




**Table 2: Trees common on soil types (texture and drainage) in Alberta.**

Site Conditions	Tree Species	
Dry, sandy, gravelly or other rapidly- to well-drained soil	<i>Jack pine</i> Lodgepole pine Aspen	
Moist, well-drained clays and loams	Aspen Birch Elm Maple Balsam poplar White spruce	
Swampy	Black spruce	
Mucks and Peats	Tamarack	

Soil drainage and moisture conditions also affect soil temperature and as a result, plant growth. Under wet conditions low soil temperatures persist longer into the growing season becoming a major constraint on rooting depth and root growth. Organic layers on the soil surface provide an insulating effect to the soil and also act to reduce soil temperatures.

## **Soil reaction and salinity**

Soil reaction refers to the activity of hydrogen ions in the soil as measured by their concentration, and is reported in units of pH. A pH of 7 is considered neutral, above 7 is alkaline while below 7 is acidic. Soil reaction regulates the activity of many soil organisms that populate the soil. Many of the organisms that mediate organic matter decay processes and the transformation of soil materials function only within a narrow range of pH. The form and availability of many chemical compounds found in the soil is often pH dependant. Some of the macro- and micronutrients necessary for normal plant growth become more or less available to roots within a narrow range of pH. Some elements, for example aluminum, can become available in toxic quantities to plants at low pH.

Forest soils are usually low in pH. The pH of the soil has a strong influence on the type of plant species that are able to grow on a site. Some species, for example blueberries, grow well only on the acidic soils of the northern boreal forest region. Many tree species have adapted to life under more acidic soil conditions.

Soil salinity refers to the accumulation of certain salts like sodium (sodicity) in the soil. Salts in the soil increase the electrical conductivity, EC. Lab measurements determine the EC value of a soil sample. Salts are a natural by-product of the soil parent material and/or weathering processes.

High soil salinity may limit the growth and survival of certain tree species (Table 2). Salinity affects both the appearance and survival of trees because excessive salts in soil will deprive plants of water and nutrients. Sap in plant roots contains a certain level of salt, which attracts water into the plant roots by osmosis. Salts dissolved in the soil water decrease the salt gradient between the root cells and the soil water, reducing the rate at which soil water enters the roots. At high salt concentrations, little water and nutrients are able to move into the plant roots. The plant is unable to extract water and nutrients from the soil water and thus starves, even though there may be plenty of water and nutrients present in the soil. Salt damage includes stunting, fewer and smaller leaves, leaf burn, and needle yellowing. Pockets of saline soils occur across Alberta and are associated with high water tables and saline sub soils.

**Table 3: Salt tolerant trees for saline areas.**

<b>Tolerance</b>	<b>Electrical Conductivity EC (dS/m)*</b>	<b>Species (Trees, Shrubs and Ornamentals)</b>	
High	16	Siberian salt tree Sea buckthorn Silver buffalo berry	Hawthorn Russian olive
	8	American elm Siberian elm Villosa lilac Laurel leaf willow	Spreading juniper Poplar Ponderosa pine
Moderate		Caragana Chokecherry Green ash Mountain ash	Common lilac Siberian crab apple Manitoba maple
Low	4	Colorado blue spruce	White spruce
		Rose, Viburnum	Aspen
		Douglas fir	White birch
		Siberian Larch	Cotoneaster
		Scots Pine	Dogwood
		Balsam fir Cottonwood	Little-leaved linden

\*Salt levels are measured by electrical conductivity, or dS/m. These measurements can be found on soil test results. Higher conductivity means higher salt levels.

Adapted from: Transplanting Alberta Trees and Shrubs, Alberta Agriculture, Agdex 275/22-1.

### **Soil Hazards**

Excess soil moisture is also a concern because operating heavy equipment on wet sites can cause serious compaction, rutting, and puddling damage and should be avoided. Heavy equipment compacts and damages wet soil far more than dry soil. Compaction increases soil density and can negatively affect rooting depth and normal root growth. Ruts left in wet soil can be starting points for serious erosion problems. Soil puddling is the process by which the structure of the soil surface is destroyed, often leading to the formation of surface crusts and restricted drainage. On wet sites, use of heavy equipment for construction of roads and landings, harvesting, and site preparation is recommended only when the ground is frozen and when snow cover present to act as a disturbance buffer.

### **Soil compaction**

Usually a forest soil is greater than 50 percent pore spaces. Ideally, the pore spaces should contain equal volumes of water and air. Compaction of soil particles squeezes air and moisture out of the pore spaces. It may occur during grazing, timber harvesting, stand improvement, site preparation, or recreation activities. Sandy soils compact the least, while clays and loams are the most susceptible. Moist soils are more likely to compact than dry or frozen soils.

In compacted soils, water infiltration is slow and root penetration is difficult. In extreme cases, roots are forced to the surface, making the tree susceptible to insects, diseases, and mechanical damage. Trees growing on compacted soils are less vigorous and more stressed, natural regeneration is slower and erosion is more of a problem, than trees growing on soils that have not been compacted.

Compaction can be reduced in a number of ways. Use heavy equipment only on dry or frozen ground and limit the number of passes over the same area. Use of skid trails, and felling trees towards the trails, reduces the travel area of harvesting equipment. Machines with tracks rather than tires cause less compaction.

Refrain from activities on compacted areas for a number of years, to allow soil organisms and freeze-thaw cycles to help open pore spaces. This also allows the litter area to accumulate, decompose and improve the soil. In areas of severe damage, for example, on skid trails, roads and landings, deep ripping plows may be necessary to break up compacted soil layers; however this may injure nearby shallow rooted plant species.

### **Soil rutting and puddling**

Soil rutting involves the displacement of soil material by wheels and tracks resulting in depressions that act as mini-dams in the landscape changing localized drainage patterns (Figure 4). Localized pooling of water can raise the water table of a site increasing the overall wetness of the area and reducing long-term productivity. On sloping land, ruts can become channels that direct surface runoff, increasing soil erosion and sedimentation into surrounding water bodies.



*Figure 5: Soil rutting destroys soil structure and changes soil drainage patterns.*

Soil puddling most often occurs on soil surfaces where the organic layer has been removed by heavy equipment or by burning. The primary mechanism leading to surface crusting is the destruction of normal soil aggregates and loss of air-filled pores due to particle movements caused by hydraulic pressure applied to the surface by heavy equipment. Where surface soil aggregates are destroyed, clay and silt particles can be carried in surface runoff to local depressions where they settle to form dense,

structureless surface crusts upon drying. Saturated soils high in clay and silt content with few coarse fragments, shallow organic layers, and weak structure are most susceptible to puddling.

Reducing harvesting related activities when soils are wet, protecting existing forest floor organic layers, retaining harvest slash on site, use of low ground pressure equipment, and reducing the number of passes of heavy equipment over the soil are all useful practices that can reduce the risk of soil rutting and puddling damage to forest soils.

### **Soil erosion by water**

Four major factors contribute to the erosion of soil by water. These are:

- The nature of the precipitation – frequency, intensity, seasonal distribution, and the rapidity of snow melt.
- Soil properties – texture, type of structure, coarse fragment content, organic matter content.
- Landform properties – slope steepness and length.
- Amount and type of vegetation cover.

Water infiltration capacity and structural stability are perhaps the most important soil factors controlling susceptibility to water erosion. Soil compaction, rutting, and puddling by heavy machinery can reduce infiltration rates and concentrate surface water runoff in heavy traffic areas. Removal of surface organic matter as a consequence of forestry operations, forest fires, or intentional land improvement increases surface flow and exposes more of the mineral soil surface to the eroding action of rainfall and snowmelt.

When soil is washed away, it carries valuable nutrients with it, potentially decreasing soil productivity and reducing future forest regeneration and growth. Water erosion can lead to the formation of gullies and washouts in highly affected areas. Decreased water quality in streams, rivers, and lakes can result from increased turbidity. Since it is rich in nutrients, surface runoff encourages algae blooms and gives water an unpleasant taste, odor and appearance. Sediment from runoff may also fill in spawning sites or small pools in streams.

Water erosion along roads and landings is generally most serious because these areas can have compacted soils with low water infiltration capacities as well as sparse vegetation. Road grades should be minimized and cross ditches installed. Culverts and ditches should be unclogged to permit proper drainage. Streams should be crossed perpendicularly and water flow should not be disrupted. A buffer strip between roads and streams helps to filter runoff and the maintain water quality. On roads with long slopes, drainage dips and waterbars should be installed to slow water flow.

To reduce the risk of erosion during harvesting operations, maintain vegetative cover on erosion-prone land. Logging in the winter when the ground is frozen and avoiding soil disturbance on high-risk areas such as steeply sloping land can reduce the potential for erosion (Table 4). Buffer strips between harvest blocks and streams, rivers, and lakes should be maintained to reduce the likelihood that eroded soil material enters these water bodies. The size of buffer strips depends on many factors including the size of the harvested area, the type of forest harvesting method (e.g., clearcutting vs. selective

cutting), amount of forest floor disturbance, and the type of landscape (slope gradient and slope length).

**Table 4: Water erosion hazard (slope and moisture).**

Moisture Status	Slope Gradient (%)												
	0	5	10	15	20	25	30	35	40	45	50	55	60
Dry or Frozen	L	L	L	L	L	M	M	M	M	H	H	H	H
Wet	M	M	M	M	M	M	H	H	H	H	H	H	H
Low	L	Normal operating ground rules apply.											
Moderate	M	Appropriate harvesting methods should be used and detailed cut block plans prepared. Reforestation and reclamation plans should be prepared.											
High	H	Alternative harvesting methods such as tracked skidding and cable yarding should be considered to remove timber.											

Adapted from: Predisturbed Watershed Assessment Manual, Alberta Forest Service, ENR Technical Report No. T/100

### Loss of nutrients

Loss of the surface organic and mineral layers as a consequence of forest harvesting operations can negatively affect the potential productivity of the site for many years to come. Burning – as a result of naturally occurring forest fires or when used as part of a forest management plan (prescribed burning) can result in rapid loss of soil nutrients to the atmosphere by the process of volatilization or to groundwater due to enhanced soil leaching (Figure 5). Removal of organic matter and consequent loss of nutrients from the soil/site can also occur, for example, during road and landing construction, harvesting (e.g., limbing at the landing and whole tree harvesting), and site preparation (e.g., windrowing of logging debris and/or blading of the forest floor). Protection of the forest floor needs to be a prime consideration in any woodlot management plan to help ensure good regeneration, growth and productivity in future stands



Figure 6: Windrowing and burning of organic material can reduce long-term soil productivity.

### Soil Survey Maps and Aerial Photography

Soils information that may be of interest to landowners who currently have a farm woodlot or to those planning to afforest areas of marginal or eroded farmland, is available from a variety of sources. Hard copy soil survey maps and reports are available for all of Alberta at a variety of scales by calling the Government of Alberta Publications Office or online through the Alberta Soil Information Centre (<http://www1.agric.gov.ab.ca/asic>). Also accessed at the Alberta Soil Information Centre is AGRASID (Agricultural Region of Alberta Soil Information Database) and the Alberta Soil Information Viewer that allows the user to query and view detailed soils information for the agricultural region of Alberta, over the Internet. Provincial agriculture extension service centres may also be sources of soils information and expertise. Soil testing services are available from a number of private soil testing labs.

Aerial photography is available for all of Alberta at a reasonable cost. Air photos are useful tools for planning land use. Tones showing different soil types or drainage are very evident from the air. Interpreting what is seen on an air photo allows one to identify and calculate the area of management zones. Knowing this one can calculate the number and types of trees needed, planting plans and productivity expectations. Likewise, air photos are useful to calculate the yield of timber from an area and develop forest harvest plans. Air photos can be purchased in hard copy and digital forms from government (Alberta Sustainable Resource Development – Air Photo Distribution [http://www3.gov.ab.ca/srd/land/g\\_airphotos.html](http://www3.gov.ab.ca/srd/land/g_airphotos.html) ) and private company suppliers.

### Summary

Soil is a complex mixture of minerals, organic matter, soil organisms, soil atmosphere, and soil water

Soil development is determined primarily through interactions of the following factors: parent material (mineralogy, texture), climate (temperature, precipitation, freeze-thaw cycles), topography (slope gradient, aspect, and length), organisms (the importance of microorganisms in organic matter decay and nutrient availability), time (soil age), and human activity (soil degradation).

Soil texture and drainage largely control the potential productivity and species suitability of a soil/landscape. Soil pH and electrical conductivity (salinity) can also have a major influence on the growth of tree and shrub species.

Maintaining a healthy organic matter layer on the soil surface is critical in ensuring the long-term productivity of the forest.

Activities associated with forest harvesting can result in soil degradation (compaction, puddling, rutting, water erosion, loss of nutrients) if they do not adequately take into consideration existing site conditions.

## Beneficial Management Practices

- Operating heavy equipment on wet sites will cause soil compaction, rutting, and puddle formation.
- Compaction increases soil density and negatively affects rooting depth and normal root growth;
- Ruts are starting points for soil erosion;
- Puddles destroy soil surface structures and may lead to the formation of surface crusts and restricted drainage.
- Use heavy equipment only on dry or frozen ground and limit the number of passes over the same area.
- Use of skid trails, and felling trees towards the trails, reduces the travel area of harvesting equipment.
- Tracked vehicles cause less soil compaction than do wheeled machines.
- Using deep ripping plows to break up the soil layers may rehabilitate areas of severe compaction damage.
- Reduce soil puddling and rutting damage by reducing harvesting related activities when soils are wet, protecting existing forest floor organic layers, retaining harvest slash on site, using low ground pressure equipment, and reducing the number of passes of heavy equipment over the soil.
- To reduce water caused soil erosion:
  - Minimize road grades and install cross ditches;
  - Ensure ditches and culvert are kept clear to allow free flow of water;
  - Cross stream perpendicularly without disrupting water flow;
  - Maintain vegetated buffer strips between roads and stream to help filter runoff;
  - Slow water flow on roads with long slopes by installing drainage dips and waterbars.
- Reduce the risk of soil erosion during harvest operations by
  - Maintaining vegetative cover on erosion prone land;
  - Harvesting during winter;
  - Avoiding soil disturbance on high-risk areas such as sloping land;
  - Protect the forest floor to ensure good regeneration, growth and productivity in future stands.
- Recognize and understand the different soil characteristics that affect tree growth or other woodlot management activities.
- Consider species suitability for different soil types.

## Further Information

Canadian Soil Information System (CanSIS) provides soil information including soil maps, reports, and manuals for all of Canada. Publications available at the CanSIS website (<http://sis.agr.gc.ca/cansis/>) include The Canadian System of Soil Classification and Manual for Describing Soils in the Field.

The Agricultural Land Resource Atlas of Alberta (AGDEX 009-1) is a collection of agricultural resource maps that are useful in activities related to agricultural land management in Alberta. Copies of the publication are available through the Government of Alberta Publications Office, while individual maps are available at the Alberta Agriculture and Climate Information Service website (<http://www.agric.gov.ab.ca/acis>).

### Selected Internet Sites

<http://www1.agric.gov.ab.ca/asic> - Alberta Soil Information Centre

[http://www3.gov.ab.ca/srd/land/g\\_airphotos.html](http://www3.gov.ab.ca/srd/land/g_airphotos.html) - Alberta Sustainable Resource Development – Air Photo Distribution

<http://sis.agr.gc.ca/cansis/> - Canadian Soil Information System

<http://www.agric.gov.ab.ca/acis> - Alberta Agriculture and Climate Information Service