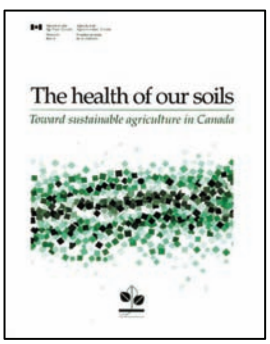
8 SOILS

INTRODUCTION

This chapter discusses soil management practices for protection of the environment. It contains introductory information on soil quality. It also contains information on environmental concerns, legislation and beneficial management practices related to:

- soil management

SOIL QUALITY FACTORS



The primary soil quality factors associated with potential environmental impacts are nutrient content, compaction, organic matter content and contaminants.

📖 **The Health of Our Soils**

The following soil quality factors are listed in alphabetical order. While these factors can be influenced by agricultural production, they also may be influenced by other human activities and natural phenomenon.

Carbon-to-Nitrogen Ratio

Applications of soil amendments high in carbon or nitrogen can alter the carbon-nitrogen (C:N) ratio of soils. In equilibrium, most soils have a C:N ratio in the order of 12:1. Woodwaste, by comparison, has a C:N ratio near 300:1. The application of wastes with a C:N ratio greater than 12:1 will tie up available nitrogen in the soil. Repeated application of high carbon wastes will continue to lower the level of available nitrogen in the soil until a new soil equilibrium is attained. Soils with high C:N ratios will have less nitrogen available for plant use.

Compaction

Soil compaction is the compression of a soil, usually caused by traffic on the site with heavy equipment. It results in a loss of soil structure and aggregate stability, and therefore a reduction in soil porosity. Compaction reduces the movement of water, air, nutrients and soil microbes through the soil. Farm traffic and tillage can result in compaction, particularly when the soil is wet, at either the soil surface or the plow layer. Soils left bare during wet periods, particularly during winter on the South Coast, often have a thin compacted or ‘puddled’ layer at the surface which significantly reduces air and water movement into and out of the soil.

Cover cropping and incorporation of organic matter in the form of crop residue, mulches, compost or manure can help to prevent compaction and may actually restore compacted soils. Timely and appropriate tillage and traffic on fields will also reduce the risk of compaction.

Livestock may also impact soil structure. Poaching, which is the destruction of structure in the upper layers of the soil, is caused by livestock hoof action in poorly drained conditions.

Potential Soil Contaminants

Agricultural Wastes. Agricultural wastes may contain metals, nutrients, pathogens, salts and organic matter. Examples of agricultural wastes which may be applied to the soil are vegetation wastes such as crop residue, used mushroom media, manure, and manure mixed with bedding (also referred to as litter).

Non-Agricultural Wastes. Non-agricultural wastes may contain metals, nutrients, pathogens, salts, organic matter, other contaminants and petroleum products. These are wastes, such as drywall, glass, biosolids or woodwaste, which are not derived from agricultural operations. They may be applied to soils as amendments or for other specific purposes.

Nutrients. Spills, improper storage and over application of chemical fertilizers or manure may lead to excess nutrient concentrations in soil. An overabundance of any one nutrient can result in toxicity to plants, soil and water pollution, and reduction of crop yield. Excess nutrients not utilized by plants can leach out of the root zone to ground water or be carried into surface waters.

Pathogens. Most pathogens such as bacteria, viruses and parasites die off rapidly when exposed to sunlight and the biological processes which occur in soils. However, there are some that can remain infectious in soils for many years. Some pathogens can be transferred between plants, soils and animals.

Pesticides. Soils can be polluted with pesticides as a result of excessive application rates, inappropriate application methods, improper disposal, and spills. The extent of contamination depends largely on the characteristics of the pesticide, particularly its persistence and solubility. Soil contamination can result in the elimination of beneficial insects, the inhibition of crop growth, and a reduction in viable crop varieties. In addition, domestic animals and wildlife may be harmed when feeding on contaminated crops or when ingesting soil particles that contain pesticides. A particular risk to humans is that pesticide accumulations in plant and animal products can make foods unfit for consumption.

Petroleum Products. Petroleum such as gasoline, diesel and kerosene, and petroleum byproducts such as oils, greases, paints and solvents, are complex organic compounds that may contain metals and other contaminants. Petroleum products that loosely adhere to soil particles are easily washed or leached into surface or ground water, while petroleum products that firmly bind to soil particles may restrict the growth of plants. Petroleum products will degrade by biological means in the soil when conditions are correct.

Woodwaste. Woodwaste leachate is acidic and will cause metals and nutrients to be released from the soil. High application rates of woodwaste, either onto the soil surface or by incorporation, will increase the soil carbon-to-nitrogen (C:N) ratio because woodwaste is high in carbon.

Leachate can be generated when soluble materials are dissolved by water passing through them. Soil leachate normally contains soluble nutrients such as nitrates which have not been used by crops. The soil pH is reduced by strongly acidic leachate such as from silage or woodwaste. Low pH makes some metals soluble, allowing them to be leached from the soil.
Metals that are beneficial to the soil-crop system are often referred to as trace metals or micronutrients. The application of wastes or fertilizers containing excess metals may result in an unwanted accumulation of metals in the soil. Mineral supplements in feed or mineral licks can result in elevated concentrations of micronutrients or metals, typically boron, copper, zinc and selenium in soils from manure.

Although crop uptake of metals is generally in low amounts due to their relative immobility in soils, avoid metal buildup to prevent reduced crop production and/or toxicity to plants or animals. Because metal solubility is pH dependent, changing the soil pH will change the potential for metal leaching. Refer to pH and Figure 8.2, page 8-5.

Nitrogen (N)

Nitrogen. The nitrogen cycle in agricultural soils is illustrated in Figure 8.1, next page. Nitrogen exists in two forms, inorganic and organic. The sum of these two forms of nitrogen is referred to as ‘Total Nitrogen’. The inorganic forms (ammonium/ammonia and nitrate/nitrite) are the simple soluble forms that plants use. Inorganic nitrogen represents between two and five percent of the total nitrogen in soil. The organic forms are complex insoluble forms.

Inorganic Nitrogen – Ammonium (NH_4^+). Ammonium is a common form of inorganic nitrogen used by plants, and is found in soil, fertilizer, manure and compost. After application to land, ammonium is converted by soil bacteria to nitrate (NO_3^-) form. Because ammonium is soluble, it is found in the liquid fraction of the soil.

Inorganic Nitrogen – Ammonia (NH_3). Ammonia is a transitional form of ammonium and easily volatizes into the air. The transition between ammonium and ammonia is affected by both pH and temperature. Fertilizer and manure application practices, cultivation, irrigation, and drainage can all affect ammonia movement.

Inorganic Nitrogen – Nitrate (NO_3^-) and Nitrite (NO_2^-). Nitrate is also a common form of inorganic nitrogen found in soil, fertilizer, manure and compost. Nitrate does not generally bind to soil particles and is therefore prone to leaching. This is particularly true in areas such as the Lower Mainland where mild temperatures, intense rainfall events and wet winters promote the formation and movement of nitrate through the soil. Nitrate leaching also occurs readily in coarse textured soils that receive high rates of irrigation. The leaching of nitrates into domestic water sources is a significant health concern. Nitrite is an unstable transitional form of nitrate. Both nitrates and nitrites can be toxic to aquatic life.

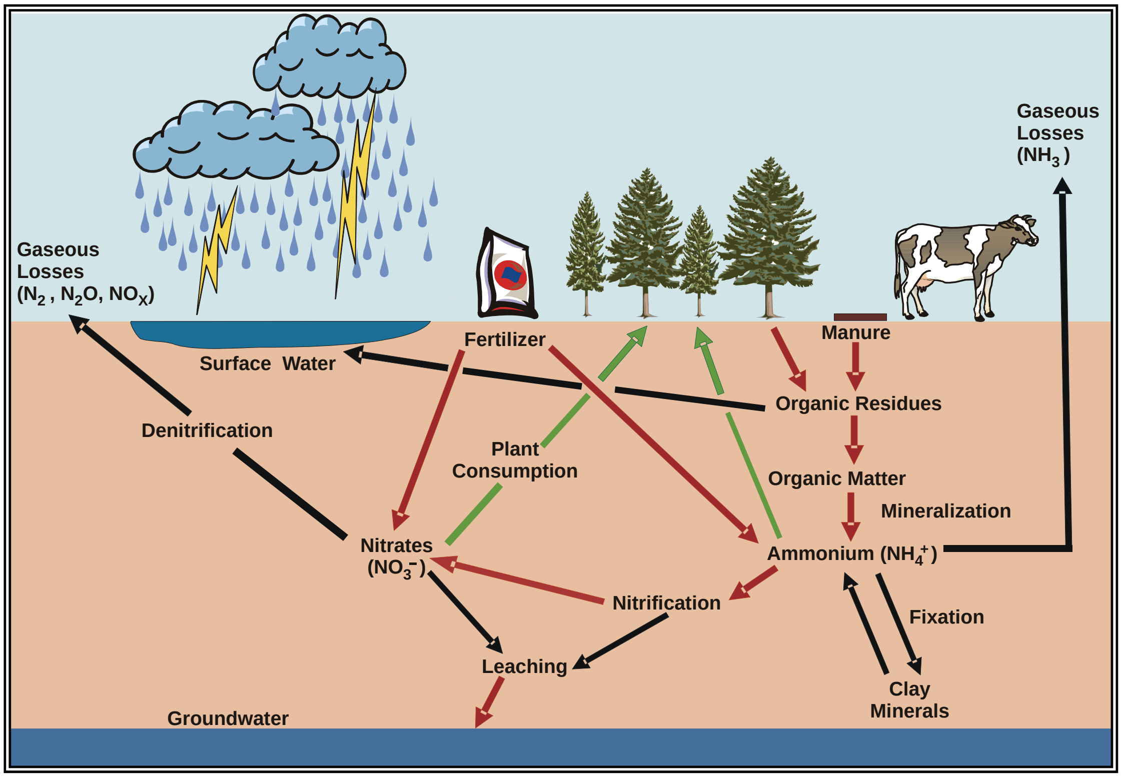


Figure 8.1 Simplified Nitrogen Cycle

Soil bacteria, under certain conditions, convert nitrate and nitrite to gaseous nitrogen or oxides of nitrogen, a process called denitrification. This conversion results in the movement of nitrogen from the soil to the air.

Organic Nitrogen. The largest pool of nitrogen in soils is in the form of organic nitrogen. As organic matter is broken down by bacteria and other soil organisms, the nitrogen is either converted to the two common inorganic forms of ammonia or nitrate or returned back to the nitrogen pool as new organic matter in the form of plant or soil microbial biomass.

Additions of manure, crop residue, compost and other organic nutrient sources can change the size of the pool of organic nitrogen held in the soil. In contrast, cultivation and other cultural practices cause oxidation of organic matter and will result in the loss of nitrogen from the pool.

Organic Matter

Soil organic matter refers to organic matter that has become part of the humus portion of the soil. It does not refer to plant residue or organic matter which is applied to or remains near the soil surface, and which may be recognizable. Soil organic matter is involved in nutrient cycling by supplying and holding nutrients. Soils high in organic matter are also more efficient in holding water. Soil organic matter levels change relatively slowly over time but are strongly influenced by farming activities and climate.

Phosphorus (P)

Phosphorus has a low potential to leach into ground water because it is normally strongly bound to soil particles. However, in coarse soils and in fields that have experienced repeated phosphorus fertilizer or manure applications over several years, the ability of soils to bind phosphorus can be low. Furthermore, phosphorus is bound more than two times as tightly in

Fraser Valley soils in comparison to Okanagan soils. Availability is very dependent on soil pH (refer to Figure 8.2, below) and the presence of mycorrhizal fungi. Aggressive tillage can destroy these valuable fungi resulting in a reduction of immediately available phosphorus. Cultivation can be of value, as it aerates and warms the soil resulting in decomposition of organic matter and the release of organic phosphorus.

Potassium (K)

Potassium leaches very slowly, and is therefore subject to build up in soils. Soil that regularly receives manure is rarely deficient in this nutrient.

pH

pH is a measure of the acidity or alkalinity of a soil. Soil pH has a significant impact on the availability of plant nutrients and metals, and on the activity of soil microorganisms. It also affects the decomposition rate of organic-based soil amendments such as manure. The impact of pH on nutrient availability varies with the type of soil with the optimum for mineral soils ranging from 6.0 to 7.0 and for organic soils between 5.0 and 6.0. Optimum soil pH for specific crops may fall outside of these ranges. Figure 8.2, below, shows the effect of pH on the availability of nutrients in both types of soil.

As pH drops, the availability of many metals increases. A low pH can create a toxic metal environment within the soil that can impact plants negatively or can cause the metals to be more susceptible to leaching. As pH rises to levels above neutral (about 7.5), certain nutrients such as boron become less available to plants.

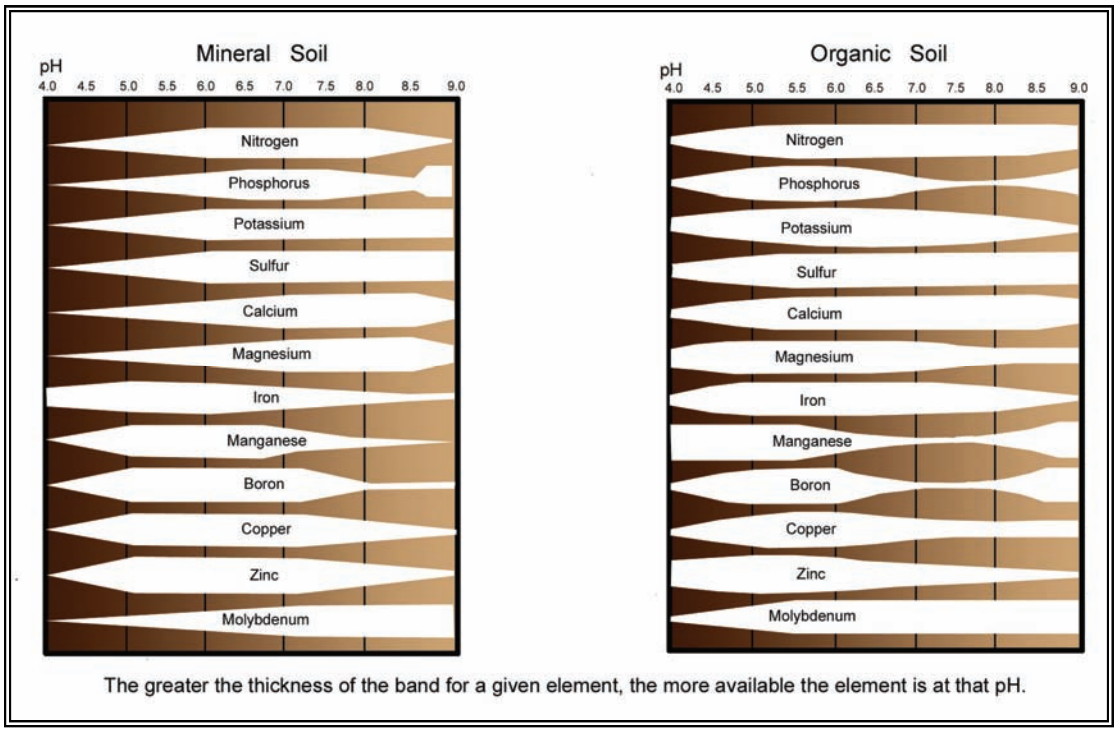


Figure 8.2 Effect of pH on Availability of Nutrients in Soil

Salts

Soluble salts in soil, which can impact crops, are measured by electrical conductivity (i.e., EC in units of dS/m). Crop species and varieties vary with respect to the levels of salts that they can tolerate. When the electrical conductivity of soils is above 2 dS/m they are considered to be salt affected. Crops are generally broken into three sensitivity groupings based on how well they perform for given ranges of salt concentration: sensitive (0 to 4 dS/m), high tolerance (4 to 8 dS/m), and very high tolerance (greater than 8 dS/m). Soils above 4 dS/m are said to be saline and will begin to cause a reduction in the yield potential of a wide range of crops.

Salt impacts on soil are measured by the sodium adsorption ratio (SAR). When the sodium adsorption ratio exceeds 13, soil structure is generally degraded, evidenced by a hard cloddy or crusted surface and reduced water infiltration due to loss of soil particle aggregation. In addition, sodium levels begin to become toxic to plants. Farms in the Interior of BC should be aware of the sodium adsorption ratio levels of their soils, and irrigation water when used on susceptible fields.

Secondary Nutrients and Micronutrients

Calcium (Ca). Calcium is an essential part of plant cell wall formation. Calcium is not readily mobile and is very important in soil structure formation.

Magnesium (Mg). Magnesium is essential to the formation of the chlorophyll molecule in plants. Magnesium is not readily mobile in soils.

Sulphur (S). Sulphur (also spelled as sulfur) is absorbed by plants in the sulphate (SO_4^{2-}) form, much the same way as nitrogen is absorbed as nitrate (NO_3^-). Like nitrate, the plant-available form of sulphur is released by decomposition of organic matter by soil microbes. Traditionally, sulphur has been considered to be mobile like nitrate. However, sulphur binding can occur in acidic soils such as in Lower Fraser Valley. In these cases it behaves like phosphorus in the soil.

Micronutrients. These include elements like boron (B), copper (Cu) and zinc (Zn). They are required for enzymes and other substances in plants that regulate important functions like photosynthesis, growth and respiration. In general, the range between deficiency and toxicity is narrow; meaning the potential for toxicity to plants (and other organisms) is quite real.

Soil Texture and Structure

Soil texture is the relative proportion of sand, silt and clay and cannot be easily changed. Soil structure is the arrangement of the particles or aggregates in soil and can be slowly changed by soil practices, such as cultivation, amendment additions, type of crops grown, and water management.

SOIL MANAGEMENT

Soil is a receiving environment just as air and water are. Good soil management promotes healthy plant growth, overall crop quality, and high productivity while preserving soil health. Productive soil depends on the appropriate integration of various field practices such as management of water, crop tillage and nutrient application. Excess water or nutrients will not only create problems associated with crop quality and yield, but will cause environmental degradation as well.

SOIL MANAGEMENT ENVIRONMENTAL CONCERNS

Primary environmental concerns related to soil management are:

- soil loss through erosion by water or wind that results in air or water pollution
- excess soil removal with harvested crops such as turf grass, nursery plants, and field vegetables, that results in loss of topsoil and eventual reduced crop yield
- soil compaction or structure degradation that results in decreased crop yield and increased runoff
- excess application of nutrients, micronutrients, metals and contaminants that results in soil or water pollution

For detailed information on these concerns:

➔ see Soil Quality Factors, page 8-1, and refer to Compaction, and to Contaminants

➔ see Water Quality and Quantity Factors, page 9-2, and refer to Contaminants, and to Overland Flow

➔ see Air Quality Factors, page 10-1, and refer to Contaminants

SOIL MANAGEMENT LEGISLATION

The following is a brief outline of the main legislation that applies to soil management.

➔ see page A-1 for a summary of these and other Acts and Regulations

Agricultural Land Commission Act

This Act requires agricultural land within an Agricultural Land Reserve to not be used for non-farm use unless permitted by the Act or its regulations. The removal of soil and placement of fill are deemed to be non-farm uses except as provided in *Agricultural Land Reserve Use, Subdivision and Procedures Regulation*.

Environmental Management Act

This Act allows emissions into the air of soil particulates or grit from soil management practices it also has sections concerning contaminated soil.

- Section 55: requires agreement before contaminated soil can be relocated

The *Code* under the *Agricultural Waste Control Regulation* lists six specific requirements regarding application of agricultural wastes to soil such as manure, compost, vegetation:

- Section 3: must be collected, stored, handled, used and disposed of in a manner that prevents pollution
- Section 11: must not be directly discharged into a watercourse or ground water
- Section 12: must be applied to land only as a fertilizer or a soil conditioner
- Section 13: must not be applied to land if …. runoff or the escape of agricultural waste causes pollution of a watercourse or ground water
- Section 14: must not be applied on frozen ground, in diverting winds, on areas having standing water, on saturated soils or at rates of application that exceed the amount required for crop growth, **if** runoff or escape of agricultural wastes causes pollution of a watercourse or ground water, **or** goes beyond the farm boundary
- Section 30: agricultural products must be managed, used and stored in a manner that prevents the escape of agricultural waste that causes pollution

Wildlife Act

The provincial *Wildlife Act* protects wildlife designated under the Act from direct harm, except as allowed by regulation (e.g., hunting or trapping), or under permit. Legal designation as Endangered or Threatened under the Act increases the penalties for harming a species. The Act also enables the protection of habitat in a Critical Wildlife Management Area.

Fisheries Act

This Act has three sections of importance to soil management concerns:

- Section 35: prohibits harmful alteration, disruption or destruction of fish habitat unless authorized
- Section 36(3): prohibits the deposition of deleterious substances into watercourses (deleterious substance could include soil sediments that erode from farmland)
- Section 38(4): requires reporting infractions of Sections 35 or 36

Species at Risk Act

This Act has sections that protect listed species, their residence and critical habitat. It applies to federal lands, internal waters (i.e., all watercourses), territorial sea of Canada, and the air space above them.

The provisions of the Species at Risk Act (known as the ‘safety net’) could be invoked on BC crown and private lands using a federal order under the Act if provincial action is not sufficient to protect listed species.

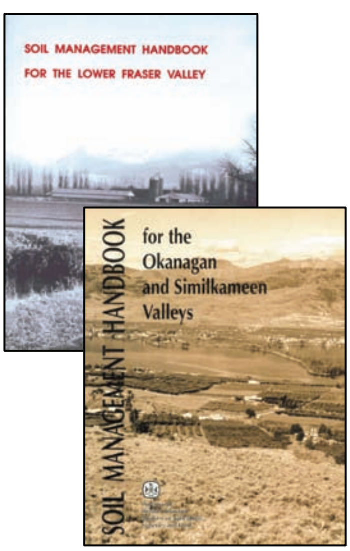
Soil Management Beneficial Management Practices

Comply with applicable soil related legislation, including the above, and where appropriate, implement the following beneficial management practices to protect the environment.

Soil Cultivation

Cultivation plays a critical role in crop management and environmental protection. Implement the following practices:

- to reduce the risk of erosion and compaction, cultivate fields only when testing has shown that soils are at the correct moisture content, such that when soil is squeezed by hand
  - soils should be dry enough to easily crumble
  - if too dry, they will be either very hard or very powdery
  - if too wet, they will smear
- cultivate fields if the chance of significant rain in the forecast that could cause erosion is not expected
- cultivate to incorporate nutrients in order to
  - maximize nutrient retention
  - improve infiltration and thereby reduce the risk of runoff flow
- cultivate prior to liquid manure application to
  - break macropores which can lead to direct discharge of manure to subsurface drainage tiles (macropores are formed by soil cracks, worm holes and mouse or mole holes)
- cultivate for weed control to
  - maximize crop yield and crop nutrient use by reducing competition
  - effectiveness is dependent on timeliness, since even small weeds can cause significant crop growth reduction
- cultivate after harvest to
  - incorporate crop residue if the risk of being carried off by wind or runoff is present
  - incorporate cover crop seed
  - break traffic or cultivation pans for improved water infiltration
- time cultivation for renovation of perennial forages to
  - minimize risk of erosion
  - minimize nutrient loss
  - maximize germination and crop cover
- cultivate the subsoil to improve aeration, to remove compacted layers and to improve water management for
  - better crop growth and nutrient use
  - increased infiltration of water



📖 **Soil Management Handbook for the Lower Fraser Valley**
📖 **Soil Management Handbook for the Okanagan & Similkameen Valleys**

Precautions. Consider the following precautions when cultivating:

- do not over-cultivate since soil with reduced structure will have an increased risk of soil erosion
- do not use a conventional rototiller for repeated cultivation, residue incorporation and/or weed control since too much cultivation with a rototiller will pulverize the soil and compact the subsoil over time

- establish and maintain adequate buffers between cultivated fields and sensitive areas to keep soil erosion and dust from causing a nuisance or pollution ➔ see Buffers, page 11-4

Soil Erosion Risk

Erosion refers to the loss of soil due to water or wind. Erosion risk depends not only on management practices, but on the topography and climate of a region. Water erosion can be the result of surface runoff caused by rapid snowmelt, heavy rainfall or excessive irrigation. Wind erosion occurs if soils are allowed to remain bare for extended periods of time. Wind and water erosion can both lead to loss of soil productivity and environmental problems. Eroded soil nutrients or fine-grained materials, such as silt or clay, can impact watercourses. Wind-blown soil can also cause dust nuisance and respiratory health problems. Wind-blown sand in particular causes physical damage to stems and leaves. The damaged plants are then susceptible to diseases, fungi and other pests.

The susceptibility of a site to soil erosion depends on several factors, some of which apply to both wind and water, and others to wind or water alone. The following list may help to assess the site for its erosion risk.

Soil Texture and Structure. Soil texture and structure play a role in both wind and water erosion. Fine textured soils such as very fine sand, silt and silt loam are highly susceptible to erosion. Soils with good structure (arrangement and stability of soil particles and pores) are more resistant to erosion than are individual particles. Organic matter helps to create good structure, with the result that soils high in organic content are more resistant to erosion.

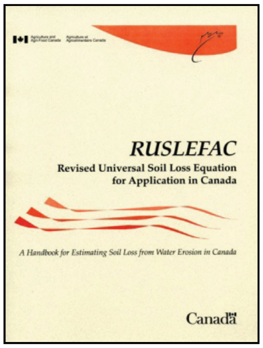
Soil Condition. Saturated or compacted soil conditions facilitate erosion because excess water will flow over the soil surface rather than seep into the ground. Similarly, very dry soil conditions create an environment where wind erosion is more probable.

Topography. Topographic conditions play a major role in whether a site is prone to water erosion. In general, the greater the slope, the greater the risk that erosion may occur. Erosion increases at a rate of more than 2.5 times for each two fold increase in slope. Slopes of greater than 5% are considered to present a moderate risk of soil loss if left bare, while slopes of more than 10% are considered to have high risk of eroding. Erosion increases by 1.5 times for each two fold increase in slope length. If slopes are longer than 100 m, the erosion risk is considered high.

Rainfall Intensity. Sites subject to high-intensity, short-duration rainfall events or subject to rapid snowmelt runoff over frozen soils require extra management to prevent severe erosion.

Wind Exposure. Winds with sufficient velocity and of high frequency can contribute to the movement of significant amounts of soil if low soil moisture is coupled with the absence of surface cover or wind barriers.

Surface Cover. Bare and exposed soils increase both water and wind erosion potential. Bare soils are susceptible to a 100 fold increase in erosion potential when compared with grass-covered soils.



Orientation of Rows. Crop rows that are planted up and down slopes facilitate the overland flow of water and therefore promote soil erosion. Similarly, crop rows planted in the direction of prevailing winds promote wind channeling effects that increases erosive forces.

Detailed Assessment of Erosion Risk. Producers who wish to do a more complete water and wind erosion risk assessment on their sites can use a tool known as the Revised Universal Soil Loss Equation (RUSLE). This is a mathematical equation that predicts annual soil loss.

📖 **The RUSLEFAC - Revised Universal Soil Loss Equation for Application in Canada**

Field Soil Erosion by Water

The potential for soil erosion due to runoff flow varies between operations depending on the risk factors discussed above. To reduce the erosion potential implement the following practices:

- ♦ establish cover crops or maintain crop residue between plant rows, along headlands, and on fields during non-cropping periods to reduce the destructive impact of rain drops – refer to Figure 8.3, next page
  - maintain a suggested minimum 30% to 50% cover crop foliage on the soil surface during high rainfall or runoff periods
- ♦ plant crop rows along contours instead of up and down slopes to slow down and filter runoff flow
- ♦ install and manage drainage systems to maintain unsaturated soil conditions
- ♦ if cover crops are impractical or result in too much competition for water, cover the soil with organic mulches such as straw
- ♦ establish and maintain adequate vegetated buffers between fields and watercourses to protect ditch and stream banks, and to filter and slow down runoff flow ➔ see Buffers, page 11-4
- ♦ modify tillage practices to keep crop residue on the surface for greatly reduced erosion potential
  - practice conservation tillage in all regions of the province
  - maintain a suggested minimum of 30% to 50% anchored cover crop residue on the soil surface when crops are not growing

    📖 **Estimating Crop Residue Cover for Soil Erosion Control**
- ♦ use grassed waterways, drop structures, lined channels or terraces to control more severe water erosion problems (technical advice may be needed to implement some of these special measures)

  📖 **An Introduction to Water Erosion Control**

Figure 8.3 Relay Cover Crop in Corn Stubble

Minimizing the Effects of Runoff Flow. Runoff flow results from rainfall events, snowmelt or excess irrigation water. Controlling rainfall-generated stormwater on the farm can be a critical factor in reducing soil erosion in areas around buildings, yards, roadways, ditches and fields. Uncontrolled stormwater flow is very erosive to soil, as it tends to be high in intensity and short in duration. Such flow readily carries soil, crop residue and agricultural waste by virtue of its high velocity and turbulence.

Stormwater from roofs should be collected and diverted into ponds or grassed waterways. Stormwater from roadways and yards should be collected and filtered to remove suspended solids, nutrients and other contaminants. Clean water can be diverted directly into drainage systems if they have been designed to handle the peak flows characteristic of stormwater events.

➔ see Runoff, page 9-42

The interception of surface and subsurface flow from adjacent properties can reduce soil erosion. Drain areas on hillsides with shallow soils overlying compact subsoil, or areas subject to saturation, with tile lines placed across the slope and backfilled with a porous medium. Use porous interceptors, also know as French drains, to capture runoff. Maintain the land surface above such drains in a porous, open condition by establishing permanent vegetation directly over the drain line or by growing a winter cover crop.

➔ see Drainage, page 9-36

Grassed Waterways. Grassed waterways are designed to collect and transport water from fields while protecting the soil from the erosive force of rapidly-moving concentrated water flow. Grassed waterways may be integrated into fields from which forage may be directly harvested; however, they are usually designed to contain different species, and are subject to different management practices than the rest of the field.

📖 ***Grassed Waterways***

Soil Erosion Along Watercourses

Soil erosion along watercourses often occurs when the vegetation surrounding the watercourse, known as the riparian area, is in poor condition. Healthy riparian areas are critical in protecting stream banks, and by extension farmland, from erosion. Well-vegetated riparian areas have a root mass that binds the soil together for good erosion resistance. If a watercourse starts eroding, especially if water flow volumes and velocities are high, soil loss can be dramatic and every difficult to stop. ➔ see Riparian Areas, page 11-13

Field Soil Erosion by Wind

Susceptibility to wind erosion is greatest when the ground is bare, when plants are young, or when land is unprotected from the effects of wind. Options for the control of wind erosion include reduced tillage, strip cropping, crop residue cover, mulches, windbreaks, shelterbelts, and wind barriers such as fences.

Strip Cropping. This management-intensive practice involves planting strips of crops with varying growth characteristics (e.g., alternate rows of grain and forage).

Cover Crops. Cover crops are useful for protecting the soil surface from erosion by wind. The taller and denser the crop, the better protected will be the soil. Planting cover crops provides additional benefits such as tying up nutrients until productive crops can utilize them. Most soils require a minimum 30% ground cover to prevent wind erosion. This means that choice of species, seeding rates, and planting dates are critical for cover crops to be effective. Suitable cover crops for early summer planting are cereal/legume mixes or annual ryegrass. Appropriate cover crops to follow late harvested annual crops include fall rye, winter wheat or winter barley.

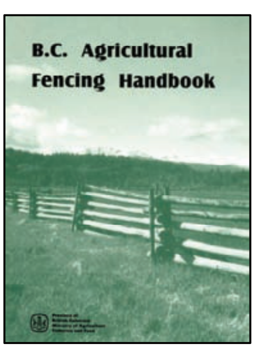
Fences. Fences can provide protection from wind erosion where vegetative windbreaks are impractical.

📖 **B.C. Agricultural Fencing Handbook (series of Factsheets)**

Mulches. The most effective mulches to reduce or control wind erosion are straw, coarse wood chips or larger pieces of crop residue. In order to be an effective erosion control practice the mulch must be anchored.

Crop Residue Cover. Crop residue left on the fields after harvest also provides erosion protection. To be effective, at least 30% of the soil surface needs to be covered by residue. Crop residue protects soil from wind erosion by reducing wind speeds at the soil surface. Residues can take the form of standing stubble or post harvest crop waste. In the case of cereal crops, a 30% cover is equivalent to about 1,300 to 1,700 kg/ha of residue. Highly erodible soils may require double this amount of residue to effectively reduce erosion.

📖 **Estimating Crop Residue Cover for Soil Erosion Control**



Reduced Tillage. The risk of both wind and water erosion is decreased by reduced tillage practices. These include minimizing or eliminating cultivated fallow, decreasing the number of tillage events, and choosing implements and methods that minimize soil and residue disturbance.

Protecting Pastures. Overgrazing reduces long-term pasture productivity and leaves soil prone to erosion. Manage grazing to leave adequate plant cover at all times.

Windbreaks. Establish and maintain adequate vegetative buffers in strategic locations around the farm to minimize soil erosion by wind and to prevent dust from creating a nuisance or causing pollution. ➔ see Buffers, page 11-4

Soil Loss by Harvest

The degree of soil loss caused by certain harvest practices is dependent on the type of crop grown and the soil moisture conditions at harvest. Harvesting of balled and burlapped nursery stock, turf, and field vegetable crops commonly remove soil from fields. In the case of field vegetables, most of this soil remains on the farm after crop washing and eventually should be returned to the field. In cases where soil loss is unavoidable, rebuild the soil by adding amendments, such as sand, and by implementing practices that improve soil organic matter content such as cover cropping.

➔ see Chapter 6, Soil Amendments

The following practices are recommended to reduce soil loss.

Field-Grown Nursery Stock. Prune roots, use large pot sizes when planting out stock, market bare root plants in place of ball & burlapped when possible, and avoid wet soils during harvest.

Turf Nursery. Reduce the depth of cut, use ground netting, and avoid wet soils during harvest.

Field Vegetables. Avoid cultivation activities on west soils which causes clodding. Avoid harvesting in wet soils. Use soil eliminators on mechanised harvesting equipment.

Nutrient Management

Nutrient requirements are likely to be different for each field and crop. It is important to understand specific nutrient requirements in order to prevent the waste of nutrients and in order to minimize the risk of pollution. This is best accomplished by following a nutrient management plan.

📖 **Nutrient Management Reference Guide**

Nutrient management requires the balancing of nutrients taken up by a crop with those supplied by both the soil and other sources. For effective nutrient management planning, check soil nitrogen, phosphorus and potassium levels yearly for annual crops and every third year for perennial crops. Check soil levels for micronutrients and metals every three to six years. ➔ see Chapter 6, Soil Amendments, for general information on nutrient management

Leachate Formation in Soil

Leaching is the removal or transfer of soluble compounds by water from soils or other materials such as manure, silage, compost or woodwaste which have been incorporated into or placed on the soil. The primary concern is the potential for leachate nutrients or metals reaching surface or ground water.

➔ see Leachate, page 9-48 for information on leachate management

Leaching of metals from soils occurs when soil pH decreases, causing metals in the soil to become more soluble, contributing to a greater risk of toxic leachate formation. In order to reduce the risk of leachate generation containing metals, implement the following practices:

- know the effect of various soil amendments and mulches on soil pH and maintain soil pH above 4.5

- woodwaste added to soil will lower soil pH
  ➔ see Woodwaste, page 2-27

Contaminant Movement in Soil

The movement of water with contaminants in soil, such as petroleum, nutrients, pesticides or leachate, is affected by:

- the amount of water moving through the soil, such as from rainfall, irrigation or runoff
- the infiltration and permeability of the soil
- the ability of the soil to bind contaminants

The rate at which contaminants on the soil surface enter the soil is controlled by the soil's infiltration rate. Permeability is a measure of the rate at which water moves through the soil. The size and continuity of soil pores control both permeability and infiltration. Factors which influence infiltration and permeability are shown in Table 8.1, next page.

The soil's ability to bind contaminants depends on soil texture and organic matter content. Coarse-textured soils (have a high percentage of sand), display a low ability to bind contaminants, while fine-textured soils (or clays), display a high ability to bind contaminants. The higher the organic matter component in a soil, the greater is its ability to bind contaminants

Risk of contaminant movement into soils (infiltration) and though soils (percolation) are governed by a range of characteristics. Each characteristic may impart a high or low risk depending on the management of the site. For example a clay soil with large pores or cracks will have a higher risk. If this same soil was compacted the risk would be lower. Soil texture and structure have the highest weighting with respect to level of risk. Structure can be modified by manipulating the soil or by the introduction of compacted organic layers, such as those that form in feedlots.

If the majority of the soil or site characteristics fall into one or the other risk category the soil should be classed within that category. Animal density and contaminant characteristics will also impact the risk of movement. There is an inverse relationship between risk of leachate and risks of runoff. Soils with a low risk of contaminant (leachate) movement generally contribute to a higher risk of runoff. Soils with a high risk of contaminant (leachate) movement are generally most desirable for cropping

Table 8.1 Risk of Contaminant [a] Movement through Soil		Worksheet 1
Infiltration and Permeability Factors	**Soils with High Risk [b] of contaminant movement have these typical characteristics**	**Soils with Low Risk [c] of contaminant movement have these typical characteristics**
Soil Texture	- coarse textured sandy or gravelly - dry cracked clay soil - organic soils	- fine textured silty or clay - greater than 15% clay - homogeneous texture throughout the profile
Soil Structure/Pores	- well structured, blocky or large crumbs with large or abundant pores (macropores)	- poorly structured, platey or smeared with few or fine pores (micropores)
Soil Organic Matter Content	- high organic matter content in well structured mineral soil - resulting in significant large pores - poorly decomposed organic soils	- low organic matter content in poorly structured mineral soil - muck or decomposed peat soils
Soil Density	- loose, easily broken into small lumps	- dense, compacted or cemented
Animals	- abundant soil animals or burrowing insects	- soil animal or burrowing insects channels are absent
Roots	- abundant coarse roots and root channels	- few root channels and many fine roots
Soil Depth	- shallow soils over gravel or fractured bedrock	- deep, well defined topsoil and subsoil over slowly pervious rock or clay

[a] Contaminants, such as manure, pesticides, petroleum, leachate, etc.
[b] High Risk of contaminant movement = infiltration more than 10 mm/hr & permeability more than 1.2 m/day
[c] Low Risk of contaminant movement = infiltration less than 5 mm/hr & permeability less than 0.04 m/day
Note - there is an inverse relationship between risk of leachate and risks of runoff:

- soils with a low risk of contaminant (leachate) movement generally contribute to a higher risk of runoff
- soils with a high risk of contaminant (leachate) movement are generally most desirable for cropping

Soil Contamination

Contaminants may include non-organic compounds (e.g., salts, metals, pesticides, excessive nutrients) and organic compounds (e.g., hydrocarbons, oils, dioxins, furans, weed seeds, pathogenic organisms). To prevent soil contamination it is necessary to know the chemical characteristics of all materials used on the farm, including pesticides, fertilizers, manure, compost and other soil amendments. Off-farm organic materials must be fully identified before use as well. Numerous beneficial off-farm organics are identified in Schedule 12 of the *Organic Matter Recycling Regulation.*

Implement the following practices to monitor and prevent soil contamination.

➔ see Farm Waste, page 2-13
➔ see Petroleum , page 2-22
➔ see Pesticides, page 5-14
➔ see Chapter 6, Soil Amendments, page 6-4

Use Caution When Bringing Non-Agricultural Waste or Products on to Your Farm!

If contamination is suspected or does occur, consult MOE and a qualified environmental professional for remediation procedures.

pH Check. pH levels in soil may be affected by application of soil amendments or cultivation. Implement the following practice:

- check pH levels every three to six years, or more frequently if soil pH levels are suspected of restricting crop growth and adjust pH in the soil as required
- when soil pH is lower than 5.5 or higher than 7.5 on mineral soils special management is required to adjust pH, such as liming or acidifying the soil
  - 📖 ***Liming Acid Soils in Central B.C.***
  - 📖 ***Soil Liming - Understanding Your Soil Test Recommendations***
  - 📖 ***Acidifying Soils***

Salt Check. Salt levels in soil may be affected by application of farm nutrients, chemical fertilizers, or irrigation water. Monitor the salt level by measuring electrical conductivity (EC) and sodium adsorption ratio (SAR) on a regular basis. Implement the following practices:

- check electrical conductivity every three to six years, or more frequently if soil salts are suspected of restricting crop growth
- in the Interior of BC, check the sodium adsorption ratio of the soil every three to six years, or more frequently if levels are suspected of negatively affecting soil structure
- reduce salt and sodium levels in soil amendments as required
- check irrigation water quality ➔ see Irrigation Water Quality, page 9-20

If salt levels within the soil are found to be high (when soil salt level exceeds 2 dS/m or when the sodium adsorption ratio exceeds 5), and if leached salts have been determined to not cause an environmental impact:

- remove the salt from the crop root zone by applying irrigation water at a rate that causes leaching to occur and/or improve drainage
- if the sodium adsorption ratio is found to be high, apply gypsum to the soil prior to applying water to cause leaching
  - 📖 ***Soil Management Handbook for the Okanagan and Similkameen Valleys***

Micronutrients and Metals Check. Micronutrient and metal levels in soil may be affected by the application of farm nutrients or chemical fertilizers. Implement the following practices:

- check concentrations of micronutrients and metals in both soils and soil amendments
  - in soils every three to six years, or more frequently if the soil tests indicate levels greater than soil limits shown in Table 8.2, next page
  - in manure every three to six years, or more frequently if the manure tests indicate levels greater than organic nutrient limits shown in Table 8.2, next page
- reduce metal levels in farm nutrient sources as required by
  - changing to feeds with lower metal levels
  - altering soil pH to reduce metal uptake in crops
- reduce metal build-up in soil where required by moving manure applications to fields with low metal levels

Table 8.2 Suggested Concentration Limits of Metals in Nutrient Sources and Soils			
Metal		**Organic Nutrient Limit** [1] (total µg/g dry weight) [3]	**Soil Limit** [2] (total µg/g dry weight)
Name	**Symbol**		
Arsenic	(As)	13	25 [4]
Cadmium	(Cd)	3	9 [4]
Chromium	(Cr)	100	150 [5]
Cobalt	(Co)	34	40
Copper	(Cu)	400	150 [6]
Lead	(Pb)	150	350 [4]
Mercury	(Hg)	2	0.6
Molybdenum	(Mo)	5	5
Nickel	(Ni)	62	150
Selenium	(Se)	2	2
Zinc	(Zn)	500	200 [4]

[1] Organic nutrient source limit (Class A Compost) from *Organic Matter Recycling Regulation, Schedule 4*
[2] Soil limit from *Organic Matter Recycling Regulation,* Schedules 9 and 10 (Agricultural Land)
[3] 1 µg/g is one part per million, or 1 ppm
[4] Specific soil standards for environmental protection based on livestock ingesting soil and fodder.
[5] Specific soil standard for Chromium +6
[6] Recommend lowering the standard to 40 µg/g for land which sheep are grazing and 150 µg/g for all other livestock

Soil Compaction

Soil compaction reduces pore spaces between soil particles, resulting in decreased air and water movement through the soil, deteriorated drainage conditions, and slower warming of the soil. The effects of severe soil compaction on crops include insufficient nutrient uptake, root damage and premature aging. Environmental concerns caused by compaction are the excessive runoff flow due to the low infiltration rate of compacted soil and the associated discharge of nutrients to watercourses.

Compaction is often caused by the operation of heavy machinery on wet soils and by inappropriate tillage techniques, such as those producing plough-pans. Excessive tillage breaks soil aggregates, disrupts structure, and encourages quick decomposition of organic matter, all leading to a low organic matter content. The resulting low organic matter, in turn, contributes to the soil being even more susceptible to compaction.

In order to determine if compaction is present, check for soil layers, including thin crusts near the surface, which restrict root or water movement by examining the sides of a constructed soil pit.

Surface Soil Compaction. It is difficult to reverse surface soil compaction. Freeze-thaw cycles, root activity, and soil animal activity are not sufficient to overcome annual compaction events. To prevent surface soil compaction, implement the following practices:

- avoid working with equipment on wet soils
- keep livestock off wet soils
- ensure that fields are well drained during the growing season
- reduce the number of trips over a field with equipment
- minimize tillage, particularly operations which pulverize the soil

- use a wide variety of tillage implements including chisel ploughs or subsoilers, and vary tillage depth
- limit the weight on an individual axle to below five tonnes
- install flotation or radial tires on equipment to better distribute weight
- use four-wheel-drive tractors for better weight distribution between axles
- limit equipment and foot traffic to the same areas in a field (e.g., establish lanes and roadways)
- employ good crop rotation practices with deep-rooted crops and cover crops
- delay entry into fields until the watertable is 50 cm (suggested) below the soil surface
  - in coastal regions, no field work should occur until 48 hours after a 50 mm/24 hour rainfall event has passed

Subsoil Compaction. Compaction of soils below the plow layer is more difficult to deal with than surface compaction. To prevent subsoil compaction, implement the following practices:

- follow the steps outlined above for preventing surface soil compaction
- work soils only if they are dry within the tillage zone
- plant deep-rooted cover crops
- use a crop rotation program
- install a subsurface drainage system

If subsoil compaction has occurred, subsoilers may provide some relief. However, this equipment may create other problems such as unwanted root pruning or increased compaction at the working level if the soil is too wet. Only use subsoiling equipment when the soil below the normal tillage layer is dry enough to fracture rather than smear.

Soil Compaction – A Review of its Origin and Characteristics

Soil Organic Matter Content

Soil organic matter is generated from the decomposition of crop residue and other organic materials. Soil organisms and microorganisms digest plant residues to form humus, the earthy, dark coloured material, often associated with topsoil. Humus breaks down very slowly, and provides fertility to the soil. In addition it binds mineral soil particles together, resulting in increased stability when the soil is wetted or cultivated. The impact of higher levels of organic matter in the soil not only improves soil fertility, but contributes to soil structure and plant vitality by:

- holding essential nutrients for plant growth
- increasing resistance to erosion, crusting and compaction
- facilitating water and air movement through the soil
- increasing water retention capacity
- improving conditions for beneficial soil microbes

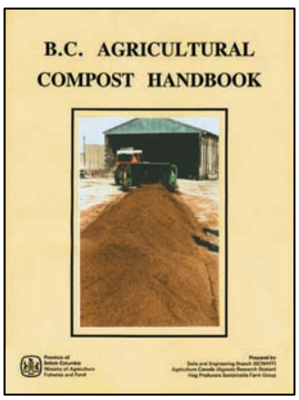
Maintaining a high organic matter content in soils may reduce the amount of irrigation water, fertilizers and pesticides required. Soils with higher organic matter content are generally characterized by better tilth and are therefore less susceptible to damage caused by improper tillage.

Cover Crops. Increasing the organic content of a soil by utilizing a "green manure" requires the growing of a legume or grass crop for deliberate incorporation into the soil before seeding or planting a new cash crop.

Mulches. Mulches are generally recognized as a tool for soil moisture conservation, weed suppression and soil temperature modification. Suitable mulch materials include straw, leaves, hay, grass clippings, crop residues, compost and woodwaste. Mulch depths range from 2 to 10 cm. Mulches will decay over time and become part of the stable organic matter pool in soil. If high carbon-nitrogen ratios mulches, such as straw or woodwaste, are incorporated by cultivation the amount of available nitrogen in the soil may be reduced.

Woodwaste. Woodwaste can be used as a soil conditioner to increase organic matter levels. Fine particle sized material or material that has been partially decomposed or composted is most appropriate. The amount of woodwaste incorporated into the soil should not raise the carbon-nitrogen ratio above 50. If the carbon-nitrogen ratio is taken above this level, available nitrogen will be tied-up for 2 to 3 years. The nitrogen will be released over time as the woodwaste continues to decompose.

➔ see Woodwaste, page 2-27



Compost. Fully composted organic wastes are an excellent source of organic matter but typically supply limited amounts of crop nutrients. Both timing of application and the nutrient content of the material are important considerations for compost application. Compost generally has a lower nutrient content than manure. In addition, the nutrients from composted materials are released at lower rates than is the case for manure. However, in some cases composted manure can have high nitrogen content that is rapidly released when applied to soil.

Composts have less impact on the nitrogen content of the soil than other raw organic materials such as mulches. Composts with a carbon-nitrogen ratio of between 10 and 20 will not adversely affect the soil-available nitrogen content. High application rates of compost should be coupled with a cover-cropping program to prevent excess nutrients from leaving the soil profile.

B.C. Agricultural Composting Handbook (series of Factsheets)

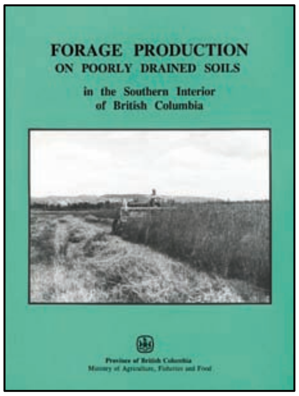
Livestock Manure. Manure may be utilized as a source of organic matter; however, do not apply at rates higher than required for its fertilizer value. If manure is used as an organic amendment it is recommended that its use be in conjunction with a cover cropping program to trap excess nutrients.

➔ see Chapter 6, Soil Amendments

Organic Soil Subsidence

Organic soil subsidence is the loss of organic material through erosion or decomposition. Subsidence can be prevented through effective water management, cultivation practices, nutrient management, and cropping.

An effective water management program will balance the drainage required to provide soil strength and aeration, with the supply of sufficient water to both promote crop growth and minimize organic soil decomposition. Maintain waterlogged soil conditions to retard decomposition of some organic soils. Use caution when flooding organic soils, particularly muck soils that are highly decomposed or soil with shallow organic layers. Flooding can create restrictive layers near the surface that reduce the effectiveness of drainage systems. Drainage systems in wetland areas should be managed to regulate water table levels in response to changing crop and habitat requirements. Do



not allow organic soils to dry out since excessive drying may discourage re-wetting and may result in the loss of the surface layers from erosion.

Avoid tillage practices that pulverize and leave organic soils exposed to air as this promotes rapid decomposition. Use minimum tillage practices for all organic soils.

Forage Production on Poorly Drained Soils - in the Southern Interior of British Columbia