.

Manure may be applied for any crop, but rates of application should not be as high for small grains as for corn or other crops requiring more nitrogen. Poor land will respond better than rich land. Knolls should be treated more heavily than other parts of the field.

**RELATIVE VALUES OF FRESH AND ROTTED MANURES**

It was pointed out above that in rotting manure, the fermentation processes release ammonia, containing nitrogen, as a gas. The loss of this gas represents a loss of valuable nitrogen. A better balance of nitrogen, phosphate and potash is attained in rotted manure, which usually means better plant growth. Weight for weight rotted manure contains larger percentages of plant food in a more available form than fresh manure. However, under the conditions of rotting there is a loss in fertilizing constituents, especially nitrogen and organic matter.

**COMPOSITION OF FRESH AND ROTTED (SIX MONTHS) MANURES**

Central Experimental Farm, Ottawa.

<table>
<thead>
<tr>
<th></th>
<th>Nitrogen</th>
<th>Phosphoric Acid</th>
<th>Potash</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh</td>
<td>0.60</td>
<td>0.31</td>
<td>0.73</td>
</tr>
<tr>
<td>Rotted and protected</td>
<td>1.69</td>
<td>1.08</td>
<td>2.60</td>
</tr>
<tr>
<td>Rotted and exposed</td>
<td>0.50</td>
<td>0.53</td>
<td>1.07</td>
</tr>
</tbody>
</table>

The manure referred to above was equal parts of horse and cow manure. This data appeared in more detail in Farmers' Bulletin No. 40 issued by the Central Experimental Farm, Ottawa.

The above bulletin proceeded to make general recommendations regarding the use of fresh and rotted manures:

“Fresh manure is better suited to clays and heavy loams than to light soils since its coarseness does much to improve their physical condition by opening them to the air and making them more friable. On the other hand, rotted manure is better suited to light sandy soils, tending to make them more compact and retentive of moisture.

“Fresh manure may with advantage be used for crops which have a long season of growth, while rotted manure, with its more available plant food, gives better results for such crops as gather their food and reach maturity during a short period, and where early marketing is an important consideration.”

**MANURE**

- low in phosphates
- high fertilizing value in the liquid portion
- must be well packed in storage
- improve crop production

12
Sweet clover as a green manure crop.
Sweet clover and other legumes accumulate nitrogen in their roots. Additional nitrogen may be needed for certain crops with high nitrogen requirements, such as corn.

Plowing under a stand of grass.
Green manuring adds organic matter in a readily decomposable form provided enough nitrogen fertilizer is added to encourage the rotting process and to offset the possibility of nitrogen deficiency in the succeeding crop.
GREEN MANURES

Green manuring is a recommended practice. Yet it has perhaps not increased organic matter levels greatly. This may be due to the fact that a green manure crop is usually followed by a row crop. Green manuring does supply organic material, and when turned under causes a great increase in the desirable microbiological activity.

Legumes are greatly superior to non-legumes as green manures, but it may not be feasible to use the slower growing legumes. Second growths or hay aftermarts are often plowed under when not required for supplemental pasture. Fall-sown rye is a common green manure crop preceding row crops like corn, tobacco and potatoes. With rye as a cover or green manure crop 10-14 days are required in the spring for partial decomposition prior to planting the succeeding crop. It is desirable to incorporate the rye with the soil before it reaches a height of 12-15 inches. This delay in planting after rye rarely permits the planting of spring grains like barley or oats. For land or conditions where a winter cover crop is desired, but no spring growth, oats may be used. The fall growth of oats protects the soil from washing, adds organic matter, but no spring growth occurs to delay planting.

FACTORS AFFECTING NUTRIENT SUPPLY

A plant is a "factory" manufacturing carbohydrates, proteins, fats and oils, using the carbon dioxide from the air, water and nutrient elements from the soil, and sunlight. Soil contains the nutrient elements nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, iron, manganese, boron, zinc, copper and molybdenum. The major elements are nitrogen, phosphorus, potassium, calcium, magnesium and sulphur. The minor elements are those required in minute amounts — iron, manganese, boron, zinc, copper and molybdenum.

Each crop has a different requirement in amount and proportion of the nutrient elements, and soils vary in their capacities to supply them. A soil test is a practical means at a grower's disposal to ascertain the amounts of these available nutrients in his soils.

THE AVAILABILITY OF NUTRIENTS IN THE SOIL

Nutrients exist in the soil in three distinct forms:

1. difficultly available,
2. moderately available,
3. readily available.

The difficultly available forms are within the soil mineral and that part of the organic matter referred to as humus. The minerals and humus are the insoluble stock piles from which available nutrients are slowly released by the forces of weathering and organisms.

The moderately available nutrients are those contained in fresh organic matter and those held in mineral forms which can be reasonably easily dissolved.

The readily available nutrient supply exists in forms easily dissolved for plant root absorption.

In depleted or rundown soils, the amounts of readily and moderately available forms are low, causing restricted growth. Fertile soils supply a crop with sufficient amounts of readily available nutrients for high yields.
After harvest, the depleted supply of the readily available forms may be regenerated from the less available forms and from the use of manure, lime and fertilizer.

**THE SOIL WAREHOUSE**

In a soil, the warehouse is the clay and organic matter. The available nutrient elements, calcium, magnesium, potassium, iron, manganese, zinc and copper, are stored here, so that the plant root may easily procure them.

Phosphorus and boron are held in a soil by a different system. Nitrogen is held against leaching in the organic matter, but once this nitrogen is released by soil organisms as nitrate, it is not stored by any system and could be leached out of the soil. The more clay and organic matter in a soil, the greater is its capacity to absorb water and store certain nutrients against leaching. A sandy soil has a small warehouse.

**SOIL REACTION**

Soil reaction refers to the degree of acidity or alkalinity of a soil. It affects crop growth both directly and indirectly. All plants have a preferred range in soil reaction in which they grow best.

**FAVOURABLE pH RANGES FOR SOME CROPS**

<table>
<thead>
<tr>
<th>FIELD CROPS</th>
<th>PRUIT CROPS</th>
<th>VEGETABLE CROPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa</td>
<td>Apple</td>
<td>Cabbage</td>
</tr>
<tr>
<td>Barley</td>
<td>Blueberry</td>
<td>Carrots</td>
</tr>
<tr>
<td>Clover</td>
<td>Cherry</td>
<td>Cauliflower</td>
</tr>
<tr>
<td>Field Beans</td>
<td>Grape</td>
<td>Cucumbers</td>
</tr>
<tr>
<td>Field Peas</td>
<td>Peach</td>
<td>Lettuce</td>
</tr>
<tr>
<td>Oats</td>
<td>Pear</td>
<td>Onion</td>
</tr>
<tr>
<td>Rye</td>
<td>Plum</td>
<td>Peas</td>
</tr>
<tr>
<td>Soybeans</td>
<td>Raspberry</td>
<td>Table Beets</td>
</tr>
<tr>
<td>Wheat</td>
<td>Strawberry</td>
<td></td>
</tr>
</tbody>
</table>

**HOED CROPS**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>6.0-7.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beans</td>
<td></td>
<td>6.0-7.5</td>
</tr>
<tr>
<td>Corn</td>
<td></td>
<td>6.0-7.5</td>
</tr>
<tr>
<td>Mangels</td>
<td></td>
<td>6.0-7.0</td>
</tr>
<tr>
<td>Potatoes</td>
<td></td>
<td>4.8-6.5</td>
</tr>
<tr>
<td>Pumpkin</td>
<td></td>
<td>5.5-7.5</td>
</tr>
<tr>
<td>Sugar Beets</td>
<td></td>
<td>6.5-8.0</td>
</tr>
<tr>
<td>Tobacco</td>
<td></td>
<td>5.6-7.5</td>
</tr>
<tr>
<td>Tomatoes</td>
<td></td>
<td>5.6-7.5</td>
</tr>
<tr>
<td>Turnips</td>
<td></td>
<td>5.6-8.8</td>
</tr>
</tbody>
</table>

**THE EXPRESSION OF SOIL REACTION**

The conventional term pH is used to denote the degree of acidity or alkalinity. The pH values for most Ontario soils will fall within the numbers 4.5 - 8.5.

The pH scale of soil reaction for Ontario soils is as follows:

- **pH below 5.5** — strongly acid soils
- **pH 5.5 - 5.9** — moderately acid soils
- **pH 6.0 - 6.5** — slightly acid soils
- **pH 6.6 - 6.9** — very slightly acid soils
- **pH 7.0** — neutral soils
- **pH 7.1 - 7.4** — very slightly alkaline soils
- **pH 7.5 - 8.5** — slightly to moderately alkaline soils.
Soils are acid not because of the presence of corrosive acids such as may be purchased in a drug store, but because the clay and the humus of the soil become low in calcium and sometimes magnesium. This gives rise to acid clay andacid humus which are characteristic of acid soils. Clays have a large warehouse, which is like a theatre with many seats. If all these theatre seats are filled with fellows like calcium, magnesium and potassium, the soil is neutral or alkaline. When the plant roots absorb this calcium and magnesium, the vacant seats are, in a good soil, filled with more of these two elements, released from soil minerals. In a soil which does not have a good reserve supply of calcium and magnesium, seats made vacant by root absorption of these elements, or by other means, become filled with hydrogen, causing the soil to be acid. Sands have a small warehouse, or a theatre with only a few seats, but the same principle applies.

The soil test is of special usefulness in determining the need of a soil for lime. For further information on liming the reader is referred to Bulletin 477 of the Ontario Department of Agriculture, Statistics and Publications Branch, Toronto, Ontario. The title of this bulletin is “Does Your Soil Need Lime”.

FERTILIZER USE

The use of fertilizers becomes necessary when crop response indicates a need for one or more of the readily available nutrient elements.

NITROGEN

When organic matter in the soil is low, available nitrogen is usually low. Legumes plowed down are a good source of available nitrogen. Nitrate
nitrogen is not fixed in any way in a soil, and if present in large quantities at any one time is susceptible to leaching. The slow gradual release of nitrate is, therefore, the preferable way to supply a crop. For this reason fertilizers are usually low in percentage of available nitrogen.

When manure is applied to a soil at a rate of ten tons per acre, about 100 pounds of nitrogen would be added, provided the manure were well stored and not strawy. The rate of manure additions should be governed by soil conditions and the nitrogen requirement of the crop to be grown.

Fall sown grains often respond to nitrogen top-dressed in the spring, because in the early spring the soil is cold and the micro-organisms which decompose the organic matter to release nitrate nitrogen are not active. When available nitrogen is low, the plants turn a pale green or even yellow colour, and growth is restricted. Where a field of cereal grain, or any other crop, is yellow because drainage is poor, additional nitrogen will not improve the colour or yields because excess water shuts off the air supply, preventing the absorption of nutrient elements by the plant.

Organic soils, such as the mucks and peats, may not contain as much available nitrogen as the supply of organic matter would imply.

**NITROGEN**

- gives dark green colour to leaves
- produces rapid growth
- increases protein content of crops
- feeds organisms while decomposing organic material

**PHOSPHORUS**

The total amount of phosphorus in Ontario soils is low. Nature wisely locks it in the soil so that it is difficult to leach out. She rations the available supply by making it soluble slowly and in small amounts.

If the plant root is not in the immediate vicinity to absorb some of the released phosphorus, the soil promptly fixes it again. Thus Nature supplies just enough phosphorus to maintain growth, but insufficient for the high yields of crops which we demand of our soils today. Thus phosphorus additions as a fertilizer can be generally recommended for all Ontario soils.

It has been estimated that up to 50 per cent of the total phosphorus in a soil is present in the organic matter. Since the topsoil contains practically all the organic matter in a soil, it is all the more important to conserve it.

Phosphorus can be applied to soils as fertilizer. The best forms to date are superphosphate or ammonium phosphate. The latter carries considerable nitrogen with the phosphorus.

**PHOSPHORUS**

- stimulates early root formation and growth
- gives rapid and vigorous plant growth
- hastens maturity
- imparts winter hardiness to fall-seeded crops
POTASH

Potash is a variable constituent in Ontario soils. The amount of potash present in soils may appear high, when compared to total nitrogen and total phosphate. Plants require more potash than any other mineral element. Potatoes, sugar beets, turnips, mangels, corn and legumes along with many fruit and vegetable crops have a high potash requirement.

POTASH

• imparts vigour and disease resistance to plants
• encourages stalk stiffness
• improves quality of seeds and grain
• imparts winter hardiness to fall-seeded crops

THE MINOR ELEMENTS

The minor elements are usually considered to be boron, manganese, iron, zinc, copper and molybdenum. Of these, only boron appears to be of general interest in Ontario. Some manganese deficiencies have been noted, but they have not been widespread.

Deficiencies of these minor elements in soils are not so widespread as to warrant their general additions to all soils. When deficiencies do exist, they can be corrected by supplemental additions to the soil or as a spray on the crop. The range between beneficial and detrimental amounts is very narrow so they must be carefully used, for too much will cause injury.

SOIL ADVISORY SERVICE

The Ontario Department of Agriculture maintains soil-testing stations where farmers may send their soil samples. There is no charge for the service, but samples should be mailed or expressed prepaid, or delivered personally.

Determinations on each sample are made for soil reaction, water soluble calcium, and magnesium. This assists in the estimation of lime requirement, and assesses the magnesium content which is sometimes low in Ontario soils. In addition, determinations are made for available phosphorus and potassium, and nitrate nitrogen.

Each sample must be accompanied by a completed questionnaire form, in which the farmer states the topography of the field, the drainage situation, the ease of growth of legumes, the rotation practised and the lime and fertilizer used during the past three years. From the results of the analysis of the soil, together with the information submitted by the farmer, recommendations are given for the kind and amount of limestone and fertilizer to use for the specific crop to be grown. Advice may also be submitted on rotations for the farm when deemed necessary. It is very important that soil samples be properly taken. The Agricultural Representatives and the testing laboratories have instruction sheets for taking samples which will be sent on request.

LAND DRAINAGE

Among our good land use practices, artificial drainage, by ditches or tile, is one of the more important requirements of soils which are limited in use by inadequate drainage. Drainage provides a direct means of bringing about the proper use of land in accordance with its capability and of
treating this land according to its needs. By increasing production on level land that was wet, the cropping strain on sloping more erodible land is eased. Drainage of the level wet land makes it possible to move erosion-inducing crops from the sloping uplands and to return these uplands to a denser, more protective type of cover.

In dealing with drainage problems one must carefully determine the economic feasibility of drainage schemes. In considering the installation of a drainage system, a farmer should weigh the estimated cost against the expected increases in revenue after drainage. The cost is normally spread over a period of time such that all drainage debts will be sufficiently repaid to assure a sound financial status before maintenance and repair costs develop against the system.

The decision on draining a small or large tract of land is best made after considering:

- the crops and their cash or feeding value
- the soil texture; plastic clays may not drain properly
- the stoniness in the surface and subsoil
- the availability of good outlets
- the proportion of good and poor land in the drainage area
- the effect on natural forest cover
- the effect on local ground water supplies
- the wild life in the drainage basin
- the contribution to flood problems farther down the watershed

Assistance in surveying and planning farm drainage systems is given by the Departments of Agricultural Engineering at the Ontario Agricultural College, Guelph, and at the Kemptville Agricultural School, Kemptville.

SOIL EROSION AND METHODS OF CONTROL

TYPES OF EROSION

Soil erosion may be defined as the wearing away of the land surface by water and wind. When this erosion proceeds faster than the soil is being formed by Nature, the soil becomes progressively poorer. It is this accelerated soil erosion that has become a serious agricultural problem on much land in Ontario.

Erosion of soil by water can be divided into three stages, although there is no fine line of demarcation:

- sheet erosion
- rill erosion
- gully erosion

Sheet erosion is a slow persistent wearing away of the soil which may go on for years without giving any warning. It is hard to see, hence it is the most dangerous type of erosion. The farmer appreciates the problem when a patch of greyish subsoil appears on a knoll. By this time the field has lost several inches of valuable topsoil.
Sheet erosion.
As land dries out, the colour differences indicate the severity of sheet erosion. When the grey subsoil appears, all the top soil is gone.

Extensive rill erosion after discing.
Too often the shallow rills are harrowed or disced in and forgotten. A strip of sod along the face of the slope would have prevented the erosion.
Rill erosion is visible. The water digs out small channels a few inches deep as it moves along sloping land. If rill erosion is allowed to proceed unchecked, gullies may eventually develop. Too often farmers rub out the rills by plowing and harrowing and forget about them. Without some control measure the problem becomes worse.

Wind and gully erosion are discussed in more detail on pages 33 and 38.

In fields where sheet erosion is prevalent it is not uncommon to find the crop on the upper slopes maturing before that farther down. Not only does the crop mature earlier but the stand is thin and short. Where the eroded material has accumulated, many crops, especially oats, will lodge and not mature properly.

The Experimental Farm at Ottawa has reported the effect of decreasing the depth of topsoil on the yield of barley and alfalfa. The table that follows shows that barley is more susceptible to thin soil conditions than alfalfa, yet in both cases the yields on subsoils were not encouraging. The difference in the root systems may account for the marked reduction in yield of barley as compared with the alfalfa.

### THE EFFECT OF SOIL EROSION ON CROP PRODUCTION

Central Experimental Farm, Ottawa

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Barley 7 yr. average</th>
<th>Alfalfa 3 yr. average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bushels per Acre</td>
<td>Tons per Acre</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>-----------------------</td>
<td>-----------------------</td>
</tr>
<tr>
<td>3” surface soil added</td>
<td>46.8</td>
<td>3.24</td>
</tr>
<tr>
<td>Normal undisturbed soil</td>
<td>45.6</td>
<td>3.07</td>
</tr>
<tr>
<td>3” surface soil removed</td>
<td>37.1</td>
<td>2.76</td>
</tr>
<tr>
<td>All but 1” surface soil removed</td>
<td>24.1</td>
<td>2.58</td>
</tr>
<tr>
<td>All of surface soil removed</td>
<td>11.7</td>
<td>1.73</td>
</tr>
</tbody>
</table>

The above data indicate that:

- three inches of added soil slightly increased production over the normal soil
- as more soil was removed, the production decreased
- without topsoil the crop produced was very meagre
- in every case the plant food added in the fertilizer encouraged greater production than from unfertilized soil

### FACTORS AFFECTING SOIL EROSION

Many people maintain that an unpastured woodlot effectively controls erosion and that our soil erosion problems commenced with the clearing and breaking up of the new land. Other people believe that some erosion did occur under Nature's plan but agree that farming has in general aggravated erosion problems. Both groups of people maintain that if it were possible to grow a dense vegetative cover on the soil throughout the year, erosion could be reduced to a minimum. It is possible to separate three variables that affect erosion and to show their individual contribution under various conditions.
Shallow gully erosion.
A gross waterway would carry the water, without causing gully erosion, that must flow over this field.

RAINFALL

The total rainfall is not so important as is the rate or intensity with which the rain falls; a heavy rainfall spread over several hours as a drizzle seldom causes serious soil losses. Serious sheet and rill erosion occur with spring rains on land with a frozen subsoil and a soft muddy surface.

THE EFFECT OF RAINFALL INTENSITY ON SOIL EROSION
(Corn planted up and down a 10 per cent slope)
Central Experimental Farm, Ottawa

<table>
<thead>
<tr>
<th>Rainfall (Inches)</th>
<th>Duration of Rainfall</th>
<th>Soil Losses in Tons per Acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.90</td>
<td>60 minutes</td>
<td>53.5</td>
</tr>
<tr>
<td>0.50</td>
<td>10 minutes</td>
<td>6.5</td>
</tr>
<tr>
<td>1.98</td>
<td>3 showers, each 30 minutes</td>
<td>18.2</td>
</tr>
<tr>
<td>1.29</td>
<td>24 hours</td>
<td>1.4</td>
</tr>
</tbody>
</table>

SLOPE

Another factor that contributes to soil and water losses is the slope of the land. A 10 per cent slope has a fall of 10 feet per 100 running feet. Both steepness and length of slope have an important bearing on soil erosion. It is not necessary to point out that water flows more rapidly the steeper the slope, and if the velocity of the water is doubled, its ability to scour is increased four times; its ability to carry soil particles is increased 64 times.
Intelligent land use.
The steep irregular slopes are reforested with an adjoining strip of hay and a grass waterway. The smoother, less erodible land is worked across the slope.

THE EFFECT OF PER CENT SLOPE ON SOIL EROSION
(for four months, June-October; rainfall 14.9 inches)
Central Experimental Farm, Ottawa

<table>
<thead>
<tr>
<th>Slope Type</th>
<th>Soil Loss in Tons per Acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn up and down a 10 per cent slope</td>
<td>77.5</td>
</tr>
<tr>
<td>Corn up and down a 5 per cent slope</td>
<td>45.2</td>
</tr>
<tr>
<td>Corn on the contour on a 10 per cent slope</td>
<td>28.8</td>
</tr>
</tbody>
</table>

LAND USE

Land use is a broad term. It includes the uses that a farmer may make of tillable land as well as natural woodlots, reforested tracts and unimproved pastures. In the tables that follow will be found a variety of land uses and cropping practices as related to soil erosion losses.

THE EFFECT OF FARM LAND USE ON SOIL EROSION
(average of five years; on a 10 per cent slope; up and down cultivation for May-October; average rainfall 20.1 inches; from a clay soil)
Central Experimental Farm, Ottawa.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Soil Losses in Tons per Acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summerfallow</td>
<td>26.5</td>
</tr>
<tr>
<td>Corn</td>
<td>27.3</td>
</tr>
<tr>
<td>Oats</td>
<td>0.7</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>0.1</td>
</tr>
</tbody>
</table>
LAND USE AND SOIL EROSION

(on a 14 per cent slope, up and down cultivation; average annual rainfall 38.9 inches; on yearly basis from a silt loam soil) (1934-1942)

Technical Bulletin No. 888, 1945, U.S.D.A.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Soil Losses in Tons per Acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous corn</td>
<td>99.3</td>
</tr>
<tr>
<td>Fallow</td>
<td>96.6</td>
</tr>
<tr>
<td>Wild grass</td>
<td>0.3</td>
</tr>
<tr>
<td>Bluegrass (fertilized)</td>
<td>0.02</td>
</tr>
<tr>
<td>Woodlot (unpastured)</td>
<td>0.01</td>
</tr>
</tbody>
</table>

In a four-year rotation of corn, wheat, hay and hay, the losses according to each crop were:

- Corn ........................................ 41.5
- Wheat ....................................... 11.4
- Hay .......................................... 0.2

On the New Hamburg runoff plots a four-year rotation of corn, oats, hay and hay is followed on a clay loam soil. This project has been in operation since 1948, which does not give an adequate length of time for evaluating the results. For the growing seasons of 1950 and 1951 soil losses from the corn plots, up-and-down cultivation, were less than 1200 pounds per acre per year. The small soil losses from the corn land were attributed to:

1. the place of corn in the rotation—after two years of sod
2. the predominance of large (one-eighth to one-quarter inch) water-stable aggregates
3. the fact that the heavy rains occurred in July at a time when the soil was being cultivated and consequently was porous and retained large volumes of water
The above tables of data indicate that:

- land in fallow was subject to soil losses equivalent to cropping with corn
- continuous corn afforded the soil little protection
- in a four-year rotation of corn, oats, hay and hay erosion was materially reduced
- hay, well-managed pastures and unpastured woodlots effectively controlled erosion
- for a single sharp shower the denser the vegetation the more effective was the control of erosion
- the farmer has within his control crop rotations and cultural practices that may reduce erosion

It is impossible to set down in a one-two-three order the exact measures that a farmer should employ on a farm, field or portion of a field. The combination of measures that will effect a control under the type of farming in York County will not serve as control measures for the type of farming in Essex County. While there is no one remedy or combination of remedies that is applicable everywhere there are three fundamental principles that have a widespread application.

PRINCIPLES OF EROSION CONTROL

To Reduce the Velocity of Runoff Water

We often hear the expression, "Make the water walk, not run, downhill." The long slopes give water the opportunity to build up a greater
velocity and hence, increase its ability to erode. If an obstacle is placed in the path of the water, its velocity is reduced; if a multitude of obstacles, as in a hay field, confronts the moving water then the water is required to "walk" or move along at a velocity not likely to cause gullying nor have the carrying power to move great amounts of soil. Such ordinary observations have become the basis of many sound recommendations; the steeper the land, crop with hay or pasture; plant corn on level or nearly level land; cultivate on the contour; long slopes must be broken up by hay strips; use sod waterways where water tends to flow in a definite channel. The farmer has no control over rainfall nor is it economically advisable to change the slope of his land; but he can effect a tremendous control over moving water by the crops he grows and the way he manages the land that grows these crops.

To Increase Infiltration of Water

When a sod field is plowed, the soil is found to have a highly desirable type of structure. Instead of being finely pulverized, floury, or cloddy, the soil appears as small aggregates ranging in size from one-sixteenth to three-sixteenths of an inch. It is a well-known fact that such a soil will take in a tremendous amount of water before it is flooded; it will also drain more quickly and be ready for cultivation earlier than a soil which previously grew corn or grain. The ability of a soil to take in or absorb large quantities of water at a high rate of infiltration significantly affects the erosion that may occur. The farmer cannot change the soil on his farm from a sand to a loam nor from a loam to a clay loam, but he does exert an important control over soil structure by the crops, the rotation and his
cultivation practices. A field of corn after spring grain does not have a stable form of aggregation and if this corn field is subjected to a beating, driving rain, the soft aggregates collapse, smear over and puddle the surface, preventing further infiltration. If water cannot enter the soil surface then it has no alternative but to run off, transporting with it the broken down topsoil.

To Absorb Energy of Raindrops

Any crop or mulch of straw that will absorb the energy of falling raindrops and allow this water to seep into the soil materially reduces the erosion hazard. Where the soil is left bare as in summerfallow or only partially protected by an intertilled crop, soil and water losses are extremely high.

CROP ROTATION AND SOIL EROSION

Crop rotation may be defined as a system of growing different crops in a recurring succession on the same land. Rotating crops is distinguished from a one-crop system or a haphazard order of crops. A systematic rotation for erosion control involves a succession of grain crops, grass and legume crops and intertilled crops.

The crop rotations to be used on any one farm involve a consideration of such factors as: soil fertility, drainage, erosion, climate, weeds and plant diseases, and many economic factors. The crops that are grown and their
sequence are frequently dependent on the productivity of the soil. A large part of the value of a crop rotation in erosion control may be judged by its effect on:

1. soil and water losses
2. soil structure
3. organic matter
4. crop yields

If corn or other row crops are to be grown it is better to select the more nearly level land where, with good management and fertility practices, a rotation of corn, oats and red clover may be adequate. Hilly land should be used mostly for hay and pasture and broken only when necessary to reseed. The rotations for each farm must be worked out individually to maintain a balance among grain, hay and row crops according to the capability of the land to produce these crops.

**EFFECT OF CROP SEQUENCE ON SOIL LOSSES**

(Slope 16 per cent, silt loam soil; average annual precipitation 31.7 inches)

(1932-1940)

Bulletin 452, La Crosse, Wisconsin

<table>
<thead>
<tr>
<th>Crop Sequence</th>
<th>Soil Loss in Tons per Acre per Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn continuous</td>
<td>89</td>
</tr>
<tr>
<td>Corn after soybeans</td>
<td>66</td>
</tr>
<tr>
<td>Corn after one year of hay</td>
<td>42</td>
</tr>
<tr>
<td>Corn after six years of hay</td>
<td>28</td>
</tr>
<tr>
<td>Barley after corn after one year hay</td>
<td>24</td>
</tr>
<tr>
<td>Barley after corn after six years hay</td>
<td>10</td>
</tr>
<tr>
<td>First year hay</td>
<td>0.75</td>
</tr>
<tr>
<td>Bluegrass sod</td>
<td>0.20</td>
</tr>
</tbody>
</table>

The above table indicates that:

- more hay in the rotation reduced soil losses
- the denser the crop, the better the soil was protected
- row crops induced greater soil erosion than spring grain or hay
- after hay was a preferred place in the rotation for corn; the aggregation effect of the hay tends to stabilize the soil
- if five tons of soil loss per acre is considered a significant loss, then on the 16 per cent slope it is doubtful if corn should be grown at all.

**TILLAGE**

In using the word tillage, we are referring to the various mechanical operations upon a soil for the purpose of providing soil conditions favourable to the growth of plants. Tillage is more an art than a science, most operators knowing only what they have experienced. Various colleges and experiment stations have tillage experiments under way examining the effect of numerous farm implements on soil properties and crop yields.
OBJECTIVES IN TILLAGE

Tillage has three principal objectives:

- to prepare a suitable seedbed
- to eliminate weeds
- to improve the physical condition of the soil

TILLAGE IMPLEMENTS

The plow is the most widely used implement for the primary preparation of a seedbed. On a heavy soil or on a dense sod the plow is perhaps the most effective and economical implement on a farm at the present time. It turns the soil over, partially loosens it and covers the organic matter. However, there is much controversy over the merits of a plow and other tillage implements.

Clay soils have a high water-holding capacity; water usually penetrates them slowly, and as a result they are frequently worked too wet. Working a clay soil when too wet impairs the physical condition of the soil, instead of a granular structure large clods result. Fall plowing permits the frost to mellow these soils. If the soil is left bare over the winter serious erosion occurs on sloping land. Under such conditions some thought should be given to a tillage operation that does not completely bury the crop residue. These residues act as a mulch to prevent soil and water losses.

Somewhere in between the kind of plowing that wins at the matches and trash cultivation there must be tillage methods applicable to the wide range of conditions found in the problem areas of Ontario.

The disc appears as a farm implement in various forms. In general, the discs do not work as deeply as a plow, leave more residue on the surface, prepare a favourable seedbed after certain crops like soybeans, and are often the basic tillage implement on sandy soils. Discs are widely used in after-harvest cultivation for weed control and in seedbed preparation following the plow.

In certain areas of Western Canada trash farming is successful. Farmers use a cultivator type of implement with attached sweeps. The sweeps are sharp blades that slide underground cutting of all roots, shattering the soil but not turning it over. On sloping soils these implements are reported to be soil- and water-conserving machines because:

1. trash left on the surface acts as mulch
2. water is allowed to soak in
3. conserves more moisture for subsequent crops

Rotary tillage implements thoroughly pulverize the soil and mix the organic matter throughout the entire depth of working. Only a small rain is required to puddle the surface of a heavy soil and almost prevent further entrance of water into the soil. This water has no alternative but to run off, carrying with it the soil already loosened up and very easy to move along. These unfavourable conditions are not critical if a quick-growing crop, like rye, is planted immediately after. A cover crop or a mulching of straw or manure frequently reduces this erosion hazard.

Cultivation, particularly in row crops, is primarily for the purpose of destroying weeds, aerating the soil and temporarily improving the physi-
cal condition, as in breaking up crusts. Under the discussion of organic matter it was clearly pointed out that cultivation destroys organic matter. Hence cultivation should be done mainly for weed control and as shallow as practical. On rolling land the amount of cultivation must be kept to a minimum. Generally, a soil after two years of hay or pasture will have less annual weeds and will be in better structural condition than a soil after spring grain. For these reasons it is preferable to have corn follow a sod crop.

CONTOUR CULTIVATION AND CROPPING

Of recent years there has been much talk of "contour plowing" and "contour cultivation." This means plowing and cultivating across or around the slope rather than up and down. A contour is a line connecting points of equal elevation. Therefore, a contour line must be level throughout its length. The objective in this type of cultivation is to leave a series of ridges across the slope so that more of the water will soak in, rather than run off over the surface.

While it may not be practical to plow and cultivate exactly on the contour, it is advisable to work across the slope rather than up and down. It is important that the last operation at seeding time be across the slope. Where it is necessary to grow row crops on sloping land, planting and subsequent cultivation should be approximately on the contour.

Contour cultivation alone is limited in its effectiveness. Any cultivation that is slightly off the contour leaves small depressions on the slope where water tends to accumulate. If there is sufficient runoff to break over the ridges left by the implement, serious rill or gully erosion may result. However, this erosion can be prevented by a grassed waterway.

Contour plowing, seeding, cultivation, etc., become more effective in controlling erosion when combined with a practice of alternating strips of cultivated crops or grains with sod strips. This is known as strip cropping.

STRIP CROPPING

The practice of strip cropping is an erosion control method which is adaptable on long smooth slopes. It is a means of maintaining strips of sod alternately with strips of grain or row crops, thus increasing the amount of infiltration, reducing the runoff and keeping erosion at a minimum. On some farms it involves removing or changing the location of interior fences to be most practical. The width of strips varies from about 60 to 150 feet, depending on length and steepness of slope, erodibility of soil and the crop rotation. In other words, the greater the erosion hazard the narrower the strips should be.

ADVANTAGES IN STRIP CROPPING

The main advantages of a strip cropping programme are:

- reduces the velocity of the water
- increases the infiltration of the water
- holds the soil in place
- encourages a definite crop rotation
- facilitates contour cultivation
- requires less power in operating farm machinery
A practical erosion control measure.
Strip cropping is an effective erosion control measure on this 8 per cent slope. Each strip is approximately 80 feet in width.

TYPES OF STRIP CROPPING
There are three general types of strip cropping:
1. field strip cropping
2. contour strip cropping
3. strip cropping for wind erosion control

FIELD STRIP CROPPING
In field strip cropping, the strips are of uniform width and placed across the general slope of the land. The strips are usually parallel to some fence line and do not curve to fit a contour. Field strips are recommended on uniform slopes where it appears that no greater control would be attained by contour strips. On irregular topography where it would be impractical to lay out contour strip cropping, field strips may effect some measure of control.

CONTOUR STRIP CROPPING
There are two types:
1. even width strips, most common
2. uneven width strips, less common

In contour strip cropping, the crops are arranged in strips or bands on the contour insofar as it is practical to operate farm machinery. This results in curved even-width strips with a minimum deviation from the true contour. When both edges of a strip are on the contour the result is strips of irregular widths. This type has not been widely used in Ontario but may occur as a correction strip when the even-width strips are running too far from the true contour.
Plowing a contour strip.
One year plow "out" leaving the dead furrow in the middle of the strip; the next year, turn a back-furrow in the centre and plow "in". This alternate "out and in" plowing prevents the development of boundary or centre ridges.

LAYING OUT STRIPS AND CONTOUR LINES

In laying out a farm or field for this practice, the first step is to select the most critical area on the slope. This is usually the steepest part of the field. After marking this point with a stake, fencepost or tree, etc., a line is run with the aid of a level. This contour is marked with a line of stakes and later scratched in with a plow. The strips are laid out parallel to this line. One man walks in the first furrow and another at the end of a tape or rope, while a third follows with a plow to mark the next line. Each strip is marked out in this manner until the line is no more than 1 or 2 per cent off the contour. When that happens a new line is run with the level and the irregular area left is known as a correction strip. These irregular areas are kept to a minimum and wherever convenient are left more or less permanently in sod.

STRIP CROPPING PROBLEMS

A common misunderstanding of strip cropping is the difficulty of pasturing the aftermath of the hay strips. This can be taken care of in planning the farm. For example, let us consider a four-year rotation of hay, hay, fall wheat and spring grain seeded. The area for these crops can be approximately divided into halves by a fence. On one side would be fall fall wheat with first year hay. The hay aftermath could be pastured as soon as the fall wheat was harvested. On the other side would be second year hay and spring grain seeded. The second year hay would be plowed for fall wheat. The following year pasture would be available on the other half. This practice is looked upon as an emergency measure, not one to be practised yearly. The second year hay aftermath usually provides some growth that should be plowed under, not pastured off.
The question often arises as to what to do about the triangularly-shaped areas which may occur when contour farming is applied to a square or rectangular field. These areas do occur but are usually left, along with wide headlands, for hay.

In plowing strips, two approaches are possible: use the strip as a land and plow around, or strike out with a line of stakes in the centre of the strip.

**MULCHING FOR EROSION CONTROL**

The application of organic material such as straw, spoiled hay, leaves, sawdust, etc., to the soil surface is known as mulching. The advantages and purposes of mulching are:

- to break the force of falling raindrops
- to prevent soil puddling, allowing clear water to soak in
- to reduce soil and water losses
- to retard evaporation
- to assist in the control of weeds

Mulches of the type mentioned above are usually restricted to horticultural crops or orchards. With these crops, the mulching material is applied to the surface by yearly additions. Mulches may not accomplish their purpose if applied during a dry season when an insufficient rainfall only wets the mulch. The water must be enough to saturate the mulch and enter the soil.

Many farm operations prepare a mulch of one kind or another. With the increase in the use of the combine, the straw is spread and left in the field. This acts as a mulch until such time as it is plowed under or disked in with applications of nitrogen, as discussed earlier. In the section on tillage reference was made to new types of farm equipment that slide under the soil and leave a trash-covered surface. This form of mulching is of particular value in reseeding steep hillsides subject to severe erosion. Mulching may be necessary to satisfactorily establish a dense cover in grass waterways or in gullies.

Manure is often left on the surface to act as a mulch, especially in newly established meadows. While this practice increases the loss of available nitrogen, there may be compensating advantages in the control of erosion and in the improvement of the stand of clovers and grasses.

**WIND EROSION**

In Ontario, wind erosion or soil drifting is largely a localized problem and is confined to sandy and peat or muck soils. Some drifting occurs on any soil under certain conditions, usually cultivating the soil when very dry and leaving surfaces unprotected in high winds. These conditions are found where summerfallowing is practised.

Except for the shifting sand dunes along some lake shores, the soils now subject to wind erosion were once covered with trees. When these soils, principally sands and mucks, were cleared, broken up and cultivated, the soil organic matter was rapidly depleted and the exposed areas began
drifting. Small dunes and "blow-outs" were formed. At this stage the fields or farms were often abandoned, insofar as cultivated crops were concerned.

The principal means of control are:
1. windbreaks
2. strip cropping
3. ground cover

In planting windbreaks it is customary to plant two or more rows of trees, one row a rapidly growing variety like Carolina poplar, and other rows of slower growing spruce, pine or hardwoods. One should make sure that he is using adaptable varieties. Assistance may be obtained from the Regional Forestry Offices.

Strip cropping is used in some tobacco growing areas, where a two-year rotation of tobacco and rye is practised. The rye is tall enough to protect the adjoining strip while the land is being prepared for tobacco.

In parts of Ontario, potatoes are grown on sandy soils. A recommended practice to control soil drifting is to sow a winter cover crop of rye or oats and plow it under in the spring in preparation for grain or other row crops.

The control of wind erosion on muck soils is largely obtained by windbreaks and cover crops.

The Forestry Department, conservation-minded farmers and others have done outstanding work in reclaiming many soil drifting areas by planting with adaptable trees. This problem is comparable to gully control in that preventative measures are eventually more economical. The operator of sandy soils must realize the difficulties involved once the natural soil covering is removed and utilize effective cultural treatments.

SURPLUS WATER

In the preceding sections various ways and means have been presented for increasing the amount of water that enters the soil. It is generally agreed that if all the water entered the soil, erosion would not be a problem and crops should not be limited in growth by a water deficiency. There are conditions when it is physically impossible for a soil to absorb additional rainfall. Under these circumstances provision must be made for the safe disposal of this surplus water.

Serious gully erosion or flooding may develop when water from adjoining land is not restrained but allowed to flow at will over land at a lower elevation. A farmer is not permitted to construct an obstacle and impound the water on his neighbour's land even though the water came entirely from the neighbours. However, a farmer whose land must carry such water may construct grass waterways, diversion ditches or revegetate gullies, and use these structures to dispose of or spread the surplus water without damaging his own land. On the other hand a conservation-minded and cooperative farmer would discuss with his neighbours or his road superintendent the possible effects his water disposal plans might have on the property under their administration, and so work together.

GRASS WATERWAYS

Grass or sod waterways describe the waterways on sloping land that have been broken up, properly shaped and reseeded to mixtures of grasses
An effective grass waterway.
This waterway carries surplus water without causing gully erosion. Note the irregular edges left in plowing, this prevents small gullies forming on either side of the waterway.

and legumes. Open ditches with steep sides and unprotected subsoil often become clogged up with shrubs, weeds and grasses on many farms. When these channels are cleaned out, shaped and seeded they become grass waterways and utilize the land more efficiently. Unless these established channels are protected by a dense surface cover of grasses, the active erosion continues until the area is impassable with machinery.

Grass waterways are an effective control measure that farmers may utilize. The construction of a waterway is done by plowing, one-way discing or grading out a broad saucer-like channel. The larger the area drained the wider the waterway should be, but a channel less than 20 feet in width is not recommended. Waterways less than 20 feet in width seldom receive the proper attention. The soil is carefully and thoroughly prepared by discing for seeding with a cultipacker seeder. If a packer-seeder is not available, the grass and legumes may be sown with a hand seeder and then rolled or packed. The soil should be heavily fertilized and if possible mulched with manure. Mulching with straw or manure and a light seeding of oats hold the soil in place until the grass becomes established. A waterway may be established in the spring, or in fall when the remainder of the field is in hay. It is a risky undertaking to try to establish the waterway when the field is in corn or grain, because if heavy rains occur unusual amounts of water will run off and wash out the channel.

It is essential that the waterway always be treated as a hay strip by cutting and removing the grass and legumes two or three times a year. The strips must be fertilized regularly, must not be used as laneways and not disturbed by plowing or cultivation.

The seeding mixture should consist of broad-leaved grasses like reed canary and brome and others that make a dense cover, such as creeping red fescue and Kentucky blue, along with ladino or white Dutch clover. It is advisable to avoid bunch grasses such as timothy and the tap-rooted
legumes like alfalfa. The waterway must have an effective surface cover that is best obtained with the more shallow-rooted or creeping grasses and legumes.

DIVERSION DITCHES

Diversion ditches, channels or terraces are low embankments of soil thrown up on slopes for the purpose of diverting surface water away from the land farther down the slope. These channels, usually about 30 feet in width, are left permanently in sod regardless of the crops above or below. The sides of the ditches are gently sloped and present no difficulty in hay removal.

The diversion ditches find their greatest use in three major situations:

1. to break up long uniform slopes where strip cropping is not entirely effective
2. to divert water from gullies while being revegetated
3. to protect buildings, structures or property from periodic flooding

Their most effective use is on long slopes where other conservation measures, such as strip cropping, do not adequately control soil erosion. Diversions may be used to divert water from land not under the farmer’s control, and avoid flooding or gullyng his own land.

Only estimations are given for the conditions under which a diversion might be recommended. A slope of 4 per cent and around 1,000 feet in length may be strip cropped, but beyond 1,000 feet a diversion may be necessary to break up the great length. In general as the per cent slope increases there is a reduction in the length of the slope that may be strip cropped before a diversion is found necessary. Factors like soil and local climatic conditions will materially affect the per cent and length of slope that may be strip cropped without diversions.

A diversion ditch may be built by plowing, disc plowing, grading, or by special machines. The location must be carefully staked out to give a graded channel. This grade varies with soil type, length of channel, type of cover and the area to be drained. If the grade is too steep then erosion in the channel results; if the grade is low then over-topping or break-outs follow. The slope of the channel increases toward the outlet to permit more rapid removal of the water. Where the water will not penetrate or the soil admits water slowly, then the grade should be increased. On long diversions with a moderately tight subsoil, the grade may be as high as 10 inches fall per 100 feet (less than one per cent). On a loamy soil where the water will soak in, this grade may be reduced to 5 inches per 100 feet. The final grade should be established after consulting soils and agricultural engineering specialists who have had experience with a variety of conditions.

It is wise to establish the grass waterway outlets before constructing the diversion channel, otherwise gullies may be formed. The outlet may be into an unpastured woodlot if some attempt is made at spreading the discharge, or perhaps into an old sod field where erosion and gullying will not readily develop. Naturally, the outlet must be placed so as to have no ill effect on the balance of the farm or on neighbouring property.
A well-built diversion ditch.

Diversion ditches are prepared channels across the slope which are kept permanently in sod. They effectively break long slopes.

TERRACES

Terraces have been used in China, Peru, Italy, and many parts of the world for centuries, often in conjunction with vineyards. The modern terrace has been used in America largely within this century and in those areas where the annual rainfall is high, where a large percentage of the crop is intertillled, such as cotton, peanuts, corn and tobacco, and where winter does not stabilize the soil as long as it does in Ontario.

Early terraces were of the bench type, the top nearly horizontal and the front or back very steep. Many lawns have this type of terrace but they are rarely found in modern agriculture. In some parts of the world the bench terrace was faced with stone and the nearly level top planted to grapes. Such structures were used on very steep hillsides, but construction and maintenance costs would be prohibitive in this country.

Modern terraces might be described as a low embankment on sloping land for the purpose of intercepting surface runoff. Many terraces have a graded channel leading to a well-established outlet to safely dispose of the water; other types, the absorption terraces, have a level channel to permit the water to soak into the soil. Terraces are usually found on land with slopes under 12 per cent; if built on greater slopes the interval becomes too narrow for practical farming.

It should be pointed out that terraces are cropped with the rest of the field in the regular rotation. In this respect they differ from diversion
ditches or channels, which are left permanently in sod. The graded terrace with a gently sloping channel results in point rows when cropped with corn, potatoes, or other row crops. For this reason a terraced field is difficult to handle for those operators familiar with square or rectangular fields. Provision must always be made for maintenance of the ridge and the outlet channel.

We suggest that farmers who believe terracing will assist them contact soils and engineering specialists who will advise them on the many details of layout, construction and maintenance.

GULLY CONTROL

Gully erosion is often the most spectacular type of soil erosion. Sheet erosion may proceed unnoticed for several years, but a small gully one to two feet in depth is very prominent and cannot be overlooked, especially when it is necessary to cross the eroded channel with machinery. A farmer may have to spend some time in the spring plowing or discing in gullies; he may leave his grain binder and throw in several sheaves of grain before attempting to cross the gully, or, if no control is begun, the gully becomes a permanent feature of his farm marked by shrubbery, weeds, rubbish, and stones.

Gullies will form in all types of soil, but in Ontario a common location is on sandy soils where intertilled crops like corn, soybeans or tobacco are produced. Extensive gullies have developed in rolling clay land adjoining deep river channels and lake shores. On many farms gullies may develop with one heavy rainfall, especially if the crop is young and the soil loose. If hay or pasture follows in this field then these gullies are plowed in and generally forgotten. When a gully has developed then the situation calls for immediate action to stabilize the soil and prevent recurrence.

Gullies are formed in sloping cultivated land by the concentration of unusually large volumes of water in a small channel. Once a small channel has formed both velocity and volume increase tremendously enabling the water to loosen, scour and carry away topsoil and subsoil.

Wheel tracks made up and down slopes are ideal places for the concentration of water and the starting of gullies. Cattle often follow one path day after day and if the path is developed up and down a slope the vegetation is soon destroyed, leaving the soil susceptible to erosion. Dead furrows, up and down the slope, lead to a collection of water in a narrow channel and with loose unprotected soil severe gullies may develop easily. Many farms, especially on sloping land, are faced with the problem of getting excess water safely away from farmsteads and other areas which have a high runoff. These discharge outlets, unless protected, easily develop into gullies.

A preferred method for gully control is to make some alterations in the direction of the surface runoff by using a diversion ditch to divert the water onto some stabilized surface. The diversion may be a temporary measure while the gully is being filled in, shaped, and reseeded.

A situation may arise where it is not feasible to construct a diversion at the head of a gully and no apparent means exists for handling the water other than down the gully. Under these conditions intensive measures are necessary to reduce the erosive action of the water. A common approach
A large gully now under control.
Many gullies become revegetated when the water is temporarily diverted and livestock are excluded.

is to dump in loads of stones, cut brush or old wire fencing. This haphazard action seldom gives the desired result. The water merely flows around the stones and gouges out an alternate path, or a great volume may accumulate behind an obstacle and when suddenly released create a worse gully than before. Experience has shown that the fundamental approach lies in reducing the speed of the water over the full length of the gully. This may be accomplished by a series of small check dams of logs, boards or sandbags placed across the gully at frequent intervals, with some provision for absorbing the energy of the water when it flows over the top of the dam. It is advisable to place an apron of large stones at the foot of the check dam.

Another method of control is generally referred to as “brushing”. Liberal amounts of straw are placed in the bottom of the gully. Brush or shrubbery, 8-10 feet in length, is placed on the top of the straw with the trunk end upstream. The final operation consists of securely anchoring straw and brush by driving in stakes. If willow stakes are used a small percentage, depending on soil moisture, will grow and eventually revegetate the gully. The straw and brush reduce the velocity of the water causing less erosion and allowing whatever soil may be in suspension to settle out and slowly fill in the gully.

Relatively large gullies, such as occur along some lake shores, may be classed as an engineering project. For adequate control the sides must be pushed in and given a more gentle grade, stabilized and planted. Such projects often require masonry or concrete structures to ensure the safety of buildings, roads, etc.

The proper time to control a gully is at the very beginning. A shallow gully one foot deep is easily filled in by plowing, etc., but the soil is very
A farm pond fenced from livestock.
Properly built farm ponds become a supply of water for livestock as well as providing recreation.

Loose and more subject to erosion. Prevention begins by careful planning. Avoid concentrating the water in a small channel by spreading it over a stabilized surface, or if the concentration cannot be avoided, provide a properly shaped grass waterway. Often strip cropping, greater use of hay and pasture or grass waterways will prevent gullying.

FARM PONDS
A farm pond is a real asset if constructed so that it will hold water even during the dry seasons. In dry seasons, winter or summer, there are many areas in Ontario which suffer a water shortage. Most common in this respect are the rolling clay plains. Properly constructed farm ponds could help this situation tremendously.

Farm ponds conserve water that may be used for:
- fire protection
- irrigation
- livestock
- recreation

In order that a pond be watertight there must be sufficient clay in the soil so that the base and walls of the pond will “seal”. A practical method which has been used is as follows: "Take a handful of the soil which will be at the bottom of the pond, wet it thoroughly and make a mud-ball. Slap it against a post and if it sticks go ahead and build the pond."

There are several types of farm ponds such as the dugout, the by-pass—which is near a permanent stream, the spring-fed type, the runoff, and the permanent stream pond. These are all discussed in more detail in a
bullets on "Farm Ponds" prepared by the Department of Planning and Development and reprinted by the Department of Agriculture. It is available from either Department or from the Agricultural Representatives Offices.

Assistance and advice in the layout of farm ponds is provided by the Agricultural Engineering Department of the Ontario Agricultural College.

WOODLOTS, REFORESTATION AND WILDLIFE

The interest in farm woodlots and reforestation appears to be greater in the past few years than at any time since the land was cleared. Many areas, which were cleared and cultivated for farm crops, have proven to be unsatisfactory for that purpose and are now being reforested. This applies particularly to sandy soils. There are also many thousands of acres of rough, hilly or stony soils which would produce good stands of timber but are now producing very scanty pasture. These latter soils are costly to reforest.

Some of these rough areas, which have scattered seed-producing trees, would reforest themselves if fenced from livestock. In many pastured areas thorn and wild apple trees have grown up and in some cases almost cover the ground. Where left undisturbed the thorn and apple trees are eventually crowded out by hardwood trees.

Where woodlots are pastured the soil becomes packed and the leaves of young saplings are eaten off. Then as the older trees are cut off the woodlot gradually thins out. Under this treatment the woodlot is not as productive as where the natural undergrowth is allowed to remain.

Farm woodlots are a source of fuelwood, lumber, posts, maple syrup, etc., depending on species. In addition they are important to a community
A woodlot protected from livestock.
When livestock are fenced from a woodlot, the young seedlings are allowed to form a protective cover.

as a windbreak, as an aid in the reduction of the rapidity of runoff, valuable in reducing the severity of floods, a shelter to birds and other wildlife, and enhance the beauty of the landscape.

Many bulletins on farm forestry are available on request from the Department of Lands and Forests or the offices of the Regional Foresters.

EDUCATION, RESEARCH AND EXTENSION

In this bulletin those factors influencing an applied land use programme for Ontario soils have been discussed. Suggestions and recommendations have been made in the full knowledge that a successful action programme must be accompanied by a sound research and educational programme. Recommendations and suggestions have been made for the best possible use and treatment of Ontario soils according to the knowledge that is available at the present time. Continuing research is an absolute necessity to provide answers that will reveal a better understanding of the capabilities and potentialities of our soils. Through continuing experimental and research work in all the fields of soil science a fuller knowledge of our soils will evolve.
A pastured woodlot.
Livestock has been allowed to graze through the woodlot destroying all young growth.

At the half-way mark of the twentieth century considerable interest is being shown in the need for improved land use and soil conservation. Much remains to be done in the educational field. No longer can the urban and rural resident think and act independently of one another. In conserving the soil we are conserving a great natural and national resource. Our people must come to realize that we must develop an intelligent public understanding of the value of natural resources in terms of the individual and of national life.

Accepting the fact that it is a myth to look upon Ontario as a land of unlimited and inexhaustible resources then let us use every means at our disposal to educate all people in the principles of better land use. Beginning with pupils in elementary schools let us impress upon their young keen minds the great need for a genuine interest and pride in our soil resources. The secondary schools, colleges, universities, and organized clubs and societies provide us with the opportunity to stress the principles of improved land use and soil conservation. Modern methods of communication and visual aids permit reaching the majority of our people through an educational programme. In developing a philosophy of land use we must not fail to emphasize that in practising good land use and soil conservation we are not only conserving a great natural resource but are also protecting a way of life, liberty and happiness.
The erosion plots near New Homburg.

Research is a necessary part of soil conservation if the best results are to be achieved. All the soil and water lost from each plot is caught in the tanks. From such research the effects of crops and methods of planting on soil and water losses are evaluated.

**TITLES OF REFERENCE READING**

**BOOKS:**

**PERIODICALS:**

**BULLETINS, PAMPHLETS, MAGAZINES:**
- Canadian farm magazines frequently carry articles on various phases of soil conservation.
- Technical bulletins may be obtained from the various colleges and Departments of Agriculture in Canada and the United States.
- Machinery companies publish various articles and loan films on phases of soil conservation.
- Various bulletins, pamphlets and extension circulars from the Statistics and Publications Branch, Toronto, Ontario.

**MOVIE FILMS:**
- Appropriate films are available through the National Film Board, machinery companies, Agricultural Representatives and the Ontario Agricultural College, Guelph.