CHAPTER 2.0

Environmental Considerations

This chapter describes the potential environmental effects of crop production on soil, water, air and wildlife. Subsequent chapters will describe beneficial management practices to address these issues.

Soils consist of four major components including organic matter, mineral particles, water and air (Figure 2.1).

2.1 Soil Organic Matter

Soil organic matter is composed primarily of plant residues in various stages of decomposition. It accumulates when the return or addition of plant residues is greater than their rate of decomposition by microbes. Organic matter occurs naturally in all Alberta soils, though the amount varies considerably from place to place (Table 2.1).

TABLE 2.1

SOIL ORGANIC MATTER LEVELS IN CULTIVATED SOILS IN ALBERTA

ECOREGION	SOIL ZONE	PERCENT SOIL ORGANIC MATTER
Peace Lowland	Dark Gray	5 - 7
Boreal Transition	Gray	4 - 6
Fescue Grassland, Aspen Parkland	Black	5 - 7
Moist Mixed Grasslands	Dark Brown	4 - 5
Mixed Grasslands	Brown	1 - 3

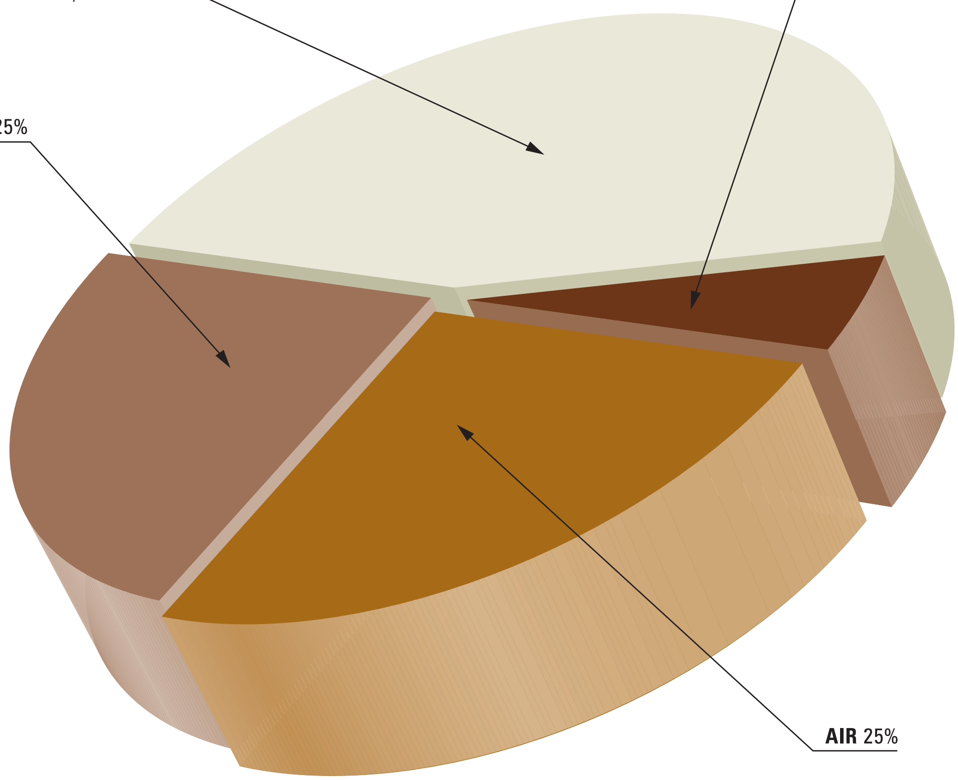
Adapted from: Alberta Agriculture, Food and Rural Development. 2001. AESA Soil Quality Benchmarks Study. Alberta Agriculture, Food and Rural Development, AESA Factsheet FS2001-1SQ.

Soil organic matter improves the physical and chemical properties of soil by:

- holding individual soil particles together in **soil aggregates**, thereby reducing the risk of **soil erosion**;
- improving **soil structure**, workability, aeration, water penetration and water-holding capacity;
- reducing the risk of **crusting** of the soil surface, which can reduce or prevent seedling emergence; and
- storing and supplying nutrients essential to plants and soil microorganisms.

FIGURE 2.1

COMPOSITION OF SOIL



Adapted from: Agriculture and Agri-Food Canada and Ontario Ministry of Agriculture and Food. 1997. Best Management Practices: Soil Management. Agriculture and Agri-Food Canada and Ontario Ministry of Agriculture and Food. p. 7.

Loss of soil organic matter results in reduced fertility, poor water-holding capacity, greater risk of erosion, and lower crop yields.

Factors affecting organic matter content:

- Organic matter tends to accumulate faster in cooler, wetter areas, and to decompose faster in warmer, drier areas.
- Crop rotations with more perennial forages, especially legumes, result in higher organic matter levels because these crops leave more residues than other crops. (**Crop residues** are the plant material remaining after harvest, including leaves, straw and roots.)
- Greater application of fertilizers, including manure, increases organic matter levels by increasing crop production and therefore the amount of crop residues.
- Tillage increases aeration, leading to faster decomposition of soil organic matter by soil microbes.
- Summerfallow decreases soil organic matter content over time because less plant residues are returned to the soil.
- Practices that leave the soil prone to erosion (see Section 2.2) increase the risk of organic matter loss by erosion.

Soil crusting can reduce seedling emergence.

Courtesy of AAFRD

Cultivated

No-till

Sod

Aggregation is best under sod or no-till. Annual cultivation hastens decomposition of organic matter.

Courtesy of AAFRD

Legumes protect soil and add organic matter.

Courtesy of Roger Bryan

For more information, see *The Health of Our Soils* (Agriculture and Agri-Food Canada (AAFC)), *Soil Organic Matter* (Alberta Agriculture, Food and Rural Development (AAFRD)), and *Environmental Sustainability of Canadian Agriculture: Report of the Agri-Environmental Indicator Project* (AAFC).

2.2 Soil Erosion

Soil erosion is the removal of soil by wind, water or tillage. Erosion removes the topsoil, the most productive portion of the soil, reducing levels of organic matter and nutrients, and resulting in lower productivity. Eroded soil particles can reduce water quality and air quality. As well, eroded soil can include soil-attached pesticides and nutrients that further decrease water and air quality (Sections 2.6 and 2.7).

For more information on soil erosion, see *The Health of Our Soils* (AAFC), *An Introduction to Water Erosion Control* (AAFRD), and *An Introduction to Wind Erosion Control* (AAFRD).

Bare soils are vulnerable to erosion.

Courtesy of AAFRD

Crop residue protects the soil.

Courtesy of AAFRD

2.2.1 Water Erosion

Water running over the surface of the soil, called **runoff**, can pick up, carry and deposit soil particles. Water erosion removes topsoil, reducing soil quality and contributing to lower crop yields. If the eroded particles are carried to a **water body**, they can degrade water quality and harm the aquatic habitat.

Water erosion removes topsoil, reducing soil quality.

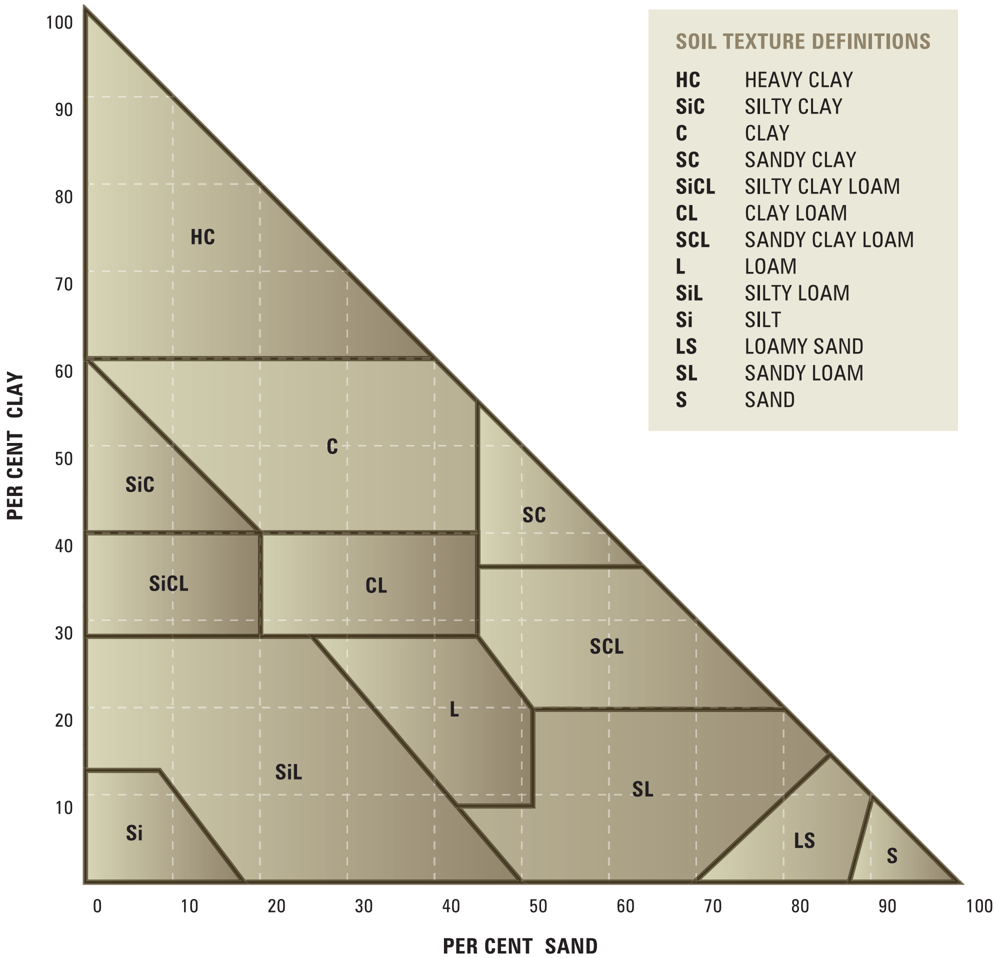
Courtesy of AAFRD

Factors affecting the risk of water erosion:

- Soil covered by plants or plant residues is less susceptible to water erosion than bare soil. Growing plants and a crop residue cover absorb the energy of raindrops and slow the flow of runoff, reducing the risk of erosion. Roots hold soil in place and contribute organic matter, which further stabilizes the soil.
- The greater the amount and intensity of snowmelt or rainfall, the greater the risk of water erosion.
- Steep and/or long, uninterrupted slopes are especially prone to erosion because water can pick up speed as it travels downslope.
- **Fine-** to **medium-textured soils** (Figure 2.2), especially clays and silts low in organic matter, are very prone to water erosion.
- Sometimes clayey and silty soils can be prone to crusting. Crusting reduces water **infiltration** (the movement of water into the ground). Less infiltration means more runoff and a greater risk of water erosion.
- Soils with a shallow, **impermeable** layer (**hardpan** layer) are more prone to erosion because this layer limits infiltration deeper into the soil.
- Tillage leaves the soil prone to water erosion by decreasing the size and stability of aggregates, thus decreasing infiltration, and by burying the crop residue cover.

FIGURE 2.2

SOIL TEXTURE



Adapted from: Agriculture and Agri-Food Canada and Ontario Ministry of Agriculture and Food. 1997. Best Management Practices: Soil Management. Agriculture and Agri-Food Canada and Ontario Ministry of Agriculture and Food. p. 8.

2.2.2 Wind Erosion

Soil particles can be picked up, carried and deposited by the wind. Wind erosion removes the topsoil, resulting in less productive soil and lower crop yields. It tends to carry away the smaller particles leaving the larger particles behind. The visible effects of wind erosion include soil deposited along fence lines and in ditches, blackened snowdrifts and eroded knolls.

Visible effects of wind erosion include soil deposited along fence lines and in ditches.

Courtesy of AAFRD

Factors affecting the risk of wind erosion:

- Smaller soil particles are easier to erode than larger ones.
- Organic matter helps hold soil particles together in soil aggregates; these aggregates are harder for the wind to move than small individual soil particles.
- A cover of plants or plant residues prevents wind erosion.
- High wind speeds and persistent winds have more erosive power.
- Wind barriers, such as shelterbelts and wooded areas, reduce wind speeds and the risk of wind erosion (see section 3.3.3).
- Dry soils are more susceptible to wind erosion.
- Tillage leaves the soil prone to wind erosion by burying crop residues, drying out the soil, decreasing soil organic matter and decreasing soil aggregate size.

Shelterbelts reduce wind erosion.

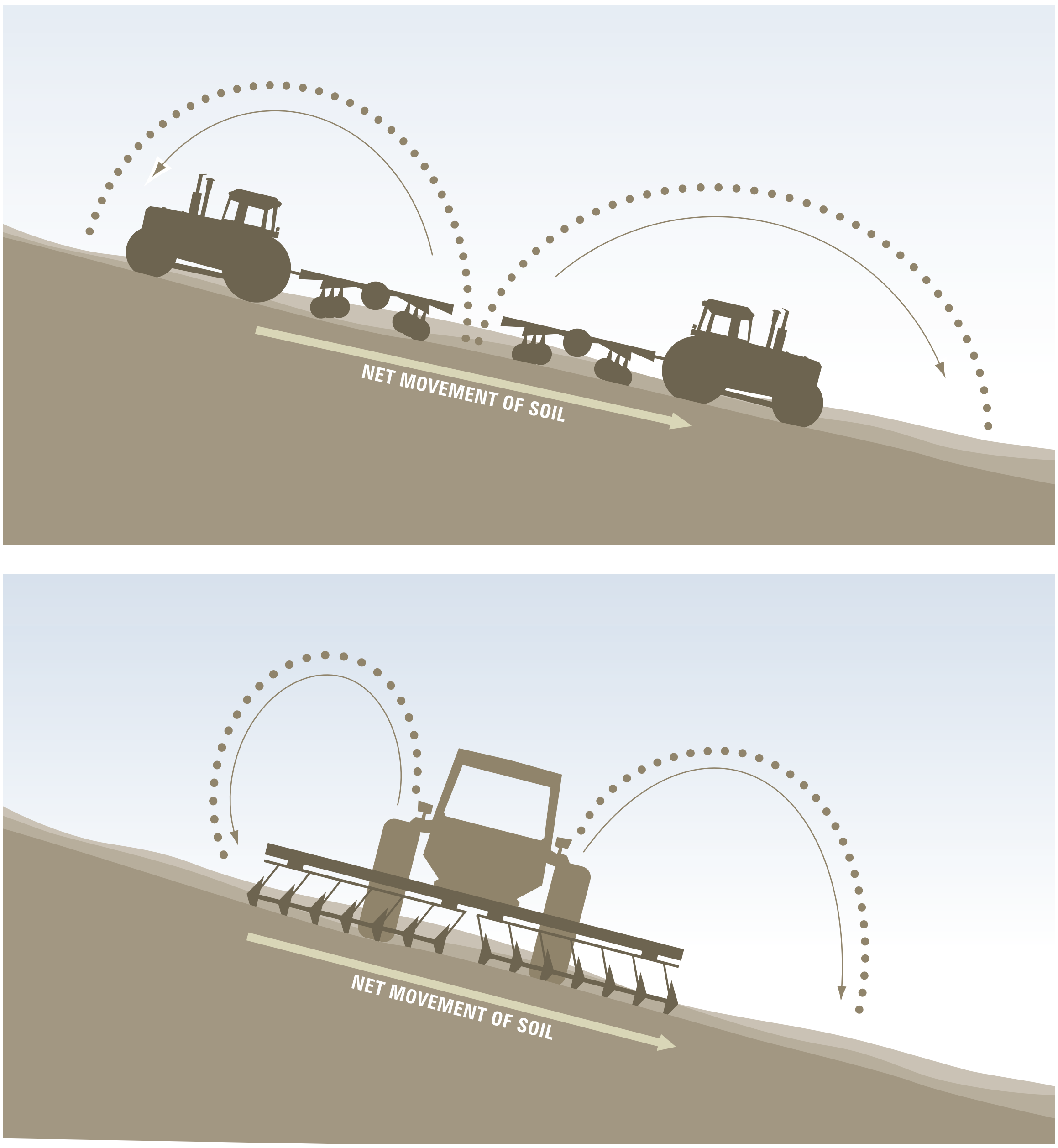
Courtesy of Agriculture and Agri-Food Canada – PFRA

2.2.3 Tillage Erosion

Tillage erosion is the downslope movement of soil by gravity with tillage operations (Figure 2.3). Tillage erosion increases with more tillage passes and greater tillage intensity. It redistributes soil within the field, resulting in topsoil losses on hills and knolls, and accumulations in low areas.

FIGURE 2.3

TILLAGE EROSION



Adapted from: Agriculture and Agri-Food Canada and Ontario Ministry of Agriculture and Food. 1997. Best Management Practices: Soil Management. Agriculture and Agri-Food Canada and Ontario Ministry of Agriculture and Food. p. 46-47.

Factors affecting the risk of tillage erosion:

- More tillage passes and more intense tillage increase the risk of tillage erosion.
- Use of tillage and seeding implements that cause very little soil disturbance reduces the risk of tillage erosion.
- The risk of tillage erosion is greater on steeper slopes.

For information about results from soil erosion research, see the CAESA Soil Quality Program Research Factsheets (http://www.agric.gov.ab.ca/navigation/sustain/research/index.html)

2.3 Soil Salinity

Saline soils contain excess soluble salts in the root zone. High salt concentrations limit the plant root's ability to take up water and nutrients, which restricts crop growth and reduces yields.

Saline seeps can form where salty groundwater discharges.

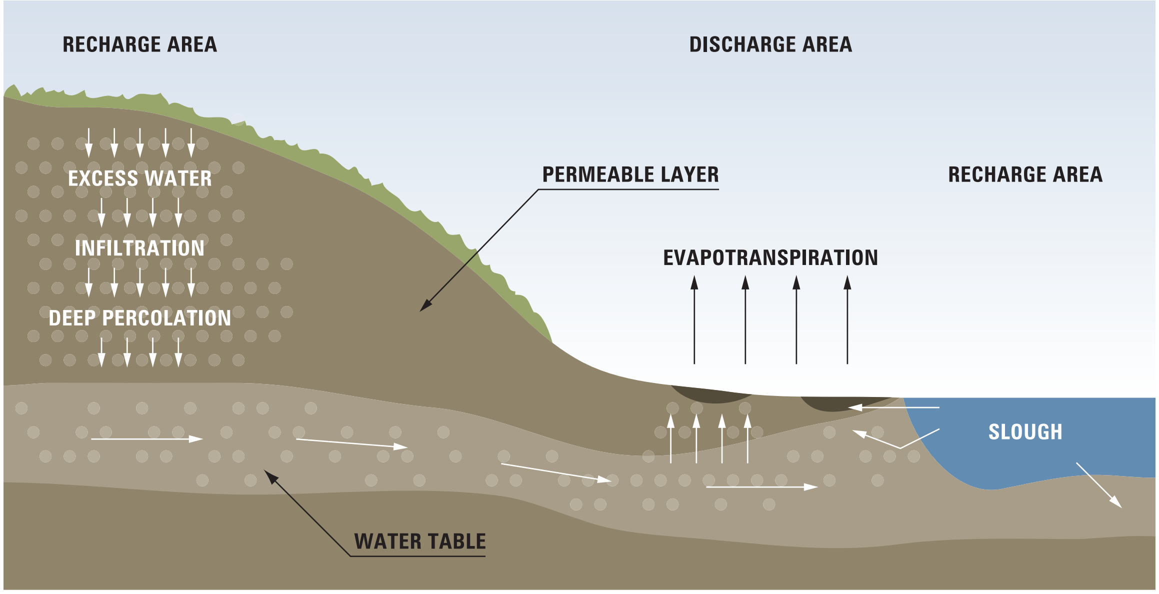
Courtesy of AAFRD

In Alberta, salts occur naturally in many bedrock deposits and in some deposits on top of the bedrock. Groundwater flowing through these deposits dissolves and transports the salts. Under certain conditions, groundwater discharges at the soil surface. When the water evaporates, the salts are left behind. Over time, the salts accumulate in the groundwater **discharge area**, forming a **saline seep** (Figure 2.4). A white salt crust forms where the salt concentration is very high. Only salt-tolerant plants grow in these visibly saline areas (see Table 2.2). The land around the visibly saline area often has saline subsoils, which can lower crop yields.

A saline seep is fed by one or more **recharge areas**. In a recharge area, water in excess of the soil's water-holding capacity moves below the root zone. This movement raises the local **water table**, causing the groundwater to flow downslope. Groundwater flows through the subsoil or bedrock, and dissolves and transports salts in the soil. Eventually, the groundwater discharges near or at the soil surface and a seep gradually forms.

FIGURE 2.4

GENERALIZED SALINE SEEP FORMATION



Adapted from: Wentz, D. 2000. Dryland Saline Seeps: Types and Causes. Agriculture, Food and Rural Development, Agdex FS518-12.

Soil salinity can be measured by **electrical conductivity** (EC), a measurement of the flow of electricity through a material, such as water or a soil solution. The more salts in the soil sample, the greater its electrical conductivity. EC measurements are usually expressed in deciSiemens per metre (dS/m).

Other Types of Salt-Affected Soils

Saline soils are one type of salt-affected soil. The two other types are:

- sodic soils, which are affected by too much sodium, and
- saline-sodic soils, which are affected by an excess of both soluble salts and sodium.

Some practices suited to saline soils can be used for saline-sodic soils. Sodic soils, however, require different management than saline soils. Sodic soils have restricted water movement, are easy to get stuck in when wet, form lumpy seed beds and often have unfavourable pH for crop growth.

People sometimes refer to both saline soils and sodic soils as 'alkali soils', an outdated term used to describe soils with sufficient sodium levels affecting crop growth. To add to the confusion, people sometimes mix up alkaline (high pH) soils with alkali soils. The result can be a misunderstanding of the actual soil condition and use of unsuitable management practices.

If you suspect that you have salt-affected soils, collect samples from the affected area, have them analyzed by a laboratory, and contact a soil specialist to interpret the results.

TABLE 2.2

SALT TOLERANCE OF PLANTS

SALT TOLERANCE	EC (dS/m)	FIELD CROPS	FORAGES	VEGETABLES
Very high	20		beardless wildrye Fulks altai grass Levonns alkaligrass alkali sucatan	
High	16	kochia sugar beets	altai wildrye tall wheat grass Russian wildrye slender wheat grass	
	8	6-row barley safflower sunflower 2-row barley fall rye winter wheat spring wheat	birdsfoot trefoil sweetclover alfalfa bromegrass	garden beets asparagus spinach
Moderate		oats yellow mustard meadow fescue flax canola	crested wheat grass intermediate wheat grass reed canary grass	tomatoes broccoli cabbage
	4	corn		sweet corn potatoes
Low		timothy peas field beans	white Dutch clover alsike clover red clover	carrots onions strawberries peas beans

Adapted from: Wentz, D. 2001. Salt Tolerance of Plants. Alberta Agriculture, Food and Rural Development, Agdex FS518-17.

Factors affecting the formation of saline seeps:

- Generally, recharge areas occur in upper slope positions, while discharge areas occur in lower slope positions.
- Periods of high precipitation and irrigation canal seepage can increase the risk of seep formation.
- Growing high-moisture-use crops, like alfalfa, in recharge areas can reduce the flow of water to discharge areas.
- Summerfallow in recharge areas can increase the risk of saline seep formation because there are no crops to take up moisture from deep in the soil.

For more information, see *Dryland Saline Seeps: Types and Causes* (AAFRD) and *The Health of Our Soils* (AAFC).

Manure and Salt Accumulation in Soils

Manure contains salt originating from the salt in animal rations. Overapplication of manure can lead to increased levels of salt in soil. See Section 9.1.1 for information about manure application regulations to prevent salt accumulation.

2.4 Soil pH

Soil pH is a measure of acidity or alkalinity in the soil. It is measured on a scale from 1 to 14. The higher the number, the more alkaline the soil; the lower the number, the more acidic. A pH of 7 is considered neutral (neither acidic or alkaline). Most crops in Alberta grow best in soil where pH values range from 6.0 to 7.5. Soil pH can affect crop yields along with the physical, chemical and biological properties of soils.

Soil pH influences the availability of plant nutrients (Figure 2.5). Crop growth, quality and/or yield may be affected if any nutrient is lacking in the soil or is not adequately balanced with other nutrients. Soil pH can also adversely affect the growth, survival and diversity of soil microorganisms, like nitrogen-fixing bacteria associated with legumes. Some plant species are more acid-tolerant than others (Table 2.3).

TABLE 2.3

CROP TOLERANCE TO ACID SOILS

Non-tolerant Crops: Alfalfa, sweet clover	Tolerate pH 5.5 to 6.0
Moderately Tolerant Crops: Barley, wheat, rapeseed, alsike, red clover, trefoil	Tolerate pH 5.0 to 5.5
Tolerant Crops: Brome, timothy, creeping red fescue, flax, oats	Tolerate pH 4.5 to 5.0

Adapted from: Alberta Agriculture, Food and Rural Development.

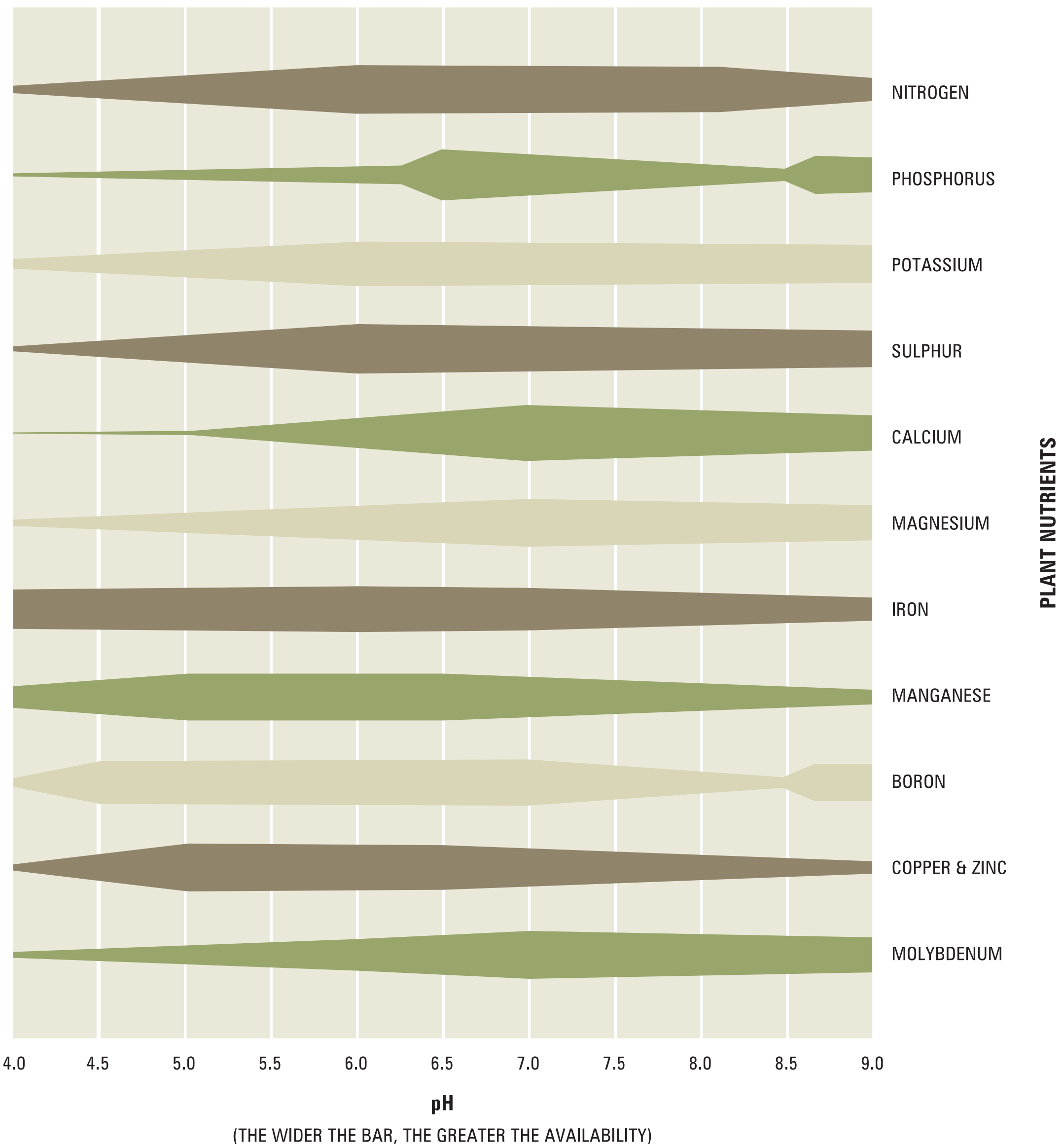
Acid soils are most commonly found in central Alberta and in the Peace River region. However, pockets of acid soils can be found in neutral pH areas. The opposite can also occur. Not all soils become acidic. Alberta has naturally high pH soils in the southern dry prairie regions where alkaline (calcareous) subsoils are near the surface.

Factors affecting soil pH:

- Fertilizer applications (particularly nitrogen-based fertilizers and manure) can increase acidity over the long term.
- Plants and soil nutrients are in a complex relationship with soil acidity, increasing pH in some cases and decreasing it in others.
- Peat soils and forest soils are naturally acidic.
- Acid deposition by rain can increase acidity over the long term.

FIGURE 2.5

NUTRIENT AVAILABILITY AS AFFECTED BY pH



Adapted from: Agriculture and Agri-Food Canada and Ontario Ministry of Agriculture and Food. 1994. Best Management Practices: Nutrient Management. Agriculture and Agri-Food Canada and Ontario Ministry of Agriculture and Food. p. 26.

2.5 Soil Compaction

Soil compaction is the reduction of pore space due to equipment and animal traffic. Compaction can develop in any soil type. Because of low porosity, compacted soils are less permeable to air and water. Plant roots have difficulty penetrating the soil, resulting in restricted root growth, reduced nutrient and water uptake, and lower yield potential. Compacted soil is also slower to warm in the spring and more difficult to till.

➡ Wheel traffic can result in increased compaction, especially on wet soils.

Courtesy of AgTech Centre – AAFRD

Factors affecting compaction:

- Wet soils can be compacted more easily than dry soils.
- Medium and fine-textured soils and soils low in organic matter are easier to compact.
- Frequent tillage increases compaction.
- Frequent wheel traffic and animal traffic increase compaction, especially on wet soils.

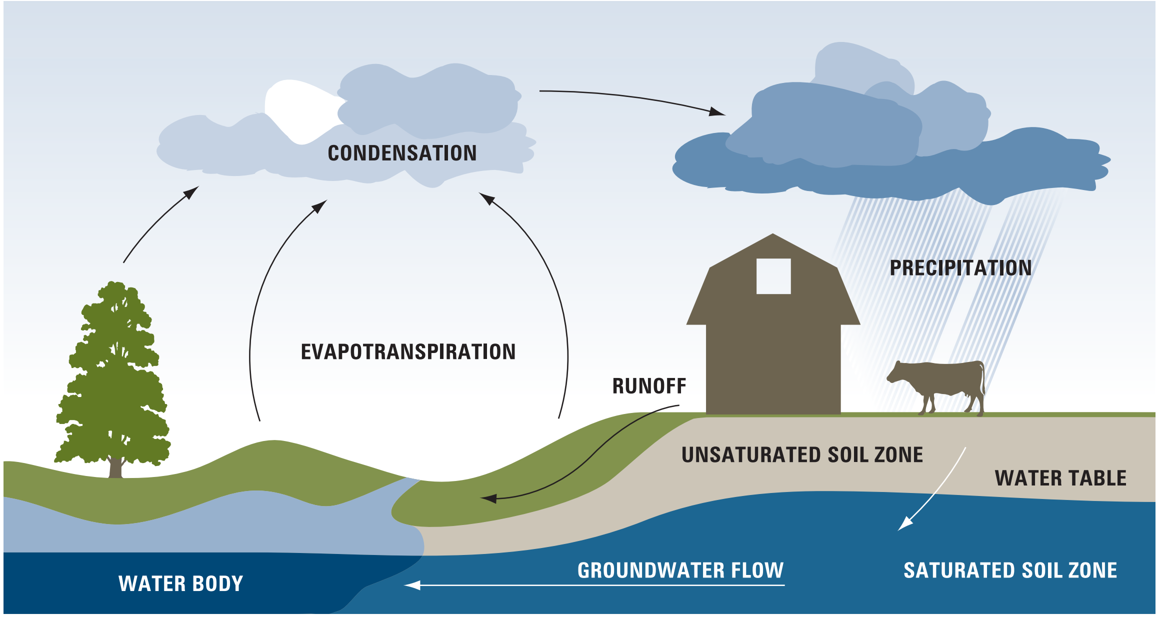
2.6 Water Quality

Crop production can affect water quality if water carries contaminants from fields to surface water or groundwater. Precipitation that falls on the field either as snow or rain can take several paths (Figure 2.6). It can be stored as snow and ice or in puddles, it can flow across the land as **overland flow,** or it can seep into the ground by infiltration.

Water that seeps into the ground may be stored in an unsaturated zone as soil moisture where it is available for plant use, or it may move down to the groundwater. Under some conditions, water can move laterally in a saturated zone as **interflow**. The term **runoff** includes both overland flow and interflow.

FIGURE 2.6

WATER CYCLE



Adapted from: Figure 2-1 in Coote, D.R. and Gregorich, L.J. (eds). 2000. The Health of Our Water: Toward Sustainable Agriculture in Canada. Agriculture and Agri-Food Canada, Publication 2020/E. Reproduced with the permission of the Minister of Public Works and Government Services Canada, 2003.

When water leaves a field by runoff or gravity drainage, it can potentially carry contaminants – such as nutrients, disease-causing organisms, pesticides, sediments, or fuel – to water sources. Surface water sources are most vulnerable to contamination from overland flow and interflow, whereas groundwater sources are most vulnerable to contamination through **leaching**. Contaminants may be dissolved in water, or they may be attached to soil particles and carried away during soil erosion events.

2.6.1 Nutrients: Phosphorus and Nitrogen

Phosphorus and nitrogen are two nutrients that are essential for plant growth and crop production. Both nutrients are components of chemical fertilizers, animal manures and decomposing crop residue. In soil, they are found dissolved in soil water, attached to soil particles or as particles of fertilizer.

Nitrogen and phosphorus can be transported by runoff and leaching to surface water and groundwater. Elevated levels of these nutrients degrade water quality by promoting growth of rooted aquatic plants and algae.

Phosphorus is the nutrient that most greatly affects aquatic plant growth. Even a small amount of phosphorus, measured in parts per billion, can promote the growth of algae and other aquatic plants. Large masses of algae, called **algal blooms**, are a key concern for several reasons:

- When algal blooms exhaust the supply of phosphorus, they die and start to decompose. During decomposition, dissolved oxygen is removed from the water by microorganisms that break down the organic material. The lack of oxygen can result in the death of fish and other aquatic organisms.
- Some types of blue-green algae can release toxins deadly to livestock and humans when the algal bloom decomposes.
- Algae can block water intakes, reduce the appeal of water bodies for recreation, and give an unpleasant taste and odour to drinking water.

Nitrate is a form of nitrogen that is highly susceptible to leaching because it is readily dissolved in water. Drinking water guidelines place an upper limit on the allowable concentration of nitrate (10 mg/L of nitrate-nitrogen) in water because high concentrations can pose health hazards to humans and livestock. Ammonia, another form of nitrogen, poses a threat to water quality because it can be toxic to aquatic organisms such as fish.

Factors affecting the transport of nutrients to surface water and groundwater:

- Areas at greater risk of water erosion (see Section 2.2.1) are also at greater risk for contributing nutrients to runoff and surface waters.
- Infiltration of water is slower in fine-textured soils (silty and clay soils), making them more likely to have runoff, and increasing the risk of surface water contamination. Infiltration is faster in **coarse-textured soils** (sandy soils) and more likely to lead to groundwater contamination.
- Wet soils that are frozen have lower infiltration, which can lead to increased runoff and a greater risk of surface water contamination.
- Permanent vegetation cover along the banks of a surface water body can capture some of the nutrients in runoff.
- If there is an excess concentration of a particular nutrient, then there is a greater risk of transport of that nutrient.

2.6.2 Pathogens

A **pathogen** is a disease-causing microorganism. Three classes of microorganisms are important in disease transmission via water: bacteria, viruses and parasites. Pathogens found in contaminated water may include strains of *Escherichia coli*, *Camphylobacter* species, *Salmonella* species, *Shigella* species, *Cryptosporidium parvum* and *Giardia lamblia*.

Livestock manure can harbour a number of these pathogens. Runoff from manured fields can carry the pathogens to surface waters, and leakage from improper manure storage can potentially contaminate surface water and groundwater.

Ingestion of pathogens from manure can lead to various illnesses in humans. Most pathogens in water can be killed through disinfection with chlorine; however, some pathogens, including *Cryptosporidium parvum,* are resistant to chlorine and require more expensive treatment methods.

Factors affecting the transport of pathogens to surface water and groundwater:

- Areas at greater risk of water erosion (see Section 2.2.1) are at greater risk for contributing pathogens to surface water.
- Areas with a greater risk of contributing nutrients from manure to surface waters are also at greater risk of contributing pathogens.
- Downward movement of water is slower in fine-textured soils, making them more likely to have runoff and a greater risk of contributing contaminants to surface waters. Downward movement of water in coarse-textured soils is faster and more likely to lead to leaching and a greater risk for shallow groundwater contamination.
- Wet soils that are frozen have lower infiltration, which can lead to more runoff and a greater risk for contributing pathogens to surface water.

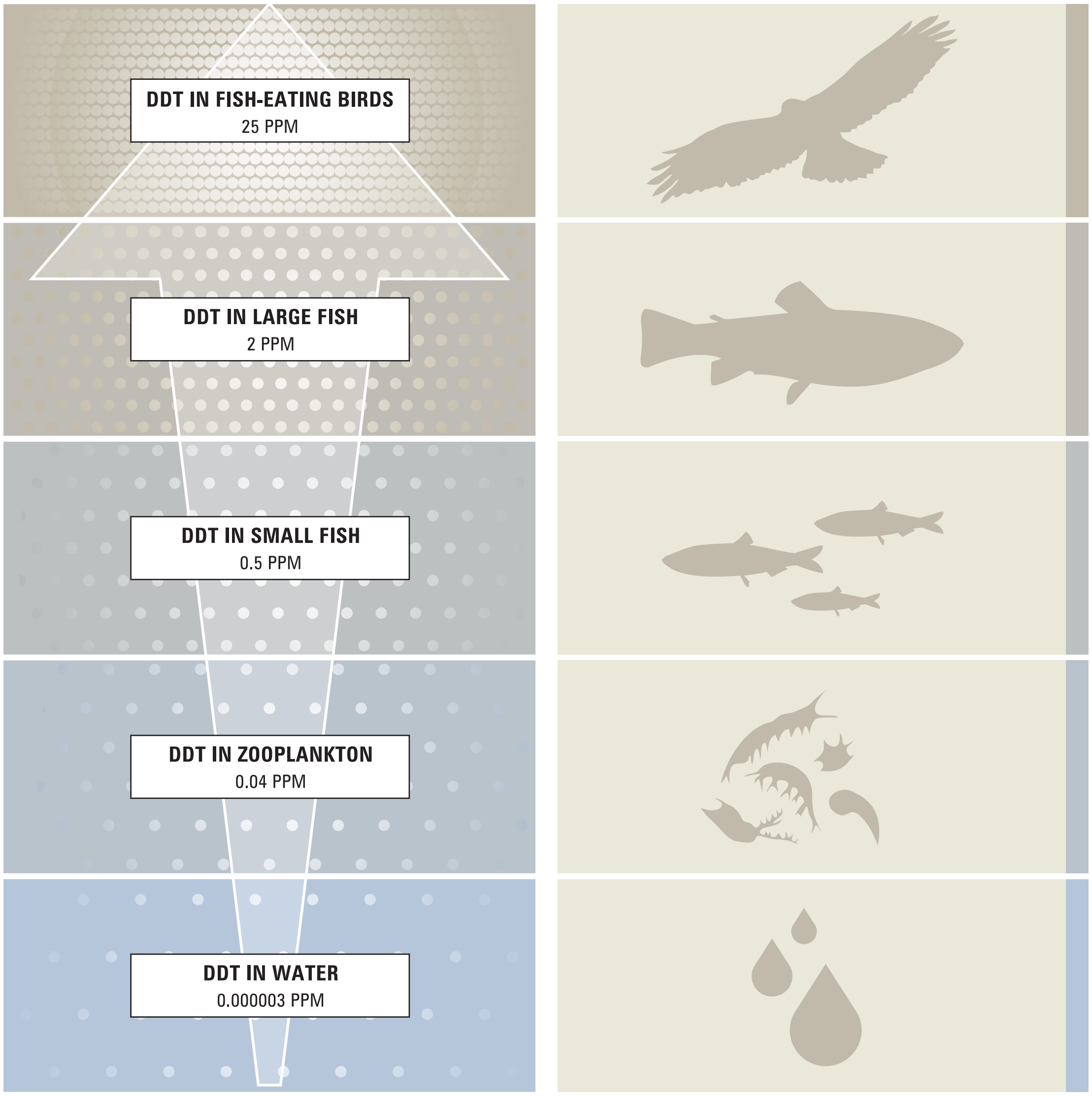
2.6.3 Pesticides

Pesticides are chemicals designed to control or kill specific plants, insects, animals and disease-causing organisms. Pesticides can be grouped into herbicides, insecticides, fungicides and rodenticides.

Pesticides can be harmful to organisms other than the **target** organism. When the pesticides are transported to water, any organism that resides in the water or ingests the water comes into contact with the pesticide. While some pesticides degrade quickly in the environment, others can accumulate in the tissue of organisms, in a process called **bioconcentration**. With every step in the food chain, larger quantities of the accumulated pesticide are eaten. This accumulation, called **biomagnification**, may continue to the point where the animals are harmed or are unsafe for human consumption (Figure 2.7).

FIGURE 2.7

BIOMAGNIFICATION



Over-reliance on certain pesticides can also lead to the development of **resistance** in the target species.

Pesticides can be carried from the target area to water bodies in several ways: dissolved in runoff water or infiltrating water, as soil-attached particles carried by wind or runoff water, or as spray drift (see Section 2.7.3).

Factors affecting transport of pesticides to surface water and groundwater:

- Heavy rainfall soon after a pesticide application greatly increases the risk of contaminating runoff and groundwater, and also reduces the effectiveness of the pesticide application.
- Pesticides can reach surface water directly through spills or improper mixing/loading techniques. In particular, **backflow,** the backward flow of liquid from the sprayer through the filling hose when the pump is shut off, can cause serious contamination of the water source used for mixing.
- Pesticides that are very soluble have a greater potential to percolate through the soil and reach the groundwater.
- Areas at greater risk for erosion (see Section 2.2) are at greater risk for the movement of soil-attached pesticides.

Table 2.4 provides more details on the factors affecting the transport of pesticides to water bodies.

TABLE 2.4

FACTORS AFFECTING PESTICIDE TRANSPORT TO WATER

CHEMICAL FACTORS	Solubility	Soluble pesticides will move easily with water and are more likely to leach through soil.
	Binding to soil particles	Some chemicals adhere very tightly to soil particles and are not subject to loss by dissolving into water, but can be carried to water bodies through erosion of soil particles.
	Rate of breakdown (half life)	A persistent chemical, because it is around longer, is more likely to be transported than one that 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 subject to more 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 spraying	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 lakes, or spraying when it is too windy can all increase losses.

Adapted from: Agriculture and Agri-Food Canada and Ontario Ministry of Agriculture and Food. 1992. Best Management Practices: Field Crop Production. Agriculture and Agri-Food Canada and Ontario Ministry of Agriculture and Food. p. 36.

2.6.4 Sediments

Sediments are soil particles carried by runoff and deposited in water bodies. Sediments can eventually fill in the water body where they are deposited. They can also degrade aquatic habitat and reduce water quality.

Sediment deposition can smother fish eggs, aquatic larvae and other aquatic organisms. Increased sediment in water reduces light penetration, which may inhibit the growth of bottom-rooted aquatic plants, resulting in a shift toward the growth of algae.

Sediments suspended in water decrease the effectiveness of chemical water treatment methods, resulting in the need for expensive pre-treatment of drinking water. Other contaminants, such as nutrients, pesticides, pathogens, or fuel compounds, can be attached to sediment particles, further reducing water quality.

Factors affecting transport of sediments to surface water:

- Areas at greater risk of soil erosion (see Section 2.2) are also at greater risk for movement of sediments into surface waters.
- Vegetation along the banks of a water body stabilizes the bank, reducing the risk of erosion by the stream. Bank vegetation also traps sediments carried by runoff, preventing them from entering the water body.

Damaged stream banks contribute sediments to the stream, damaging the aquatic habitat.

Courtesy of Cows and Fish Program

2.6.5 Other Contaminants

Fuels, lubricants, solvents, and paints can be a source of pollution. The most common way for these contaminants to enter surface water or groundwater is through spills or leakage.

Most paint, fuels, lubricants and solvents are toxic to aquatic organisms, and many of these compounds are also toxic to other organisms, including humans, when ingested. Products such as gasoline, diesel fuel and kerosene can move quickly through the soil and into groundwater. It takes only a few litres of gasoline to severely pollute a farmstead's drinking water.

Factors affecting transport of other contaminants to surface water and groundwater:

- Contaminants such as fuels, solvents and paints are easily transported by runoff to surface water bodies and by seepage to groundwater.
- Areas at greater risk of water erosion (see Section 2.2.1) are also at greater risk for the movement these contaminants in runoff.
- Infiltration of water is slower in fine-textured soils, making them more likely to have runoff leading to a greater risk of surface water contamination. Infiltration in coarse-textured soils is faster and more likely to lead to groundwater contamination.
- Wet soils that are frozen have limited infiltration, which can lead to more runoff and a greater risk of transportation to surface water bodies.

For more information on water quality, see *The Health of Our Water* (AAFC), *Primer on Water Quality* (AAFRD).

2.7 Air Quality

Greenhouse gases, blowing soil, pesticide drift, smoke and odour from cropping operations can reduce air quality.

2.7.1 Greenhouse Gases

Water vapour, carbon dioxide, methane, ozone, halocarbons (used in refrigerants), and nitrous oxide are the main **greenhouse gases** in the atmosphere. The trapping of heat by these gases controls the earth's surface temperature. Emissions from human activities are important additional sources of greenhouse gases. Increasing concentrations of these gases are believed to increase global warming. Global warming could result in such problems as more severe or extreme weather events like tornadoes, droughts and winter storms, more forest fires, and damage to water resources.

The main greenhouse gases emitted by the cropping industry are nitrous oxide and carbon dioxide. Nitrous oxide is emitted from soil through a biological process under low oxygen conditions (called anaerobic conditions). Thus waterlogging and any high nitrogen inputs (such as nitrogen fertilizer, legume crop residues, or manure) will increase nitrous oxide production.

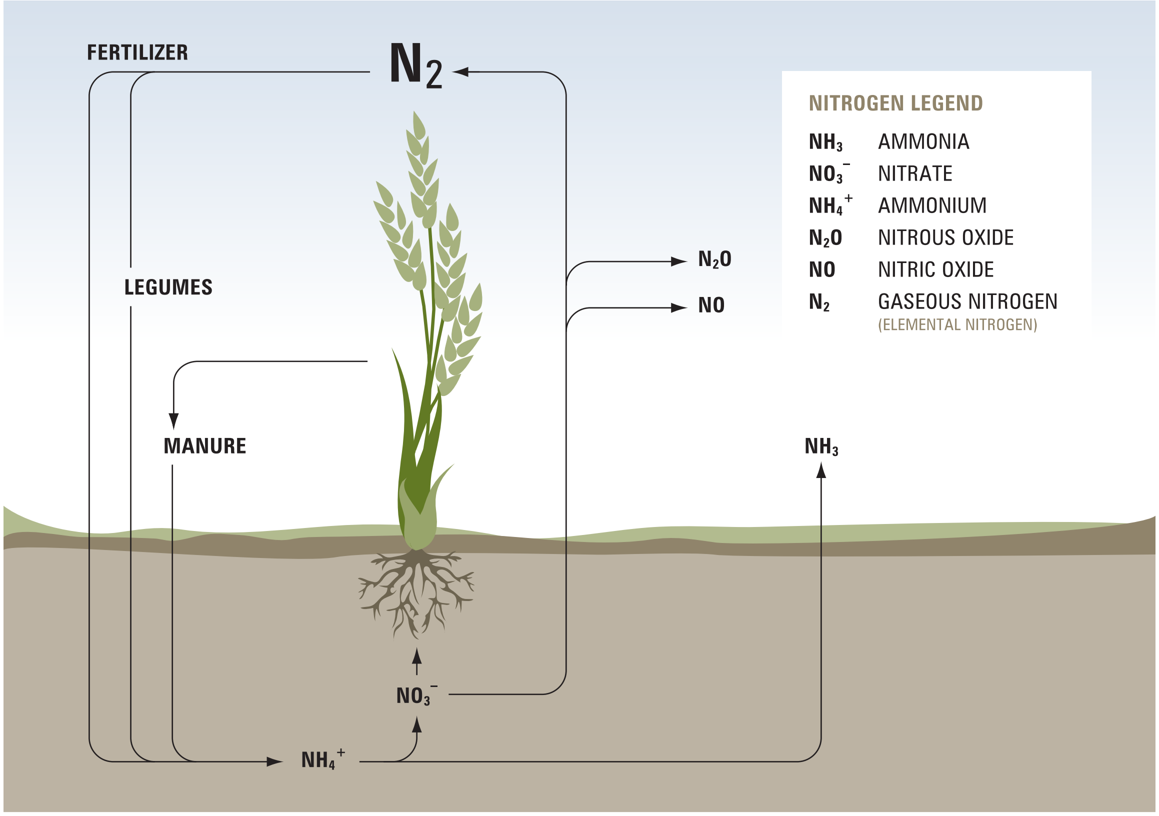
Factors affecting emissions of nitrous oxide:

Emission of nitrous oxide is part of the cycling of nitrogen through the soil and air (Figure 2.8). The nitrogen cycle is affected by complex, interacting factors. In general, nitrous oxide emissions tend to increase:

- when the soil is waterlogged.
- when more nitrogen fertilizer or manure is applied to soils that are or become waterlogged.
- when nitrogen fertilizer is broadcast rather than banded.
- when nitrogen is applied long before the time the crop will use it (e.g. emissions from fall **banding** will be more than emissions from spring banding).
- when manure is left on the soil surface (rather than being incorporated into the soil or injected).

FIGURE 2.8

NITROGEN CYCLE IN AN AGROECOSYSTEM



Adapted from: Figure 21 in Janzen, H.H., Desjardins, R.L., Asselin, J.M.R., and Grace, B. (eds). 1999. The Health of Our Air: Toward Sustainable Agriculture in Canada. Agriculture and Agri-Food Canada, Publication 1981/E. Reproduced with the permission of the Minister of Public Works and Government Services Canada, 2003.

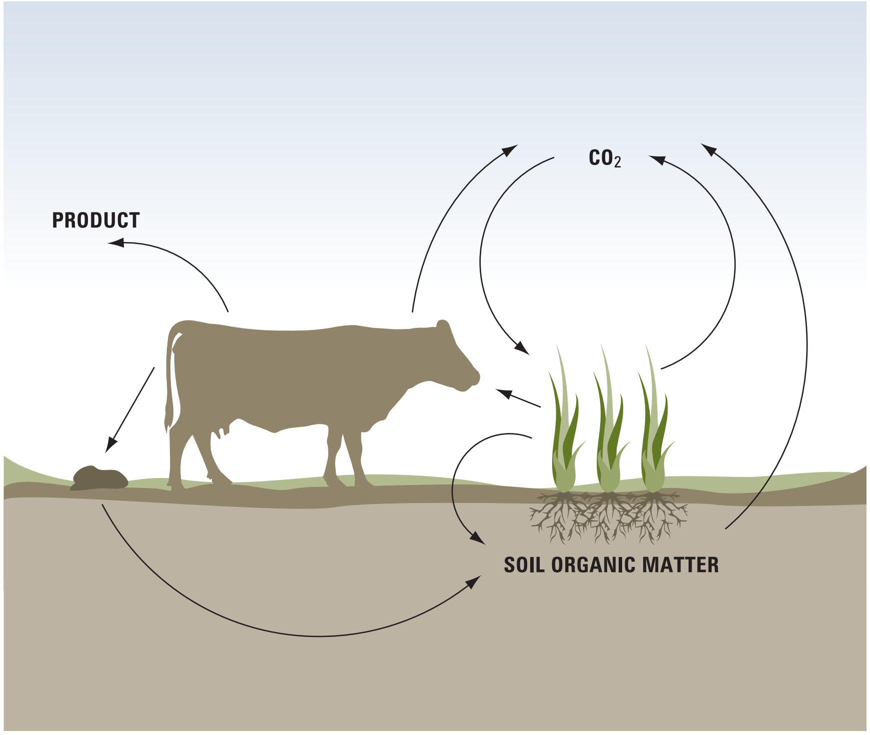
Carbon dioxide emissions from crop production result mainly from decomposition of soil organic matter (Figure 2.9) and burning of fossil fuels. Cropping practices that increase soil organic matter levels remove carbon dioxide from the air and store the carbon in the soil. Carbon storage, also called **carbon sequestration**, reduces agriculture's greenhouse gas emissions.

Factors affecting emissions of carbon dioxide:

- Practices that increase accumulation of soil organic matter (see Section 2.1) reduce carbon dioxide emissions.
- Frequent tillage increases carbon dioxide emissions by increasing the rate of decomposition of soil organic matter and increasing fuel usage.
- Burning of crop residues releases carbon dioxide into the atmosphere.
- Renewable energy sources, such as wind or solar power, do not emit carbon dioxide.

FIGURE 2.9

CARBON CYCLE IN AN AGROECOSYSTEM



Adapted from: Figure 9 in Janzen, H.H., Desjardins, R.L., Asselin, J.M.R., and Grace, B. (eds). 1999. The Health of Our Air: Toward Sustainable Agriculture in Canada. Agriculture and Agri-Food Canada, Publication 1981/E. Reproduced with the permission of the Minister of Public Works and Government Services Canada, 2003.

2.7.2 Dust

Along with being a social concern (see Section 8.2.2), dust also creates environmental problems. It can cause respiratory problems for people and animals. It can reduce visibility on nearby roadways and may result in traffic accidents. Dust may contain diseases, seeds, pollen and plant tissue, as well as agrochemicals, such as pesticides. These materials can cause health problems and, in the case of pesticides, contaminate non-target areas. Dust from road travel can be a concern during such activities as harvesting or manure hauling.

➡ Wind erosion can reduce visibility.

Courtesy of DUC

Factors affecting dust levels:

- Areas at greater risk of wind erosion (see Section 2.2.2) are at greater risk of contributing dust to the atmosphere.
- Dust from traffic on gravel roads increases with higher vehicle speeds, more vehicles, and lower moisture conditions.

2.7.3 Pesticide Drift

During pesticide application, spray droplets, mists or vapours may form. These airborne particles can drift and contaminate nearby land and water, and present a hazard to humans, animals and plants.

Spray drift onto water bodies can harm water quality and aquatic habitat. Drift toward farmsteads and other residences can cause human health problems or can damage gardens and trees. Some pesticides accumulate through **bioconcentration** and **biomagnification**, harming fish, birds and mammals higher in the food chain (Figure 2.7). Herbicide drift onto neighbouring fields can injure or kill sensitive crops in those fields. Insecticide drift can increase the risk of harming or killing non-target, beneficial insects.

➡ Herbicide drift can injure or kill crops on neighbouring fields.

Courtesy of Agriculture and Agri-Food Canada – Tom Wolf

Factors affecting pesticide drift:

- Small spray droplets drift more easily than larger droplets.
- Wind speeds greater than 16 km/h create a high risk of spray drift.
- Air temperatures above 25°C and low relative humidity reduce droplet size through increased evaporation, and so increase the risk of spray drift.
- Higher boom heights increase the risk of spray drift. Boom height determines how much time droplets are exposed to air currents and other forces that reduce droplet size.
- Volatile pesticides can easily move into the air and be deposited elsewhere. Volatility is the ability of a substance to vaporize into the air. Higher spray pressure tends to increase spray drift.
- Spraying during a **temperature inversion** can increase the risk of spray drift (Figure 2.10).

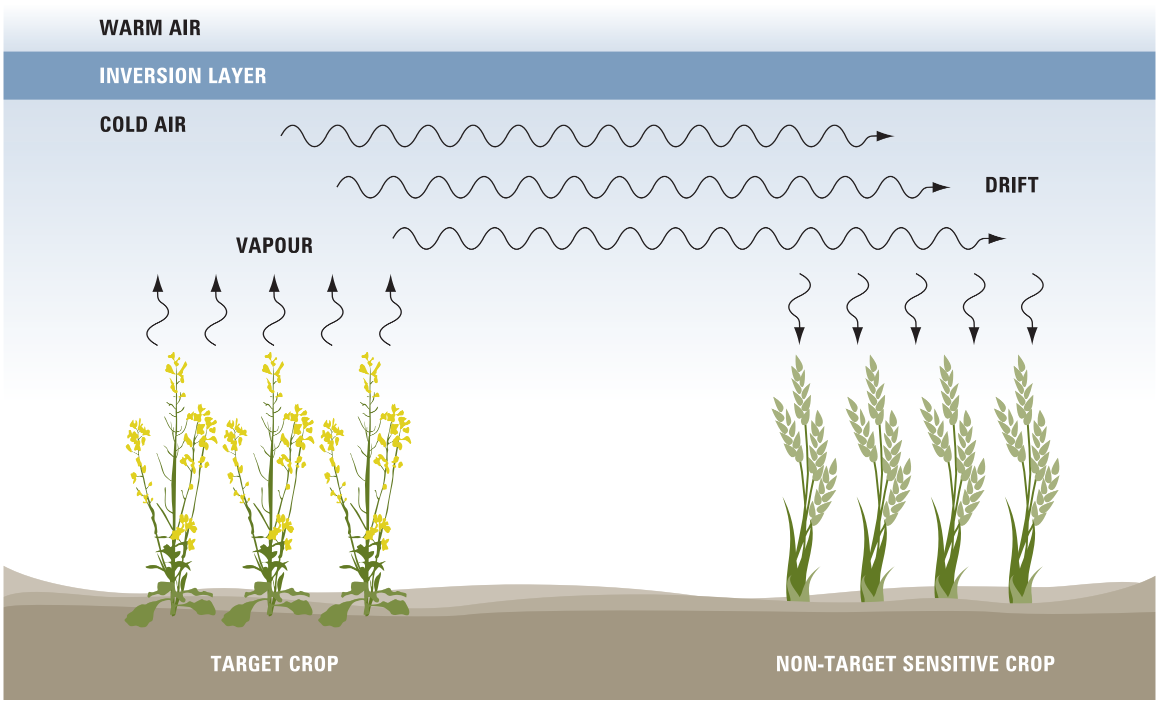
Temperature Inversions and Pesticide Spraying

Air temperature generally becomes cooler higher in the sky. However, during a temperature inversion, the air gets warmer with increased elevation. Temperature inversions occur during very calm conditions, usually in early morning or late evening. An inversion is occurring when it seems you can hear noises for miles or when smoke moves across the sky in a cloud rather than moving upwards and dispersing.

During an inversion, spray droplets can hang in the air as a concentrated cloud for some time after application. When winds pick up, the cloud can move to adjacent areas.

FIGURE 2.10

TEMPERATURE INVERSIONS CAN RESULT IN SPRAY DRIFT DAMAGE



Adapted from: Figure 14 in Ozkan, H. Erdal. 2000. Reducing Spray Drift. Bulletin 816-00. The Ohio State University Extension Bulletin.

2.7.4 Smoke

Smoke contains soot (particles of carbon) that can cause respiratory problems. Smoke can also reduce visibility. If the fire gets out of control, it can endanger property and life, and there may be liability associated with fire and smoke hazards. Before burning, check local bylaws; many municipalities require permits for burning.

The two most common reasons for burning in a crop production system are to get rid of crop residues and to get rid of brush piles from cleared land. Burning of crop residues leaves the soil prone to erosion and all the problems that soil erosion generates (see Section 2.2). As well, excess straw beyond that needed to protect the soil has many potential uses, including bedding and roughage for livestock.

Burning crop residues leaves soils prone to erosion.

Courtesy of Roger Bryan

Factors affecting smoke from burning:

- Higher wind speeds and drier conditions increase the risk of fires getting out of control.
- The material being burnt affects the amount of smoke and odour; green material is smokier.
- The degree of smoke hazard increases when smoke blows across roads or toward residences.
- Burning in the middle of the day reduces the degree of smoke hazard because air movement is usually better, resulting in better smoke dispersal.

2.7.5 Odour

Odours are primarily from ammonia and hydrogen sulphide. The main sources of ammonia and hydrogen sulphide in crop production are manure, fertilizers, crop residues and silage.

Factors affecting release of ammonia or hydrogen sulphide to the air:

- Ammonia is part of the cycling of nitrogen in the soil and air, which is affected by many factors. In general, ammonia emissions increase under wetter conditions, warmer conditions and when the soil is more alkaline.
- The release of ammonia tends to increase as more nitrogen fertilizer is applied and if the fertilizer is broadcast rather than incorporated or banded. The amount of ammonia released also depends on the type of fertilizer. Coated urea fertilizer releases nitrogen slowly, reducing the risk of nitrogen losses to the air.
- Incorporating surface-applied manure soon after application or injecting manure reduces ammonia and hydrogen sulphide emissions.

For more information, see *The Health of Our Air* (AAFC), *Greenhouse Gas Emissions and Alberta's Cropping Industry* (AAFRD), *A Workbook on Greenhouse Gas Mitigation for Agricultural Producers* (AAFRD) and *Pesticide Drift Management* (Alberta Environmental Protection).

2.8 Wildlife Habitat

Agriculture relies on a diversity of biological and natural resources to sustain key functions of agro-ecosystems in support of food production and security. Conserving and restoring wildlife habitat contributes to **biodiversity** and to the ecological functions on which agriculture depends such as:

- protection of water quality
- regional water cycling
- nutrient cycling
- maintenance of soil fertility
- pollination
- pest control
- climate regulation

Agricultural ecosystems (or **agro-ecosystems**) are ecosystems used for agriculture. Each species in an agro-ecosystem is part of a web of ecological relationships connected by flows of energy and materials. Farmers and ranchers manage this flow. Along with their environmental benefits, healthy, diverse habitats provide recreational, economic and quality of life benefits for farmers and rural communities.

Fall rye cover provides nesting habitat.

Courtesy of DUC

Factors affecting habitat on crop land:

- Agricultural practices that protect soil, water and air quality also help maintain habitat. These include such practices as reducing tillage, maintaining perennial cover, planting winter cereals, maintaining buffer zones along streams and lakes, planting shelterbelts and preventing spray drift.
- Draining or infilling wetlands, whether they are permanent or temporary, reduces habitat.
- If not properly managed, pesticide applications can harm non-target plants and animals.
- Some land uses can **fragment** natural landscapes, reducing habitat quality by reducing the ability of wildlife to move from one area to another.

2.9 Information Sources

2.9.1 Contacts

- Alberta Agriculture, Food and Rural Development: Ag-Info Call Centre, phone: 1-866-882-7677; website: http://www.agric.gov.ab.ca
- Your district office of Prairie Farm Rehabilitation Administration (PFRA) of Agriculture and Agri-Food Canada; website: www.agr.gc.ca/pfra
- Reduced Tillage LINKAGES: phone: 1-780-422-7922; website: http://reducedtillage.ca
- Cows and Fish Program (the Alberta Riparian Habitat Management Program): phone: 1-403-381-5538; website: http://www.cowsandfish.org/index.html
- Ducks Unlimited Canada: phone: 1-780-489-2002; website: http://www.ducks.ca/index.html

2.9.2 References

Acton, D.F. and Gregorich, L.J. (eds) 1995. **The Health of Our Soils: Toward Sustainable Agriculture in Canada**. Agriculture and Agri-Food Canada, Publication 1906/E. http://sis.agr.gc.ca/cansis/publications/health/intro.html [accessed December 2003].

Agriculture and Agri-Food Canada. 2000. **Environmental Sustainability of Canadian Agriculture: Report of the Agri-Environmental Indicator Project**. Agriculture and Agri-Food Canada. http://www.agr.gc.ca/policy/environment/pubs_aei_e.phtml [accessed December 2003].

Agriculture and Agri-Food Canada. 2000. **Nutrient Management Planning**. Water Quality Matters Factsheet series. http://www.agr.gc.ca/pfra/water/nutrient_e.htm [accessed December 2003].

Agriculture and Agri-Food Canada. 2000. **Pest Management and Water Quality**. Water Quality Matters Factsheet series. http://www.agr.gc.ca/pfra/water/pestmgt_e.htm [accessed December 2003].

Agriculture and Agri-Food Canada. 2000. **Riparian Area Management**. Water Quality Matters Factsheet series. http://www.agr.gc.ca/pfra/water/riparian_e.htm [accessed December 2003].

Agriculture and Agri-Food Canada. 2000. **Soil Texture and Water Quality**. Water Quality Matters Factsheet series. http://www.agr.gc.ca/pfra/water/soiltex_e.htm [accessed December 2003].

Agriculture and Agri-Food Canada. 2001. **Improved Production Efficiency Reduces GHG Emissions**. Lethbridge Research Centre Report, January 30, 2001. http://res2.agr.ca/lethbridge/rep2001/rep0130_e.htm [accessed December 2003].

Alberta Agriculture, Food and Rural Development. 1993. **Summerfallow and Soil Conservation**. Alberta Agriculture, Food and Rural Development, Agdex 570-3. http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex980?opendocument [accessed December 2003].

Alberta Agriculture, Food and Rural Development. 1999. **Insecticides and Environmental Impact**. Alberta Agriculture, Food and Rural Development. http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/prm2371 [accessed December 2003].

Alberta Agriculture, Food and Rural Development. 2000. **Greenhouse Gas Emissions and Alberta's Cropping Industry**. Alberta Agriculture, Food and Rural Development. http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/cl3010 [accessed December 2003].

Alberta Agriculture, Food and Rural Development. 2001. **AESA Soil Quality Benchmarks Study**. Alberta Agriculture, Food and Rural Development, AESA Factsheet FS2001-1SQ. http://www.agric.gov.ab.ca/sustain/somfactsheet.html [accessed December 2003].

Alberta Agriculture, Food and Rural Development. 2002. **Farm Enterprise Information: Irrigation - Irrigated Soils**. Alberta Agriculture, Food and Rural Development. http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/fem4502?opendocument [accessed December 2003].

Cooke, S. 2000. **Managing Phosphorus to Protect Water Quality**. Alberta Agriculture, Food and Rural Development, Agdex 576-2. http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex929?opendocument [accessed December2003].

Coote, D.R. and Gregorich, L.J. (eds.) 2000. **The Health of Our Water: Toward Sustainable Agriculture in Canada**. Agriculture and Agri-Food Canada, Publication 2020/E. http://res2.agr.gc.ca/publications/hw/index_e.htm [accessed December 2003].

Cross, P. and Cooke, S. 1997. **A Primer on Water Quality**. Alberta Agriculture, Food and Rural Development. http://www.agric.gov.ab.ca/sustain/water/quality/index.html [accessed December 2003].

Glossary of Meteorology. Second edition, electronic version. American Society of Meteorology. http://www.ametsoc.org/AMS/ [accessed January 2003].

Janzen, H.H., Desjardins, R.L., Asselin, J.M.R., and Grace, B. (eds). 1999. **The Health of Our Air: Toward Sustainable Agriculture in Canada**. Agriculture and Agri-Food Canada, Publication 1981/E. http://res2.agr.gc.ca/publications/ha/index_e.htm [accessed December 2003].

Larney, F. Cessna, A.J., and Bullock, M.S. 1999. **Herbicide Residues in Windblown Sediment**. Canada-Alberta Environmentally Sustainable Agriculture Agreement, Alberta Agriculture, Food and Rural Development, Agriculture and Agri-Food Canada. www.agric.gov.ab.ca/sustain/caesa7.html [accessed December 2003].

Lickacz, J. and Penny, D. 1985. **Soil Organic Matter**. Agriculture, Food and Rural Development, Agdex 536-1. http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex890?opendocument [accessed December 2003].

McLean, Janet. 1999. **Pesticide Drift Management**. Alberta Environmental Protection, Agriculture, Food and Rural Development, Saskatchewan Agriculture and Food, Manitoba Agriculture, Canadian Aerial Applicators Association, and Crop Protection Institute of Canada. http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/prm2381 [accessed December 2003].

Noss, R.F. and Cooperrider, A. 1994. **Saving Nature's Legacy**. Island Press.

Ozkan, Erdal H. 2000. Reducing Spray Drift. Bulletin 816-00. Ohio State University. http://ohioline.osu.edu/b816/b816_13.html [accessed December 2003].

Timmermans, J. and Larney, F. 1998. **An Introduction to Wind Erosion Control**. Alberta Agriculture, Food and Rural Development. Agdex 572-2. http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex3524?opendocumentl [accessed December 2003].

Vanderwel, D. and Abday, S. 1997. **An Introduction to Water Erosion Control**. Agriculture, Food and Rural Development, Agdex 572-3. http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex2074?opendocument [accessed December 2003].

Wentz, D. 2000. **Dryland Saline Seeps: Types and Causes**. Agriculture, Food and Rural Development, Agdex FS518-12. http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex167?opendocument [accessed December 2003].