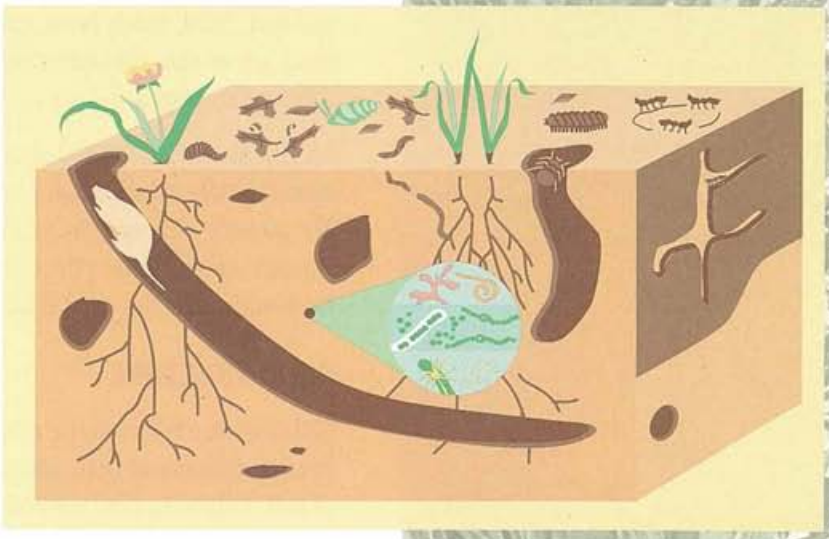
UNDERSTANDING THE BASICS

SOIL MANAGEMENT

The goal of every farmer is to have healthy, productive soils that have:

- ►Consistently high yields,
- ►Minimal erosion by wind or water, and
- ►Minimal losses of nutrients or pesticides.

The diagram in the sidebar shows what healthy, productive soil looks like.



Well-managed soil has a wide variety of living things.

On the surface:

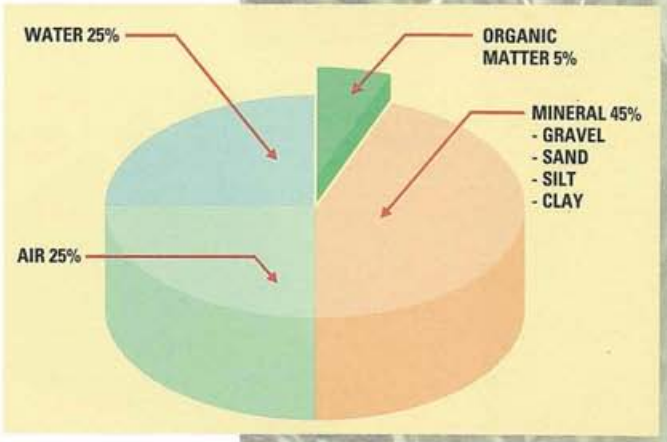
- ►Soil is covered with crop residue to protect it from wind and water erosion. The residue also slows moisture loss during the growing season.
- ►Water moves into soil soon after a rainfall and will not pond on the surface.

Below the surface:

- ►The soil favours root growth by having a proper mix of large and small pores.
- ►Organic matter helps hold moisture.
- ►The soil has sufficient fertility.
- ►Organic matter and soil life (bacteria, fungi, earthworms, insects, etc.) help to cycle nutrients.

Let's take a closer look at the make-up of soil. A shovel full has four parts:

- ►Mineral material.
- ►Air.
- ►Water.
- ►Organic matter.



Components of a well-structured loam soil.

TYPE	% SAND	% SILT	% CLAY
SANDY LOAM	58	30	12
SILT LOAM	20	60	20
LOAM	45	35	20
CLAY LOAM	28	36	36
CLAY	18	32	50

These are examples of soil texture. Percent of sand, silt and clay may vary within a texture.

SOIL TEXTURE

The largest part, about 45% of the volume, is mineral material. That is what you can see and feel. Sand, sandy loam, clay loam, clay, etc., describe soil texture. The proportions of sand, silt or clay determine soil texture. This table shows examples of percentages for five different soil types.

Ideally, about half the soil should be empty space, split evenly between water and air. The space in soils is called soil porosity. Two things affect porosity: soil texture and structure. The particle size, or texture, affects the amount of soil space because large particles, such as sand, create larger pores than small particles, such as clay. The ideal soil is based on loam which has the most equal portions of the three types of particles.

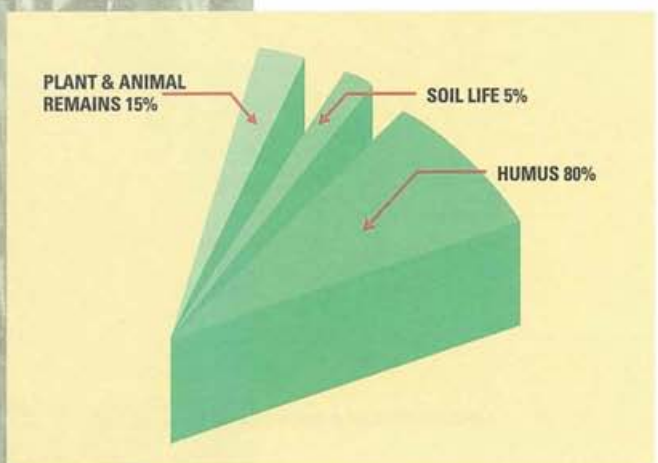
SOIL STRUCTURE

Soil structure refers to the mineral and organic particles being held together by sticky, binding substances (clay and decayed organic matter) to form larger clumps (aggregates) of soil. In healthy soil, these clumps stay together when wet and so resist breakdown by wind and water. This, in turn, reduces the chance of erosion and crusting.

The clumps should be variable in size with pores between them. This allows for root growth and air circulation. A clay soil with good structure could be more porous than a sandy soil. When a soil with good structure is squeezed in your hand, it readily crumbles. This type of soil is usually found in fence rows, woodlots and in forage fields.

The final part of the soil, about 5%, is organic matter. About 80% of organic matter is humus, a stable material, which does not break down easily. This part helps the soil store water and nutrients and reduces erosion. It also makes the soil attractive to soil life and easier to work (improves soil structure).

Another 15% of the organic content is the remains of plants and animals which can break down quickly. The rest is living creatures such as earthworms, insects, bacteria and nematodes.



Types of organic matter.

Earthworms and soil insects help to break down the larger pieces of plant residue so that bacteria can further break them down. This contributes to the nutrient cycle. The hundreds of kilometres/hectare of burrows that an earthworm creates, help root growth and improve drainage. Other soil life feeds on plant material and on each other.

Organic matter is a part of soil that you can affect. Excessive tillage and poor crop rotations speed the loss of organic matter. The table shows the impact of organic matter losses on different types of soil. Crop residues and manure combined with crop rotations help to maintain or improve levels of organic matter. These additions also help improve soil structure and increase the soil's ability to hold water. The nutrient balance will improve and with it, yield potential. Improved soil structure also increases air pore space and helps soils resist compaction.

THE EFFECTS OF LOSS OF SOIL ORGANIC MATTER

SOIL	INCREASED CRUSTING	SLOWER MOVEMENT OF WATER INTO AND THROUGH THE SOIL	INCREASED CHANCE OF SURFACE COMPACTION	INCREASED ERODIBILITY	DECREASED WATER HOLDING CAPACITY
Sandy materials at surface	–	–	–	–	S
Loamy surface material over sand or gravel	–	–	–	S	S
Loamy material with a high sand content	–	S	S	S	–
Loamy material with a high silt content	S	S	S	S	–
Clayey material at surface	S	S	S	S	–

S = Susceptible **– = Not Susceptible**

Tile drainage is an important part of soil management.

Drainage

Good soil drainage helps both the grower and the environment. It increases the air-filled spaces in the soil which, in turn, improves yield. Other benefits of good drainage include:

- ▸ Increased efficiency of fertilizers.
- ▸ More rapid warming of the soil in the spring.
- ▸ Improved soil structure.
- ▸ Reduced soil erosion because surface run-off decreases.

Some of the practices which improve drainage also improve other parts of the system. Examples are:

- ▸ Do not overwork the soil. Pulverizing the soil increases the risk of surface crusting which, in turn, increases run-off and makes it difficult for crops to emerge.
- ▸ Rotate row crops with cereals and forages. Root growth, especially with deep-rooted forages, opens up pores in the soil through which water can drain.

Soil Compaction

Soil compaction reduces the percentage of pore space in soil. It can cause problems with any tillage system. Compaction can occur near the surface or below the plow layer. Compaction below the plow layer is caused by loads in excess of five tonnes/axle. Surface compaction is caused by low organic matter, and excessive tillage.

In the case of surface compaction, tillage and sometimes, frost action, will break up the problem layer. When deep compaction occurs, the problem is much harder to fix. Root growth and wetting and drying cycles over a long period of time, may relieve the problem. Subsoiling is a Band-Aid solution at best and will likely cause more problems than it solves. The best remedy is prevention.

Reducing compaction risks:

Timing - use a crop rotation that spreads field operations over the full season.

Moisture - avoid field operations when the soil is wet at the working depth.

Control traffic - keep traffic patterns to limited areas of the field. Ridge till is ideal for keeping traffic off the row.

Reduce trips - reduce the number of trips and the size of the tractor.

Load distribution - keep axle weights below five tonnes/axle. Use trailers with tandem axles.

Narrow footprint - if possible, use tires with larger diameters rather than dual tires.

Radial tires - choose radial tires where extra traction is needed. These tires have up to 27% more surface contact than similar-sized biased ply tires.

4-Wheel drive vs. 2-Wheel drive - a tractor with 4-wheel drive distributes weight better between its axles than 2-wheel drive tractors.

SOIL SUITABILITY

When deciding what tillage system is best, you should consider the type of soil on your farm. Suitability depends on soil texture and drainage characteristics.

Soil Moisture

As more residue is left on the soil surface, less water escapes to the air and soil moisture may increase. Keeping moisture in the soil is good for light textured soils such as sands and sandy loams. Increased residue aids in moisture conservation. On heavier-textured soils such as clay and clay loam, increased soil moisture may pose a problem in early spring by delaying planting.

Reduced tillage tends to work best on well-structured, well-drained soils. The moldboard plow may be the best option on poorly-drained soils as they need working to speed the drying process. Advocates of ridge till report that ridged soil dries quickly and allows more timely planting. Ridge tillage may, therefore, be an option for reducing tillage on poorly-drained soils.

Texture

Texture and drainage go hand-in-hand when looking at soil suitability for a tillage system. Lighter textured soils such as sands and sandy loams work well in no-till and mulch till systems. Heavier, poorly-drained soils such as clay and clay loams need more tillage for soil drying.

Compaction can occur near the surface or below the plow layer.

Protection from Erosion

We know that some soils are not as likely to erode as others and are best-suited to the moldboard plow. Examples are clay and clay loam soils that are relatively flat. Other soils, particularly loamy and sandy soils with long or steep slopes, are very likely to erode. These soils need residue to protect them from water and wind erosion. Fortunately, these are the soils that are most suitable for no-till or mulch tillage systems.

The table (below) offers general guidelines for soil suitability for various tillage systems. If your soil structure is not average, then results for the tillage system may vary.

How to Use this Table

1. Use your county soil map to help you determine soil texture and natural drainage.
2. Compare the tillage system suitability ratings for your soils.
3. Determine the most suitable options for your soils.

SUITABILITY OF TILLAGE SYSTEMS ON ONTARIO SOILS

TEXTURE	DRAINAGE	YIELD*		EROSION		SUITABILITY RATING					
		MULCH TILLAGE	*NO-TILL*	*WATER*	*WIND*	*CONVENTIONAL*		*MULCH TILLAGE*		*NO-TILL*	
						FALL	*SPRING*	*FALL*	*SPRING*	*FALL*	*SPRING*
SANDY	Well	E	I	S	S	5	4	3	2	1	1
	Imperfect	E	I	H	S	4	3	2	1	1	1
	Poor	E	I	M	M	4	3	3	2	3	3
LOAMY	Well	E	E	S	H	3	3	2	1	1	2+
	Imperfect	E	E	H	M	3	3	2	2	1	2+
	Poor	E	E	M	L	1	2	2	3	2	4
CLAY LOAM	Well	E	D	H	M	3	3	1	2	1	3+
	Imperfect	E	D	M	L	2	3	3	3	2	4+
	Poor	E	D	L	L	2	3	3	4	3	4
CLAY	Well	D	D	M	M	2	3	3	4	1	4+
	Imperfect	D	D	L	L	2	4	4	4	2	4+
	Poor	D	D	L	L	3	4	4	4	3	4

YIELD POTENTIAL
I = Increase
E = Equal
D = Decrease
*** Compared to moldboard plow**

EROSION POTENTIAL
S = Severe
H = High
M = Medium
L = Low

SUITABILITY RATING
1 = Very Suitable
2 = Well Suited
3 = Moderately Suited
4 = Not Well Suited
5 = Not Recommended

+ Coulters on planting equipment to till a narrow strip of soil will improve rating.

Suitability Rating

The suitability rating combines yield potential, need for erosion control and relative ease of management of the tillage system on that soil (timeliness, effective equipment operation, an adequate and functioning tile drainage system, etc).

For example, well-drained sandy soil can be expected to yield as much with mulch tillage as under a conventional system. No-till could result in higher yields. Potential for wind and water erosion is severe. This type of soil is considered very suitable for no-till, both spring and fall, well-suited for spring chisel plowing, moderately-suited for fall chisel plowing and unsuitable for moldboard plowing.

RESIDUE MANAGEMENT

Crop residue is beginning to be recognized as a resource rather than a nuisance. Residue is an important source of organic matter. If it is left on the soil surface or worked into the top few inches of the soil, organic matter levels can be maintained or increased. This helps improve soil structure and leaves the soil more manageable.

Residue management is an important part of farming operations. In the past few years, farmers, researchers and extension personnel have come to recognize that careful management of residue is the most cost-effective means we have of reducing erosion.

RESIDUE

- ►Protects the soil surface from the impact of rain.
- ►Reduces soil erosion.
- ►Reduces soil crusting and sealing.
- ►Adds organic matter to soil.
- ►Helps rain to soak into the soil.
- ►Reduces the loss of soil water to the air.

CROP YIELDS AND RESIDUE

All crops yield differently and supply various amounts of residue. Generally, higher-yielding crops produce more residue. Remember this when planning a residue management program for your farm.

The table (sidebar) shows the estimated straw to grain ratios for selected crops. For example, if a winter wheat crop yields 70 bushels/acre, there would be about 70 bu/ac x 60 lbs/bu x 1.7 or 7140 pounds/acre (8,000 kg/ha) of residue. This exceeds 95% residue cover. Of course, this number is an estimate and will vary with hybrid/variety, weather and the amount of straw removed at harvest.

ESTIMATED STRAW TO GRAIN RATIOS FOR SELECTED CROPS

CROP	STRAW: GRAIN RATIO
BARLEY	1.5:1
CORN	1.0:1
OATS	2.0:1
RYE	1.5:1
WINTER WHEAT	1.7:1
SPRING WHEAT	1.3:1

RELATING RESIDUE COVER TO WEIGHT OF RESIDUE

RESIDUE COVER %	CORN STALKS KG/HA	(LBS./AC.)	CEREAL STRAW KG/HA	(LBS./AC.)
20	700	(625)	400	(360)
30	1000	(890)	500	(450)
40	1500	(1340)	800	(715)
50	2000	(1780)	1000	(890)
60	2500	(2230)	1300	(1160)
70	3400	(3035)	1700	(1520)
80	4300	(3840)	2200	(1960)
90	5800	(5175)	3000	(2680)
95	7800	(6960)	4000	(3570)

Spread residue evenly behind the combine to eliminate windrows.

GOOD RESIDUE MANAGEMENT STARTS WITH HARVEST

To get good erosion control and, more importantly, to make tillage and planting easier, residue must be spread evenly behind the combine rather than windrowed. An even spread pattern protects more soil and reduces plugging problems with tillage and planting equipment.

Large-capacity combines with wide heads make even spreading of residue more difficult. Ideally, combines should be equipped with straw and chaff spreaders capable of spreading residue evenly over the full working width of the combine. Some combines may also require the addition of a shredder.

Disadvantages to windrows of straw or chaff left in the field are:

- ▸Tillage implements become plugged with residue.
- ▸Planting equipment may need modification to operate properly.
- ▸Seed openers on planting equipment may push residue into soil (called hairpinning) which limits soil/seed contact.
- ▸Certain types of residue excrete toxins as they decompose. These toxins may sicken or even kill the next crop (called allelopathy). Heavy accumulations of residue in the crop row may increase the chances of this problem. The toxins are most likely to be harmful when planting corn into corn or cereal stubble.
- ▸Heavy residue insulates the soil and reduces the warming effect of the sun. Lower soil temperatures may slow seedling germination and emergence.
- ▸Windrows of residue can intercept herbicides and prevent uniform application rates over the soil surface.

An even stand of soybeans emerging through wheat residue.

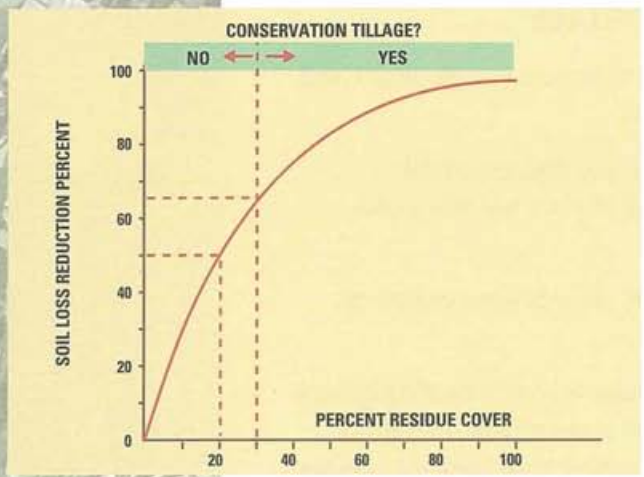
RESIDUE MANAGEMENT OPTIONS IN REDUCED TILLAGE

- ▸Grow hybrid/varieties with good stalk strength. This will make sure that the plant is still standing at harvest so the combine head can be set higher.
- ▸For small grains, set the cutting head on harvest equipment as high as possible without sacrificing yield. That way, more of the stalk is left in place and less passes through the combine.
- ▸Maintain an even speed when combining to avoid residue pile-ups when equipment slows. If you have to stop, back up to spread the residue.
- ▸Speak to your dealer to find out what changes you can make to your harvest equipment to improve the spread pattern for chaff and straw. Add-on equipment is available for most large-capacity combines. Before modifying your combine, make sure the changes will not alter the working capacity, endanger the operator or damage the combine.
- ▸Modify planting equipment with coulters or trash whippers to move crop residue out of the row area. This helps eliminate any toxic effects and clears the row so soils warm up.

Knowing the crop you will be harvesting and the amount of residue you may have to deal with gives you an idea of the options to consider. A good residue management program can:

- ▸Maintain or build soil organic matter levels.
- ▸Improve soil structure.
- ▸Conserve and recycle nutrients from previous crops.
- ▸Reduce soil losses due to erosion.
- ▸Reduce soil moisture losses due to evaporation.

A residue management program will reduce soil losses.



The examples show that 20% residue cover will reduce erosion by 50% as compared to a clean tilled field, while residue cover of 30% can reduce erosion by as much as 65%.

EROSION AND RESIDUE MANAGEMENT

When considering the best residue management program, examine what equipment you have and take a look at the average soil losses on your fields. Fields with high levels of wind and water erosion should have the most residue left on the soil surface. The diagram to the left shows how 20% residue cover reduces soil loss. As residue cover increases, the amount of soil saved increases too. When implementing a tillage system to reduce erosion, aim for at least 30% residue cover in order to reduce soil loss by 65% over a clean-tilled field.

RESIDUE COVER AND SOIL LOSS REDUCTION FOR VARIOUS TILLAGE SYSTEMS

RESIDUE TYPE	TILLAGE SYSTEM	% RESIDUE COVER	% EROSION REDUCTION FROM MOLDBOARD PLOW
CORN	Moldboard plow, 2 cultivations, plant.	7	–
	Chisel plow, cultivate, plant.	35	74
	Disc, plant.	21	72
	Ridge till plant.	34	86
	No-till plant.	39	92
SOYBEAN	Moldboard plow, 2 cultivations, plant.	2	–
	Chisel plow, cultivate, plant.	7	32
	Disc, plant.	8	26
	Field cultivate, plant.	18	46
	No-till plant.	27	64
WHEAT	Moldboard plow, cultivate, plant.	9	–
	Chisel plow, cultivate, plant.	29	72
	No-till plant.	86	96

The table shows the amount of residue you might expect after various crops under different tillage systems. It is important, both economically and to reduce erosion, to keep the number of trips over a field to a minimum. Crops, such as soybeans and field beans, leave very little residue and need very little tillage to prepare the ground for the next crop. In these cases, one or two light cultivations may prepare a good seedbed or no-till may be an option.

On the other hand, corn stalks and wheat straw leave the soil surface completely covered with residue. Too much residue may slow soil warming and drying to the point where planting is delayed and yield affected. High residue levels can also interfere with planting equipment, particularly in a mulch tillage system where the ground is loose beneath residue. If you are working the ground, aim to keep between 30 and 60% of the soil covered with residue.

You may want to modify your equipment to handle more residue. Be aware of your rotation and what crops are following each other. If soil warming and drying are problems, follow a rotation that alternates between high residue and low residue crops, such as corn and soybeans.

Best Management Practices for Residue Management

- ►Spread residue evenly behind the combine to eliminate windrows.
- ►Know the amount of residue you will be dealing with by checking crop selection and tillage system.
- ►Choose residue levels that will reduce soil erosion.
- ►Use tillage equipment matched to your soil type, the amount of residue and farming needs.
- ►Modify planting equipment to handle residue left on the soil surface.
- ►Residue left on the soil surface or worked into the soil will maintain or increase organic matter.

Good residue management means even emergence.

CROP ROTATION AND COVER CROPS

CROP ROTATION

Rotating crops is a best management practice because:

- ▸It reduces the risk of crop disease.
- ▸It reduces the population of pests specific to one crop.
- ▸It will increase the yields from a crop grown as part of a rotation compared to continuous cropping.
- ▸It can reduce soil erosion and run-off.
- ▸It spreads the workload for planting and harvesting over a longer time period as seasons vary with each crop.
- ▸It can complement each crop under rotation. For example, growing legumes provides nitrogen for non-legumes. And, alternating crops that successfully compete with weeds will reduce pressure on crops that do not.
- ▸By increasing crop yields and reducing inputs, profits on the combined crops can be higher.
- ▸Growers can stagger planting and field operations to avoid time pressures.
- ▸Special features of the farm can be taken into account, such as water resources, the nearness to markets and processing plants, special skills and labour availability.

At the same time, there are a few precautions that should be taken:

- ▸Planting times may conflict with critical phases of other crops such as weed control or an application of fertilizer that will boost yields.
- ▸New management skills may be needed.
- ▸Problems in one crop may make it difficult to manage another effectively.

Crop rotations can increase net returns.

The yields of corn and soybeans will improve if they are rotated with each other. By including a cereal in the rotation, yields and erosion control are improved. Adding a forage hay crop to the rotation improves yields and soil conditions even further.

If you are a cash cropper and cannot find land to put into forages, see if you can make a deal with a livestock-producing neighbour. That way, you have a market for the forage grown and get the benefits in your rotation.

COMMON CROPS AND THEIR PROS AND CONS IN ROTATION

CROP	BENEFITS/CHARACTERISTICS	PRECAUTIONS
ALFALFA, CLOVERS	• Fix nitrogen for non-legumes. • Deep rooting opens soil pores. • Reduces soil erosion. • Planting is in spring, either alone or inter seeded into a cereal, or in summer following a cereal harvest.	• High removal of potassium. • May be difficult to market. • Poor growth of alfalfa on acid soils. • Alfalfa difficult to establish on poorly drained soils.
GRAIN CORN	• Produces high levels of residue which adds organic matter. • Tolerant to broad range of herbicides for weed control. • Early spring planting, later fall harvest.	• Potential disease problems in wheat following corn. • Late harvest does not allow timely planting of fall-seeded crops or tillage.
SOYBEANS	• Yields improve after corn. • Herbicide selection offers good control of grass weeds. • Later spring planting allows quackgrass control before planting. • Early fall harvest allows planting of fall seeded crops. • As a legume, it fixes its own nitrogen but does not leave an excess for the next crop.	• Preparing a fine seedbed will destroy soil structure and the small root system will do little to improve it. • Slow to cover ground with vegetation, especially when grown in rows.
WINTER CEREALS	• Planting season is in the fall which shifts workload, reduces amount of land to till in fall, provides winter cover. • Harvest during summer. • Extensive root systems improve soil structure. • Competition with weeds is strong so cost of chemical weed control is low.	• Large volumes of straw can form mat on ground after harvest. • Rye and wheat stubble may be toxic to corn crops and reduce yields.
SPRING CEREALS	• Planting season in early spring, before corn. • Harvest in summer. • Similar properties to winter cereals.	

Spring cereals make effective winter cover crops.

COVER CROPS

Effective use of winter cover crops is an important best management practice. Erosion potential of fall-plowed soil is high and cover crops can dramatically decrease soil loss. Smaller losses preserve the soil as a resource and maintain its nutrients. Erosion control by cover crops reduces the contamination of nearby watercourses.

Cover Crop Benefits

►Hold soil in place, preventing surface loss of nutrients or pesticides.

►Add organic matter and improve soil structure.

►Legume cover crops may provide nitrogen for next crop.

►Fall cover crops may hold soluble nutrients, and keep them from leaching.

►Vigorous cover crops will suppress weed growth.

Using Cover Crops

►Manage cover crops to use existing equipment as much as possible.

►Time planting to allow sufficient growth, but late enough that cover crop does not go to seed; e.g. red clover should be interseeded into cereals, or drilled in immediately after wheat harvest.

►Spring crops grown as fall cover have the advantage of dying over winter and don't need further control.

►Choose cover crops that will not interfere with next year's crop growth e.g. Buckwheat can carry white mould to next soybean crop. The best rotation alternates broadleaves & grasses.

►Cover crop control must be carefully timed, especially in no-till.

- ▷ Red clover should be killed in fall.
- ▷ Rye will grow from 30 centimetres (1 foot) to 1.5 metres (5 feet) in height in only a few days, if left uncontrolled and weather conditions are right.

►Only plant a cover crop you know you can get rid of.

►Use the cheapest cover crop that will do the job - most cover crop economic benefits are long-term.

NUTRIENT MANAGEMENT

Plants need 20 different nutrients for growth and seed production. Some are required in very small amounts while others make up the largest part of the plant. The most common elements in plant tissue (carbon, hydrogen and oxygen) come from the air and water. Nutrients like calcium, magnesium and sulphur are common in Ontario soils; although they are used by plants in fairly large amounts, they are not usually considered in fertilizer programs.

Primary nutrients (nitrogen, phosphorus and potassium) are the elements that most often have to be increased for crop growth. Plants use all three in large quantities. These elements make up the largest part of the farmer's fertilizer bill.

Micronutrients are used by plants in tiny amounts. They should be added when the plant shows signs of deficiency or when a soil test shows they are necessary.

THE DYNAMICS OF SOIL AND FERTILITY

Soil fertility refers to the levels of nutrients available to growing plants. Some nutrients in the soil are not available to plants for the following reasons:

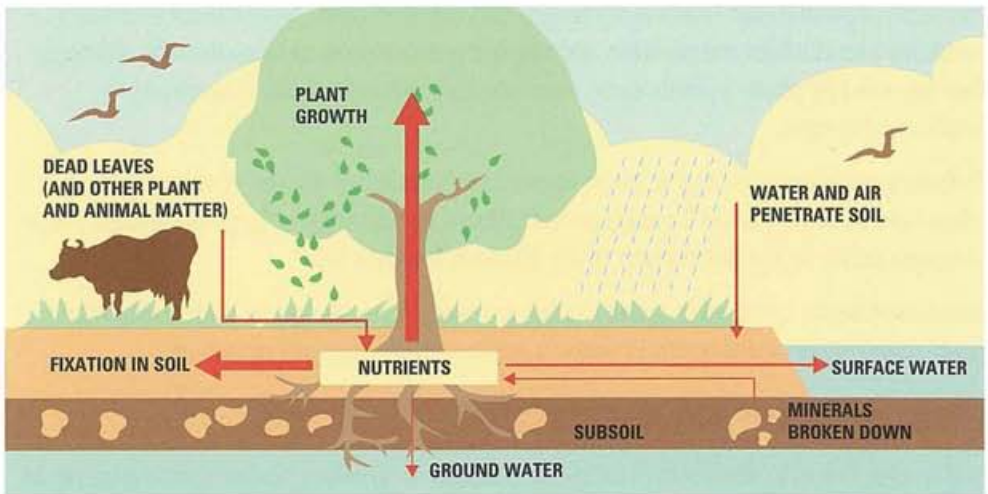
►They are in a chemical form that the plants cannot use.

►They are chemically bonded to soil minerals or clay particles.

►They are in the organic matter that has not yet decomposed.

Over time, these nutrients are made available through weathering and the actions of life forms in soil.

Erosion carries away soil and the nutrients that are in it. This particularly contributes to a loss of nutrients bound to the soil, such as phosphorus. Run-off carries sediment and dissolved nutrients downstream into watercourses. The diagram shows how gains and losses of nutrients occur.



A simplified nutrient cycle.

The removal of crops takes nutrients from the soil too. These lost nutrients must be replaced with the addition of manure or commercial fertilizers. Returning crop residues to the soil helps lower nutrient loss. Returning nutrients to the soil completes a cycle sometimes referred to as the nutrient budget.

The rate of nutrient availability is influenced by the soil's level of acidity or alkalinity. The most suitable soil pH for many crops is near neutral (pH 7). If the pH level is outside the range of six to eight, nutrient availability will drop.

Only part of the phosphorus or potassium added as fertilizer or manure is available to this year's crops. They fix onto clay particles and soil minerals and are gradually released by microbial and chemical processes. Increasing the total content of phosphorus and potassium will increase the amount of nutrient release but care must be taken to avoid excessive application. Excess can hurt plant growth and contaminate run-off.

Nitrogen in the soil is part of a different cycle. There is lots of nitrogen in the air but a plant cannot use it in that form. It must be converted, either by legumes or in the manufacture of nitrogen fertilizer, into the ammonium or nitrate form which plants can use.

Nitrogen in the ammonium form can bind to soil particles. It can also be converted to nitrate, or absorbed by soil microbes. Plants can use ammonium nitrogen, but most is absorbed as nitrate. Unused nitrate can be lost by leaching as water moves through the soil, or it can be lost to the atmosphere.

Legume crops fix their own nitrogen from soil air with the help of bacteria. They do not require much nitrogen in the soil. Legumes, then, can capture nitrogen in the air and release it when their residues decay. Forage legumes can provide considerable nitrogen to the next crop, but most of the nitrogen from grain legumes is removed at harvest.

Nitrogen efficiency improves significantly if fertilizer is placed properly or if it rains soon after application. Because nitrogen, including that in manure, is so easily lost, it is best to inject it or work it into soil immediately after application.

Organic Matter

Organic matter within the soil is an important factor in soil fertility. As plant residues decay, the plant's structure breaks down into chemical building blocks. This releases nutrients into the soil solution and to growing crops. Organic matter also allows the soil to hold nutrients. If organic matter is not replaced by adding crop residues or manure, the fertility of the soil will decline.

SOIL TESTING

Soil testing is the only way of finding out what is in your soil. Anything else is just a blind guess. The process estimates the amount of a particular nutrient which a plant could use from that soil and calculates the amount of fertilizer that should be added for crop growth. Tests for phosphorus, potassium and pH can be taken at any time of the year with only minor changes in soil test levels. Nitrogen tests, though, must be taken at planting time because levels vary so much over the growing season.

The key to any soil testing program is taking a sample which reflects the field. A poor sample cannot give you accurate information. The following points will help make soil tests effective:

1. Take enough soil cores for the sample. At least 20 are required for fields up to five hectares (12 acres) in size, more for larger fields.

2. Take enough samples from the field. A sample is required for every 10 hectares (25 acres). If the field is larger, divide it into sections and take a sample per 10 hectares (25 acres). For phosphorus, potassium and pH, samples should be taken to a depth of 15 to 20 centimetres (6 to 8 inches) below the surface. Nitrate samples can be taken to a 30 centimetre (12 inch) depth but 60 centimetres (2 feet) is preferable.

3. Spread the core sites evenly across the field. The easiest way to do this is to zig zag up one half of the field and then back down the other half.

4. Many fields have areas that yield well and others that do not. This may be a result of soil type, drainage or past fertilizer and manure applications. Crops remove different

amounts of nutrients as the yield varies. If a crop on part of the field looks different or if an area has been treated differently with fertilizer, manure or lime, sample it separately. Do this even if the area is small.

5. If you plan to treat poor-yielding areas separately, test them separately. This is the best approach since it prevents over-application in high-yielding areas. Making a map of the poor areas will help in treatment.

6. Avoid sampling bands where fertilizer has been applied recently, dead furrows, areas adjacent to gravel roads, or where manure, compost or crop residues have been piled.

7. Try to take soil samples at the same time each year. Generally soil test values will give you the amount of nutrients to apply for maximum economic yield.

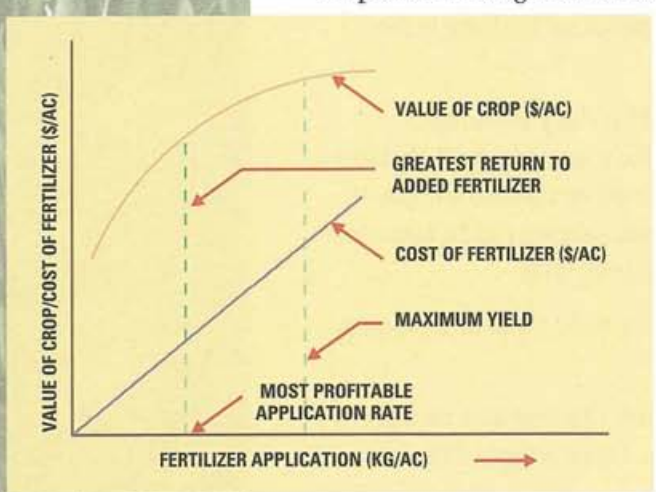
NOTE: Follow the directions given by OMAF on soil sampling kits. These are also found in OMAF Publication # 296 Field Crop Recommendations

MAXIMUM ECONOMIC VS. ENVIRONMENTAL YIELDS

The maximum yield of a crop is reached when crop needs are well met. However, the maximum economic yield is the point at which the crop returns maximum profit. The graph shows that the two yields are often different.

As crop inputs rise, crop yields rise. Yields flatten out when the maximum yield is reached then begins to drop as excessive nutrients reduce yields. As the yield rises so does your gross income. The maximum economic yield occurs when the difference between expenses and gross income is greatest.

Maximum environmental yield occurs when all available nitrogen is used by the crop rather than left in the soil. Left-over nitrate nitrogen could leach into groundwater or run off into surface water. In most cases, maximum economic yield is also the point where the plant is making the best use of the fertilizer. This is also the maximum environmental yield for nitrogen. There may be some exceptions on very sandy soils. Further research is needed.



This graph shows the maximum economic yield for fertilizer application to a crop.

FERTILIZER TYPES AND APPLICATION TECHNOLOGY

FERTILIZER TYPE	SURFACE BROADCAST (6)	BANDED (5) AT PLANTING	KNIFED UNDER SOIL SURFACE (5, 7)	APPLIED WITH ROW CROP CULTIVATOR (5, 7)
ANHYDROUS AMMONIA (GAS)	No	No	Yes (1)	Possible
AQUA AMMONIA (PRESSURIZED LIQUID)	No	No	Yes (2)	Yes (2)
28%, 32% UAN SOLUTIONS (LIQUID)	Yes (3)	No	Yes (4)	Yes (3)
AMMONIUM NITRATE (DRY)	Yes	Yes (8)	Possible	Possible
UREA (DRY)	Yes (3)	No	Possible	Possible
10-34-0 SOLUTION AND OTHER LIQUID MIXTURES	Yes	Yes (8) (most common)	Possible	Possible
DRY PHOSPHATE MATERIALS	Yes	Yes	No	No
DRY POTASH MATERIALS	Yes	Yes (8)	No	No
DRY MANURE	Yes (3)	No	No	No
LIQUID MANURE	Yes (3)	No	Yes	No

NOTE:

1. Anhydrous ammonia is a gas and must be knifed into soil to prevent escape into the air.
2. Aqua ammonia is extremely volatile. It should be incorporated by knifing in or with applicators behind tillage teeth.
3. Nitrogen can escape into the air if not worked in soon after application or if rainfall is delayed, especially in warm weather.
4. Spoke-wheel injection will disturb soil the least for no-till systems. It is intended for side-dress application after the plant has emerged.
5. Application system is suitable for reduced tillage systems where broadcast fertilizer will not be worked in.
6. Applied before the seedlings are up.
7. Can be applied before the seedlings emerge or at the side after they are up.
8. Watch safe rates close to seed.

Best Management Practices for Nitrogen Applications:

- ► Apply nitrogen at the time when the crop requires it most. For corn, this means side-dressing most of the nitrogen when the corn is about knee-high. For cereals, this will be at the early tillering stage.
- ► Where possible, work in or inject nitrogen fertilizers to minimize loss to the atmosphere. As much as 30% of the nitrogen in soil-applied urea can be lost to the atmosphere in a week.
- ► If you must apply nitrogen to the soil surface, use a form that cannot be lost. This is especially important if there are high levels of crop residue on the surface. Ammonium nitrate or UAN are less subject to loss to the air than urea. No form of surface-applied nitrogen will be effective if rain does not wash it into the soil.
- ► Adjust rates to reflect the contribution of manure and legume plowdowns.
- ► Avoid surface applications during hot, humid conditions.

Broadcast fertilizer is a low cost method of application.

FERTILIZER PLACEMENT – HOW AND WHY

Fertilizer is added to the soil in one of two ways: broadcast or banded. Although there are variations within each, the reasons for choosing one type over the other remain the same.

Broadcast

Broadcast fertilizer, as the name suggests, means spreading it over the whole soil surface, usually with a truck or tractor-drawn spreader. Fertilizer is usually mixed into soil by tillage, which helps improve efficiency rates. Nutrients may be lost if not worked in properly or may be tied up if soil fertility is low.

Broadcast fertilizer:

- ►Allows application of large quantities of fertilizer quickly.
- ►Requires less labour, is relatively low in cost, and there is little chance of fertilizer burn.

Banded

Banded fertilizer is applied in a narrow strip below the soil surface. This may be done at planting time or side-dressed after the crop is up, depending on the particular nutrient. Banded fertilizer is usually more efficient because it is placed where, and timed when, the plant can use it best. Efficiency is not affected by the form of fertilizer, whether solid, liquid or gas.

The following considerations apply to banded fertilizer:

- ►Allows starter fertilizer to be applied with or near the seed, giving an early boost in cool soils.
- ►Safe rates of fertilizer decrease as you get nearer the seed.
- ►Banded fertilizers are not tied up as quickly by the soil as broadcast fertilizers. This may give a yield boost in soils with low test results but makes no difference to soils with high fertility levels.
- ►The choice between liquid and granular fertilizers depends on cost and convenience. Both are equally safe and equally useful to the plant.
- ►Side-dressed nitrogen is more efficient than broadcast because it is placed close to where the roots are, at a time when the crop can make the best use of it.

SPECIAL CONSIDERATIONS FOR MANURE

In most of Ontario, manure is applied to large areas of farmland. Manure is a valuable resource that contains all nutrients. Properly managed, it can supply nutrient requirements and add organic matter to the soil. However, excessive rates that exceed crop needs are hazardous to the environment. They increase the risk of nutrients escaping into surface and groundwater.

Photo courtesy of Loyal Equipment Ltd.

Tractor-mounted manure injection into high residue corn.

Best Management Practices for Nutrient Management:

- ►Match nutrient requirements to crop needs and soil test levels. If a certain crop does not require much of a nutrient, don't overapply it. For example, if legumes do not need nitrogen, don't feed it to them. Put them into a rotation to benefit other crops that follow. Recognize that excess nutrients are potential pollutants.
- ►Include the contributions from previous crops and manure when deciding how much commercial fertilizer is needed.
- ►Complete regular soil tests for phosphorus, potassium and pH. Test for nitrogen when growing corn.
- ►Reduce soil erosion to eliminate phosphorus and organic matter losses.
- ►Maintain organic matter levels with manure, cover crops and residue to help cycle nutrients.

Best Management Practices for Manure Application:

- ► **Conserve the nutrient value of manure through proper storage and application.**
- ► **Avoid over application of manure to protect surface and groundwater from excessive nutrient loading.**
- ► **When applying manure, the rates of other fertilizers should decrease.**

NOTE: For further information, see the booklet on Livestock and Poultry Waste Management.

Scout fields regularly for weeds, insects and diseases.

PEST MANAGEMENT

Pest management includes the control of plants, insects or diseases that compete with a crop and restrict its growth. The best management practice is to prevent problems by using crop rotation and maintaining good soil fertility and structure. After all, a healthy, well-fed plant is best able to fight off pests.

Weed control aims to reduce nuisance plants to the point where the cost of damage to potential yield is less than the cost of control.

It is necessary to be balanced in your approach. Best management practices reduce the use of pesticides to the absolute minimum for your tillage system.

WAYS TO REDUCE PESTICIDE USE

Grow Crops Aggressively to Compete with Weeds.

Plant small grains and small-seeded legumes early so that they can become established and successfully compete with weeds that germinate later.

Narrow row spacing and increased planting densities increase the crop's ability to compete.

Drill soybeans, 18 centimetre spacing (seven inches), instead of planting in rows to increase their competitive edge. This practice will not allow cultivation and tramlines may be necessary to avoid tramping the crop when applying pesticides after crop emergence. However, Ontario research says that tramping the crop does not necessarily reduce yields if done early.

Use Cover Crops and Companion Crops as Biological Weed Control.

Cover crops compete with weeds and can provide a late season way to control weeds. Crops such as rye contain chemicals that retard weed germination and growth. Cover crops can compete with the main crop and reduce yields. Careful management is necessary.

If you seed forages into cereal nurse crops, the need for herbicides will be reduced. The cereal reduces competition from annuals such as ragweed and foxtail.

Scout Fields for Weed Problems Carefully and Regularly.

Identifying weed problems early may mean reduced needs for herbicides. Sometimes, weeds can be controlled by cultivation or rotary hoeing.

Walk all areas of a field to see which weeds need control and the weed's stage of growth. Sometimes, smaller weeds are hidden under taller ones. Sometimes, the problem is localized and requires only spot treatment. Make sure you treat weeds when they are at the proper stage of growth for control.

Keep a notebook or field maps showing weeds location when you are doing field operations. Record areas with problem weeds such as bindweed, quackgrass or Canada thistle. Treat the areas before weed growth gets out of hand.

Evaluate pesticide performance. If control is good, consider using a lower, recommended rate next time.

Rotate your Crops.

Changing the crop environment keeps weeds, insects and disease in check. Alternate crops that can successfully compete with weeds with those that cannot. Rotate crops that require different types of herbicides. Include crops that need little or no herbicide, such as cereals or pasture, in your rotation. This will help reduce the pesticide load on your soil.

Rotate the Pesticide Family.

Change the family of your insecticide each year. Insects can develop resistance to specific insecticides after repeated use.

Change the herbicide family too. By using the same herbicide over and over, weed problems will increase. Weeds that are resistant to the herbicide increase in number. For example, repeated use of atrazine has increased populations of triazine-resistant weed species such as Lamb's-quarters, Common Ragweed and Redroot Pigweed.

Make sure that you change the family of pesticides not just the chemical or brand. For example, alternating between atrazine and metribuzin (Sencor/Lexone) will not change family types. Both are triazine herbicides.

Keep Accurate Records.

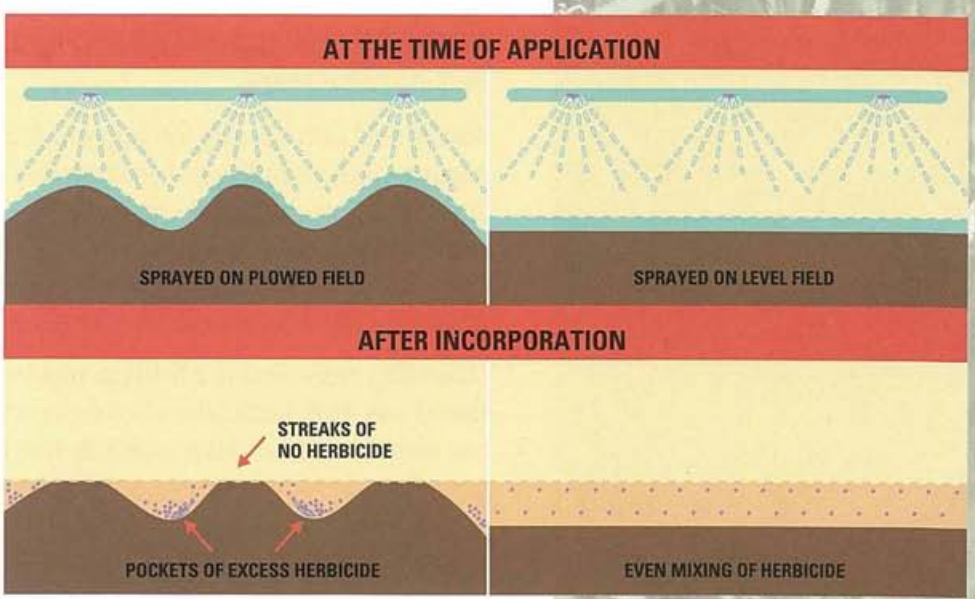
Record the date, rate, location, weather conditions (include wind speed, temperature, cloud cover, relative humidity), soil moisture, growth stage of crop and growth stage of weeds/insects/disease. Record the dates and amount of rain after application. Records will help you evaluate pesticide use and understand any problems afterwards.

Working Herbicides into Soil Requires Extra Management.

Some herbicides are more effective if incorporated. This also reduces loss to run-off because the herbicide is placed below the soil surface.

When you are incorporating herbicide, it's important to spray onto an even surface so that distribution is even. A rough surface may concentrate herbicide in valleys and clear it from ridges as shown in the diagram (below).

Read the product label carefully to know what type of incorporation is required. Some herbicides (Treflan and Edge) are immobile in the soil. While this is good for the environment, it becomes very important to thoroughly mix the soil so that herbicides are at the proper depth. Sprayed pesticide only goes half as deep as the depth of tillage on the first pass.



Apply pre-plant incorporated herbicides to level fields.

Use Tillage to Control Weeds.

When you till to create a seedbed, weeds are controlled mechanically. Weeds and crops get an even start. Tillage can stimulate some weeds, as can warm soil temperatures in spring. Apply a soil-active herbicide at planting time to destroy the major weed flush.

With careful scouting, timely tillage operations and good weather, weeds can be controlled after planting. Use a rotary hoe to kill weeds before they emerge. After emergence, this is not effective.

Blind harrowing will also control weeds before they emerge. Drag the harrows across the field before weeds and crops emerge. This disturbs and kills shallow, germinated weeds without disturbing deeper crop seeds. This does not work after weeds emerge.

Inter-row cultivation also controls weeds. Effectiveness depends on the skill of the operator, the machine and careful adjustment.

Wet soil conditions can keep the tractor off the fields and allow weeds to grow beyond the point where mechanical control is effective. Post-emergent herbicides applied at this time are also ineffective. This is why some growers continue to include pre-emergent herbicides in their systems.

Band Herbicide Over the Row.

Banding herbicide over the row before crops emerge reduces the field area treated and the amount needed. Areas between rows can be treated with tillage or herbicides applied after crops emerge.

Use Herbicides Applied after Crop Emergence rather than Soil-Applied Ones.

Waiting until weeds are up will help you determine what needs to be controlled. This requires careful scouting and good weather at application. It's more demanding on the farmer too. This choice will only work if the right type of pesticide is available for the crop and will depend on its cost.

Consider the Economic Threshold of Control.

Controlling every weed in a field can require high and expensive rates of herbicides. You should only apply herbicides when the benefit from controlling the weeds will exceed the cost of the herbicide. This is especially true for post-emergence herbicides.

To complicate the decision, weeds that emerge from soil that has been treated with herbicide are often less competitive than weeds from untreated fields. The other factor to consider is the number of weed seeds produced. If the weed has potential to produce a lot of seeds (i.e. velvet leaf) in a field with no history of that weed, control is warranted. If there are only a few weeds, manual pulling is recommended.

Keep in Mind that Weeds Appearing late in the Season do not Reduce Yields as Much.

The critical time for weed removal is when the crop needs to be protected to prevent loss of yield. For corn in Ontario, as an example, the critical time starts at the third-leaf stage and continues until the tenth-leaf stage depending on weed density. No matter how much weed pressure there is, protection until the 14th-leaf stage will maintain yields. Spraying a late flush of weeds may make you feel better and prevent the weed from going to seed but it will not help crop yield.

Avoid Rescue Treatments.

Knowing what weeds to expect and using herbicides to control them will help eliminate extra passes over the field to catch "escapes".

Evalute Weed Control

Leave a small untreated check strip to evalute your weed control decision. The area can be burned off later with a backpack sprayer if there is a concern about weed seed production.

Manual pulling is an effective way to stop a weed before it gets established.

HOW LIKELY ARE MY PESTICIDES TO MOVE?

Losses of pesticides from the area they are applied depend on several factors.

FACTORS IN PESTICIDE LOSSES

CHEMICAL FACTORS:	Solubility	• Soluble pesticides will move easily with water and are more likely to leach.
	Binding to soil particles	• Some chemicals adhere very tightly to soil particles, and are not subject to loss.
	Rate of breakdown (half life)	• A persistent chemical, because it is around longer, is more likely to suffer loss than one which breaks down quickly.
	Rate of application	• A chemical with a low application rate is less likely to move away from the target.
	Timing of application	• Chemicals applied in the fall or early spring have a greater chance of loss.
SOIL FACTORS:	Texture	• Sandy soils, which allow greater water movement and bind less tightly to chemicals, are more subject to losses.
	Slope	• Steep slopes that are erosion prone are more likely to lose pesticides that are attached to soil particles.
	Depth to water table	• Shallow water tables are more easily contaminated. In the spring and fall when water tables are high, chemicals are more likely to move downward and contaminate the groundwater.
APPLICATION FACTORS:	Weather following spray	• Heavy rain within a few days of spraying can move significant proportions of the applied chemicals.
	Operator care	• Excessive rates, uncalibrated sprayers, careless handling, spraying too close to streams or watercourses, or spraying when it is too windy can all increase losses.

KEEP PESTICIDES ON TARGET

Prevent Groundwater Contamination.

Never fill the sprayer directly from the well. A well is a direct pipeline into groundwater. Spills near a well can contaminate groundwater in several ways:

- ▸ Directly from the surface.
- ▸ Through openings in and around the pump base.
- ▸ Through soil adjacent to the well.

Contamination can also be caused by backsiphoning. Backsiphoning is caused by gravity and refers to the backward flow of liquid from the sprayer into the well when the pump is shut off. To avoid backsiphoning:

► Make sure the filler pipe or hose remains above the level of liquid in the sprayer. This keeps an air break between water and pesticide. Only submerge the water pipe or hose if it is equipped with special valves that prevent backsiphoning.

Do not rinse or wash the sprayer near a well.

Prevent Surface Water Contamination.

Use the same guidelines as with your well: Never fill the sprayer directly from surface water such as ponds, ditches or lakes. Rinse and clean your sprayer away from surface water.

Protect Surface Water from Spraying.

One of the easiest ways to protect water is to maintain a buffer strip of vegetation between it and the cropped field. Buffer strips reduce the risk of run-off of pesticides into watercourses.

Protect surface water from contamination by planting buffer strips.

Avoid Spraying if Heavy Rain is in the Forecast.

Heavy rain, immediately after application, can carry as much as 5% of atrazine and 3% of metalachlor (Dual) off the field. Rain one week after application does not cause significant losses. If it rains immediately after an application of a post-emergent herbicide, weed control will be reduced. This varies depending on the product. Consult the label.

Monitor Pesticide Rates Closely. Calibrate the Sprayer Accurately.

Apply pesticides at the recommended rate. If there is a range of rates, match the rate to your soil type and the level of the problem. Calibrate your sprayer carefully to ensure the proper rate of application. Using more pesticide than is needed is expensive, wasteful and increases the load on the soil unnecessarily. Some herbicides stay in the soil and may harm the next year's crop.

When Spraying, Reduce the Drift of Pesticides.

Big drops drift less than smaller drops. Low sprayer pressure produces larger drops. If applying pesticides before planting or before crops emerge, use large drops. After crops have emerged, application requires medium drops. Other ways to reduce drift include high water volumes [more than 170 l/ha (50 gallons per acre)] and use of larger nozzles. If the winds are higher than 8 kilometres (5 miles) per hour, delay spraying.

Reduce the Pesticide Load on the Soil.

The more pesticide applied, the more likely it will contaminate ground and surface water. Properly applied herbicides will break down before they are leached into groundwater. However, surface run-off may also contain pesticides. If control is good, try reducing to the low end of the registered rates. Be aware that all pesticides have their weaknesses, and these will be more likely to show at the low rates.

Herbicides such as atrazine, metalachlor (Dual), metribuzin (Sencor and Lexone) and simazine (Princep) have all been found in ground and surface water. For a list of herbicides showing their potential for loss, see the following table.

LOSS POTENTIALS OF SOME COMMON AGRICULTURAL CHEMICALS

PESTICIDE	SURFACE LOSS POTENTIAL	LEACHING POTENTIAL
ATRAZINE	Medium	Large
BANVEL	Small	Large
BASAGRAN	Small	Medium
BLADEX	Medium	Medium
2,4-D AMINE	Medium	Medium
DUAL	Medium	Medium
FUSILADE	Large	Small
LEXONE, SENCOR	Medium	Large
LINURON	Large	Medium
POAST	Small	Small
ROUNDUP	Large	Small
TREFLAN	Large	Small
COUNTER	Medium	Small
DYFONATE	Large	Medium
BAYLETON	Medium	Medium
TILT	Medium	Medium

Source: Farm Chemicals Handbook.

NOTE: This table reflects the chemical properties of the active ingredients. Risk will also vary with application properties.

Handle Carefully and Be Prepared in Case of Emergency.

Read all product labels carefully. Wear protective clothing and have an action plan in case of a spill or poisoning. Emergency phone numbers should be posted near the phone and everyone on the farm should be completely familiar with emergency procedures.

If a spill does occur, confine it to the area where it took place and then, call the Ministry of Environment for clean-up help.

Best Management Practices for Pest Management

- ►Rotate pesticide families.
- ►Reduce chemical use.
- ►Calibrate the sprayer and apply pesticides carefully.
- ►Rotate crops.
- ►Use buffer strips and cover crops.
- ►Follow directions on the label.

FIELD PLANNING AND RECORDS

Planning what will happen in a field and then recording the details are important in evaluating your practices. Records help establish the conditions that led to success but they are particularly important if something goes wrong. Looking back at your notes may help determine what caused the problem. Working from memory alone does not provide enough information for useable answers.

Records for each field should include:

- ▸All applications of pesticides, fertilizers and manure.
- ▸The variety of seed used.
- ▸Include both rates and dates of operations.
- ▸Record weather conditions at spraying such as air temperature, wind speed, relative humidity.
- ▸Record soil conditions when doing field operations.
- ▸ Note yields and crop quality.

Evaluate the success of your management and compare your results to research programs. There may be further improvements that you haven't considered.

There are field record books available from the Soil and Crop Improvement Association.