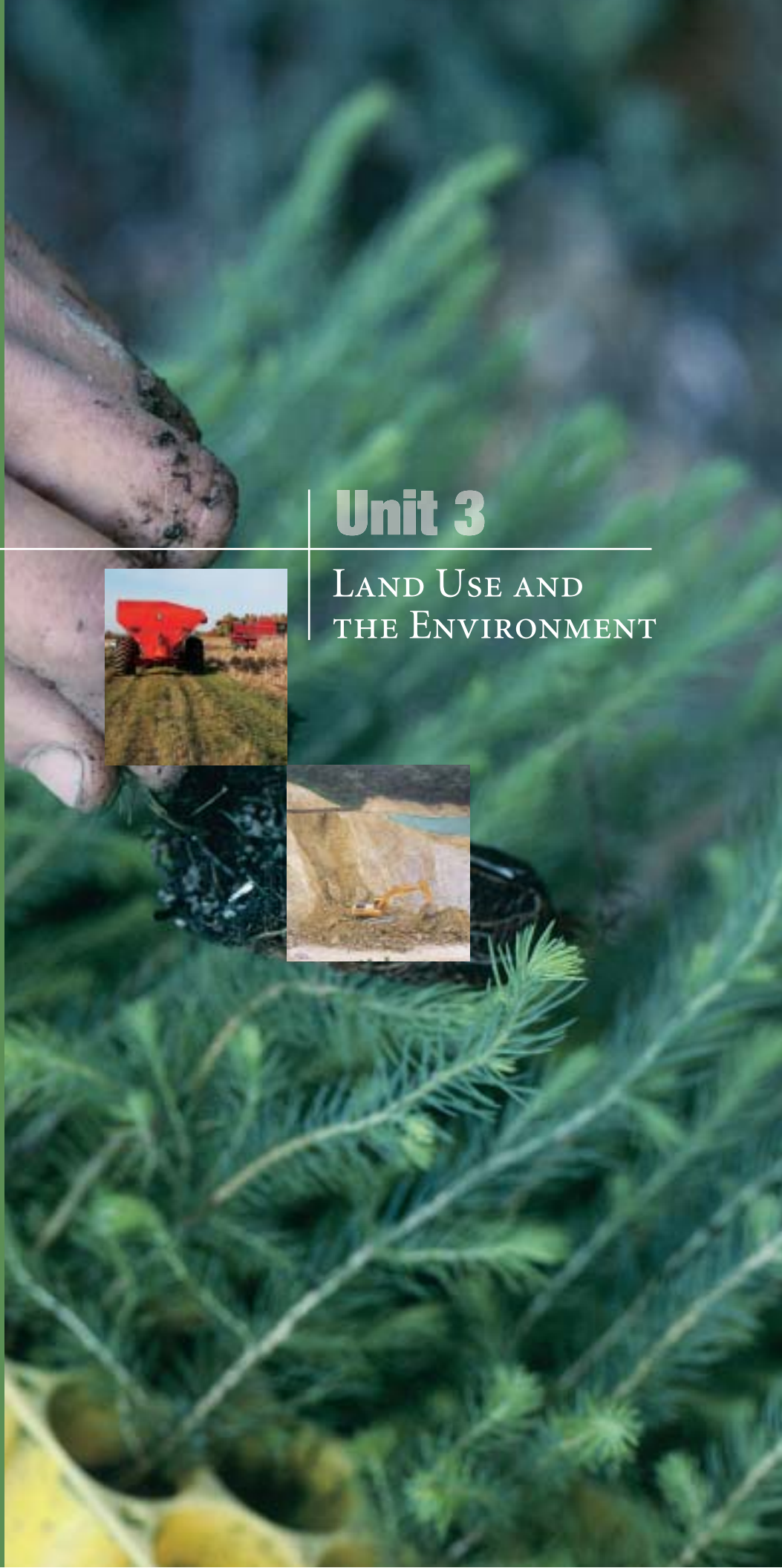
TOWARD A SUSTAINABLE FUTURE

Challenges
Changes
Choices



Unit 3

Land Use and the Environment

Chapter 9: Forestry in Newfoundland & Labrador

INTRODUCTION TO FORESTS AND FOREST MANAGEMENT

Figure 9.1: Sunset in the Boreal Forest.

Did You Know?

Original Forests are sometimes thought of as forests that existed long before significant human intervention. Information on original forests and today's forests can be found at: *www.globalforestwatch.org.*

From space it is easy to see why Earth is called the blue planet. But a closer look reveals wisps of green. Those are our grasslands and forests. In fact, if you exclude Antarctica and Greenland where no trees grow, forests cover almost one third of the Earth's land—39 million square kilometres.

Even though they cover much less of the Earth's surface than water, forests play a major role in supporting life. They regulate climate, recycle moisture, stabilize soils, control runoff, recycle the air, provide food, and serve as natural habitats for almost two thirds of all Earth's species.

Scientists are just beginning to understand the important role forests play in the recycling of greenhouse gases and carbon—a process which can have a profound impact on climate change.

Forests provide thousands of products that meet our everyday needs; wood fibre for paper, lumber, wood to heat our homes, and many commercial and traditional medicines. To ensure a sustainable source of these products, humans must take responsibility for protecting and preserving the forests and all their plants and animals that they support.

Did You Know?

Worldwide wood consumption is estimated to be 1.57 billion tonnes per year. This exceeds the use of steel and plastics combined. More than half of all the wood harvested worldwide is used for firewood and charcoal for heating and cooking.

Source: World Resource Institute

Increasing demands by humans for forest lands and products are depleting the world's forests. The loss of forests to wood harvesting, farming, and urbanization (cities and towns), as well as destruction caused by climate change, have reduced the world's original forest by fifty per cent and the losses continue. In under-developed countries, agricultural lands are being expanded into what was formerly forest to meet the growing demands for more food production.

Old-growth forests are the home for much of the world's biodiversity, many endangered species, and most indigenous human cultures. Old-growth forests, both tropical and temperate, play a major role in regulating climate.

Every year the Earth loses an area of forest about the size of Portugal. The estimated net loss of forests from 1990 to 2000 was 94 million hectares—an area larger than Venezuela! Much of the forest is being replaced by agricultural land for food production. The total estimated global forest area remaining in 2000 was approximately 3.9 billion hectares. Of that, 95 per cent was natural forest and 5 per cent was forest plantations.

Figure 9.2: Natural forest re-growth.
Photo courtesy Department of Natural Resources

The growing need for wood fibre and other resources is placing pressure on Canada's forests. Logging, agriculture, oil and gas exploration and development, settlement, mining, roads, increased recreational activities, urbanization, and air quality are all having negative impacts on our forest lands.

Newfoundland and Labrador's forest industry is facing its own challenges. Some of these challenges include the following:

- Wood and wood fibre availability for the forest industry
- Preserving the last of the old-growth forest on the island
- Protecting against insect and disease threats
- Managing the forest resources of Labrador
- Meeting the needs of recreational users
- Availability of wood for domestic use
- Managing for competing uses

Did You Know?

The Labrador Innu and the Newfoundland and Labrador Forest Service have partnered to develop one of the best forest management plans in Canada.

The Provincial Sustainable Forest Management Strategy has introduced a new vision for the province's forest ecosystems. This vision includes finding a balance between ecological, economic, and social values, while maintaining forest ecosystems that provide healthy, diverse populations of native species, a sustainable forest-based economy, and employment.

Despite growing concerns about our forests and their resources, there are success stories at the international, national, and regional levels. For example, by the mid-nineteenth century, New England had lost many of its forests to agriculture.

Vermont had only thirty five per cent of its forests standing in 1850, now it has eighty per cent. In India, where forests were decimated for firewood, the amount of forest land is now increasing. Forests are resilient and if managed properly, can provide renewable resources that support sustainable development.

CHECK your Understanding

1. What are the ecological values of forests? Why do we need them to sustain life on the planet?
2. Look around your classroom or your home. Make a list of products and materials that come directly from, or are derived from, the forest.
3. Outline some pressures facing the world's forests.
4. What are some challenges facing people who manage the forests of Newfoundland and Labrador?
5. What does the forest mean to the people of your community?

Figure 9.3: Conservation Officer conducting a sawmill inspection.
Photo courtesy Department of Natural Resources

For Further Discussion And/or Research

6. List the ways that the global forests support the planet. Choose one of those ways on your list and, through research, prepare a one page summary or a poster.
7. Through research on the Internet, find out about one forest issue in another country. Use pictures, text, and graphs to create a collage that communicates the issue.
8. Forests resources are seen by many as a store house of products. Through research, find out about unique products produced from forest resources.

The Canada Yew

Taxol is a common cancer drug. It can be extracted from any plant of the *Taxus* species including the Canada yew. Taxol was discovered in the late 1960s when companies began chemical prospecting for natural plant products that could be used to treat cancer. By the 1990s, Taxol was identified as one of the most promising anti-cancer drugs to be discovered in twenty years. The discovery of Taxol emphasizes the need to preserve forest biodiversity.

How many more potential drugs are yet to be discovered in the world's forests?

FOREST REGIONS

Approximately 32 per cent of Earth's land surface supports forests and woodlands. About 47 per cent of the world's forests occur in the tropical zone, 9 per cent in the subtropics, 11 per cent in the temperate zone, and 33 per cent in the boreal zone.

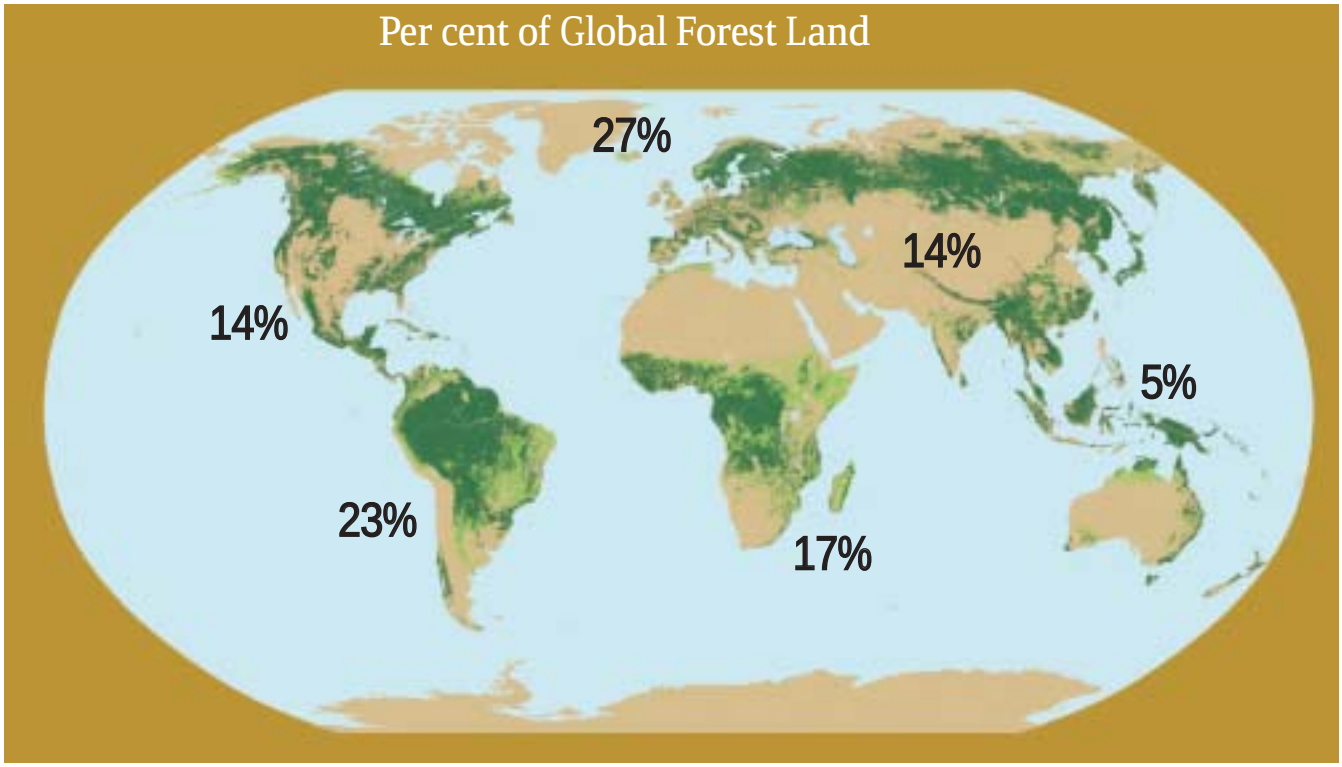


Figure 9.4: Global forest distribution. *Image source: http://www.fao.org/forestry/fo/fra/index.jsp*

Did You Know?

Nearly 183 million hectares of the country's non-commercial forest are wilderness and about two-thirds of Canada's 140,000 species of plants and animals live in the forest!

Canada's Forests

Canada contains about 10 per cent of the world's forests, that's about 417.6 million hectares of forested land. Of this, 234.5 million hectares (56 per cent) are considered commercial forest. These forests provide fibre for paper, wood for lumber, and a variety of other products. In 2002, forestry directly employed 361,400 people in Canada. The total forest industry is worth almost $74 billion to the Canadian economy. Besides industrial use, our forests contribute $11 billion to Canada's tourism industry and more than $100 million from growing and selling Christmas trees. Forests produce 11 million litres of maple syrup annually and Canadians use 4.2 million cubic metres of fuel wood to heat their homes every year.

Forests are not just valuable commercially. More than 20 million people use Canadian forests for hunting, fishing, trapping, recreation, photography, and berry picking (See Recreation and the Environment). Forests meet the cultural and spiritual needs of Canadians, particularly our Aboriginal population. Many Canadians use the forest for aesthetic reasons that range from admiring the beauty of remote forest land to using trees for shade in their backyard.

Figure 9.5: Family enjoying a canoe trip. *Photo courtesy Department of Natural Resources*

Canadian forests, like forests around the world, play an important role in preventing climate change. Forests absorb CO_2 from the atmosphere through photosynthesis and store the carbon for long periods of time. Young forests are best at removing CO_2 from the atmosphere; however, as the trees mature, forests remove less CO_2 from the atmosphere. But old forests are very effective for long-term carbon storage.

Forest Regions of Canada

Canada stretches more than 7,000 kilometres from the west coast to the east coast. Soil, water, climate and other conditions that support the forests vary from east to west and from north to south. Canada's forests are varied and are represented by ten forest regions and two subregions. Each region and subregion has its characteristic tree species and forest types.

Figure 9.6: Forest Regions of Canada. *Source: atlas.nrcan.gc.ca /site/english/learningresources/theme_ modules/borealforest/forest_regions.jpg /image_view*

CHECK your Understanding

1. What is the dominant forest type in Newfoundland and Labrador?
2. In table format, list the different ways that Canadian's use the forest.
3. What forest region(s) does Newfoundland and Labrador lie in?

For Further Discussion And/or Research

4. Through research on the web, write a one-paragraph description of the forest region(s) that southern Labrador and the island of Newfoundland lie in.

FOREST VALUES

How do you and your community use the forest? Why is the forest important to you? What you believe to be important is called **values**, your values. People value the forest in different ways. Sawmill operators use it as a source of needed logs for lumber. Paper companies use it as a fibre source for making paper. Hunters and fishers use the forest for recreation. Photographers and painters use it as a source of inspiration. Balancing the use of the forest by different individuals in a way that respects their values is a difficult challenge.

Forest Values

Ecological:
Soil generation, soil and water conservation, purification of air and water, nutrient recycling

Maintenance of biological diversity (habitats, species, and genetic resources), reducing climate change, carbon storage

Economic:
Industrial—wood fibre, wood for lumber and lumber products, wood for fuel, non-lumber forest products such as fibre, food, medicines, and craft products

Tourism—outfitting, bird watching, green landscapes

Social:
Employment and income, recreation, protection of natural, spiritual, and cultural heritage

Figure 9.7: Pulp and Paper Operations. *Photo courtesy Environment Canada/Peter Thomas*

People's values often conflict. An easy way to understand this conflict is to use an example like the purchase of a family car. Every member of the family considers different things when buying a new car. One member of the family may value good gas mileage and performance. Another may value safety and leg room. Another

member of the family may be more interested in the appearance and speed of the new car. Some of these values, for example color and performance, can be obtained together, but others, like speed and economy, cannot. To each person in the family, their value is the most important. When this family goes to purchase a new vehicle, each member will need to cooperate and work together, making sure everyone's values are considered in the decision. Not everyone will get what they want.

Efforts to preserve our forests face a similar balancing act. As with the purchase of the car, everyone in our community has his or her own reason for valuing the forest. Some place primary value on the forest's beauty, or on particular species of lichen, birds or mammals found there, while others may place a primary value on the forest as a source of wood harvesting and sawmilling, employment for their community. Some people value the forest as habitat for wildlife while others value it as a place for recreation. All of these values must be considered carefully by those who protect and preserve the forests of our province.

Figure 9.8: Many people value the forest as an area where they can get away from it all.
Photo courtesy Department of Tourism, Culture and Recreation

CHECK your Understanding

1. Summarize the economic value of forests to the Canadian economy.
2. What is a value? Give examples of values that relate to the forest.
3. Which is easier to measure, the economic value of cut wood, or the value of the beauty of an uncut forest?
4. Why might some people believe that values which are easier to measure are more important than hard to measure values?
5. In two or three paragraphs, outline how you use or have used the forest in the past.

For Further Discussion and/or Research

6. Interview one or two people in your community to find out how they perceive the role of the forest in their lives.
7. Select a region of the province other than yours and outline the role of the forest in the lives of the people that live there.

MINI-LAB ACTIVITY

Documenting Forest Values:

What is it about forests that are important to you and to your community? There are many ways to document findings about values. You can decide which method you will use before or after you've collected the information about values.

Maps—With maps you can plot identified locations using symbols and a legend for the names and values.

Artistic Maps and Murals—These maps have the same advantages as regular maps except, instead of symbols on the map, drawings and paintings may be used to show special places.

Video—Video can not only show special places, but also communicates the private thoughts and feelings of people as they talk about these places and the values they associate with them.

Photography—While photos may not always capture emotions as well as video, they are an inexpensive and interesting alternative. When compiled in a booklet or displayed with written descriptions, photographs can be a very useful tool to help describe the values of each place.

Web Page—Creating a website allows people in the online world to see and understand a little about your community and your forest values.

Forest Values Mapping

Background

Values can be mapped. If you were asked to indicate the locations of importance to you in your community on a map, you would be mapping your values. For example, if you indicated on the map that the corner store was important to you not because it is a place to buy donuts, but because it is where you hang out with your friends, then you have linked a value, in this case meeting and socializing with your friends, with a specific place.

In the following activity, you and your classmates will determine what your forest values are, map them, separate your values into different categories, and compare your values with the values of others. Groups of four students will work together. Each group will need a 1:50,000 topographic map of the local area.

PART ONE: Why is the forest important?

Everyone in your group must first agree on the meaning of "value."

Once you've agreed you will need to think about why the forest is important to you, your community, and the planet.

This may involve a shift in attitude as you begin to think about the forest in the same way you might think about a new car, motorcycle, or snowmobile.

Ask yourself what do you, your group (community), and the people on your planet value about forests?

Brainstorm and fill in the following table in your notebook.

I value the forest because:	My community values the forest because:	People on planet Earth value the forest because:

PART TWO: Bringing forest values home

Now that your group has discussed and identified forest values, the next step is to look at the things related to the forest that you value in your life. To do this, you must look closely at yourself and at your community. As a group, list these values in a table similar to the one below. Beside each value, make a connection to a place. If somebody in your group identified cross-country skiing as a value, find out where they ski and list the location. If they chose fishing, where do they fish? If one of your group members has a parent or guardian who is a forest worker, where is the forest that the

person relies on to earn his or her living? Or do they move frequently from one location to another? Does anyone have a family member employed in reforestation? Where does he or she work?

Each member of your group should fill in a table like the one below and then combine all the values in one common table and mark the location of each valued activity on your map.

You will need a topographic map of the area around your community. If possible, get a copy of a Forest Management District map from your nearest forestry office. This may be helpful in this activity.

Value	Location
Trout fishing	Logan's Stream
Berry picking	Burnet Hills
Forest worker	Ocean Pond Harvest Block

PART THREE: Mapping values

Now that you have described and located your values related to the forest environment, you can mark out the areas you value on a map that can be shared with others. This is called a values map.

A large map of the area around your community will be placed at the front of the class. Take your group's topographic map and list from part two and use coloured pencils to shade in the area or areas you value for your activity or activities.

PART FOUR: Grouping forest values

To do this part of the activity, you will need to use a chalk board. Each group will go to the board and write down its values next to a similar value. Values that are very similar need not be written on the board twice. When all the groups have finished, there should be clusters of similar values. Give each cluster a name and then transfer them to the sheet below and list the values.

Value group	Values
Harvesting plants and plant material	Berry picking, logging, picking mushrooms

So What?

What was the above activity all about? Now that we know what we value about our forests, we can begin to answer the question: are we managing our forest appropriately? Appropriate management means that valued forest activities are sustainable.

Before we go any further, we have to answer one more question:

Is the set of values you identified as important the same or different from values accepted by the community?

Check your list with the list below prepared by the Canadian Council of Forest Ministers to see if there are any differences.

Value Group	Values
Biodiversity	Establish protected areas Protect special places Protect wildlife habitats Protect native and valued species
Healthy forests	Natural processes Natural productive capacity Long-term ecosystem health
Soil and water	Water quality Soil Good forest policy and enforcement
Global Impacts	Stable climate Forests as carbon sinks
Benefits to Society	Commercial Timber Employment Non-timber forest products and services Recreation Forest products for personal use Heritage Spiritual values

Analyze and Conclude

1. Are there places on the map your class made where forest values overlap? If so, list them.
2. In many cases, overlapping values may lead to value conflicts. What kinds of conflicts might occur when values overlap?
3. Describe at least two methods that can be used to resolve conflicts associated with forest use.
4. Your favourite mountain biking trail or swimming hole is in an area that will be cut by a private company for saw logs (saw logs are sawn at a sawmill to make lumber). Explain what steps you might take to work with the company so that your values and the values of the private company are respected.

For Further Discussion and/or Research

5. Give an example where values conflict so that it is impossible for everyone to have "everything they want." Suggest a compromise that will respect each group's values.
6. What are the similarities and differences between your value categories and the set accepted by the Canadian Council of Forest Ministers? Were there any values that surprised you?

THE BOREAL FOREST

Figure 9.9: A characteristic example of Newfoundland and Labrador's boreal forest.
Photo courtesy Department of Natural Resources

Did You Know?

In ecology, a biome is a major regional group of distinctive plant and animal communities adapted to the region's physical natural environment, latitude, elevation, and terrain. A biome is made up of ecoregions or communities at stable steady state.
en.wikipedia.org/wiki/Biome

The boreal forest is an awe inspiring natural environment like no other on the planet. It is the Earth's largest biome, has the least biodiversity at the species level, with the largest number of individuals and is the slowest growing on the planet. The boreal forest is circumpolar, circling the Earth from Newfoundland and Labrador east through central and northern Norway, Sweden, and Finland, then from Leningrad east to the Ural Mountains and beyond, then across Siberia to Kamchatka on the Pacific and across mid-Canada back to Newfoundland and Labrador.

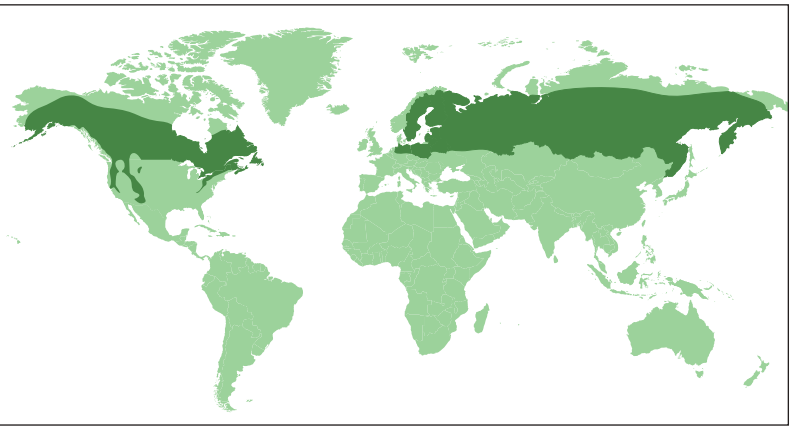


Figure 9.10: Global Boreal Forests (dark green area).
Photo courtesy www.washington.edu

The boreal forest is named after Boreas, Greek god of the North Wind. This forest type refers to needle leaved forests of pine, spruce, fir, and larch, intermixed with broad leaved poplars, birches, alders, willows, and dogberries (mountain ash). Boreal forests hold a large amount of water in uncountable numbers of bogs, fens, and water bodies such as marshes, shallow lakes, rivers, and wetlands.

The boreal forests are just as important to the global ecosystem as the tropical rain forests and deserve equal attention. Boreal forests make up eight per cent

of our planet's total forested land and contain twenty six per cent of the world's closed crown forests. Closed-crowned forests have tree canopies that cover more than twenty per cent of the forest floor. Closed-crowned forests are important sources of commercial wood.

Eighty two per cent of Canada's forests are boreal. The boreal forest biome is the largest biome in Canada, covering over half of the country. It is the breeding habitat for more than thirty per cent of North America's population of birds. It also contains twenty five per cent or 6 million square kilometres of the world's untouched forests. Canada's boreal forest contains an estimated 1.5 million lakes and some of the country's largest river systems.

Did You Know?

The dark green colouring of spruce and fir needles helps the foliage absorb maximum heat from the sun and begin photosynthesis as early as possible.

Fourteen per cent of Canada's population lives in the boreal region. The natural wealth of the boreal forest is very important to the Aboriginal peoples who have depended on the forest for thousands of years. About eighty per cent of Canada's Aboriginal people live in 600 First Nations communities in the boreal forest region. For many of the Aboriginal peoples, the animals of the forest provide food, shelter, and clothing. The trees are harvested for firewood and specific forest plants are also used for traditional medicine.

The Boreal Forests of Newfoundland and Labrador

All of the province's forests lie in the boreal forest biome. Of the island's total land area of 11.1 million hectares, slightly less than half, 5.0 million hectares, is forested. Labrador's landmass is approximately 29.3 million hectares with 18.0 million forested. The trees in our forests are relatively small with a limited variety of native coniferous species intermixed with hardwoods.

Did You Know?

The biomass of the Boreal Forest Biome is so huge that when trees are at their maximum growth rate in the spring and summer, the worldwide levels of carbon dioxide fall and the worldwide levels of oxygen rise.

Historically, natural succession patterns following repeated fires lead to the establishment of black spruce as the main species across much of central Newfoundland. As black spruce (*Picea mariana*) are a more commercially valuable tree for pulp and paper, current silviculture practices favour the continuation of this phenomenon. The major natural disturbance on the remainder of the island is insect/wind related, which is normally followed by the rapid re-growth of balsam fir (*Abies baisamea*).

Figure 9.11: The branches of a balsam fir tree.

Black spruce is the most abundant tree in Labrador, making up about two thirds of the forest there. On the island of Newfoundland, balsam fir is the most abundant tree with black spruce making up one third of the forests. Balsam fir prefers moist, well drained soils and can reach heights of up to 24 metres with ages from 70 to 100 years on the best sites.

Figure 9.12: Black spruce is the dominant species in the central portion of Newfoundland and the majority of Labrador's forested areas.

Did You Know?

- Black spruce is the province's official tree.
- One hundred fifty species of trees and shrubs grow in Labrador. That includes twenty three species of willow.
- Canada's northern boreal forest accounts for approximately twenty five per cent of the remaining intact forest ecosystems on Earth.

Some of these best sites are on the west coast of Newfoundland where forests are often stands of close to one hundred per cent balsam fir.

Moose graze heavily on balsam fir in winter on the island. Consequently, in areas with large moose populations and both spruce and fir, the proportion of spruce trees will increase. Balsam fir has a very high tolerance for poor growing conditions and is common on both wet and dry sites. Black spruce is the dominant species on the central plateau of Newfoundland where the summer climate is relatively dry and forest fires are common. The cones of the black spruce are ecologically adapted to fire, giving this tree species an advantage on fire-prone sites.

Hardwood forests types are relatively uncommon in this province. However, White Birch (*Betula papykrifera)* and Trembling Aspen (*Populus tremuloides*) stands are found throughout the island, especially in the deep river valleys of the Western Long Range Mountains and the Humber River and Red Indian Lake watersheds. Hardwoods may reach heights of twenty two metres at eighty years of age on moist fertile sites.

Trees of the Boreal Forest in Newfoundland and Labrador

Common Trees	Least Common
Black Spruce *(Picea marana)*	Trembling Aspen *(Populus tremuloides)*
White Spruce *(Picea glauca)*	Balsam Poplar *(Populus balsamifera)*
Balsam Fir *(Abies balsamea)*	White Pine *(Pinus strobes)*
Eastern Larch *(Larix laricina)*	Red Maple *(Acer rubrum)*
White Birch *(Betula papyrifera)*	Pin Cherry *(Prunus pensylvanica)*
Mountain Maple *(Acer spicatum)*	Choke Cherry *(prunus virginiana)*
Speckled Alder *(Ainus rugosa)*	Black Ash *(Fraxinus nigra)*
Mountain Alder *(Ainus crispa)*	Yellow Birch *(Betula lutea)*
Mountain Ash *(Sorbus americana)*	Red Pine *(Pinus resinosa)*

The Hardy Boreal Forest

The low temperatures, nutrient-poor acidic soils, and poor drainage favour the growth of conifers (cone-bearing trees). They dominate the boreal forest biome. Most conifers (except larch which are often referred to as "juniper" in this province) are evergreens and keep their leaves through the winter. Because of this adaptation, conifers produce their own food through photosynthesis for longer periods each year than do the deciduous trees, which shed their leaves every fall. Conifers still replace their old leaves over time, but this process takes three to four years. This adaptation also gives them an advantage over deciduous trees because they can expend more energy during each short growing season on new growth and on reproduction.

Plants of the boreal forest live in a harsh environment. Conifers, like many boreal forest species, have adapted to these demanding conditions.

Figure 9.13: Difference in growing conditions. Left: unrestricted growth; Right: restricted growth. Which example do you think came from the older tree?
Photo courtesy Department of Natural Resources

Jack Pine Makes a Stand:

In a small area of western Labrador is a region of natural growth called jack pine (*Pinus bansiana*). These jack pine stands mark the species' eastern most limit in North America. These natural stands are protected by the eighty-two square kilometre Redifir Lake-Kapitagas Channel Ecological Reserve. Climatic and environmental variations are the main reasons that its natural range does not extend farther east. However, other jack pine stands, originally planted by hand in sandy sites in the Goose Bay area, are growing well.

More than sixty per cent of Labrador is covered by boreal forest with a much higher proportion of black spruce than Newfoundland's forests. Located mostly in the south-central region, Labrador's great swath of green is one of the last remaining expanses of intact boreal forest in Canada. It is the eastern flank of the vast Canadian Boreal Forest that extends through Quebec, Ontario, Manitoba, Saskatchewan, and across the Northwest Territories. Labrador's forest has experienced far fewer human disturbances than Newfoundland's forest or the Acadian forest to the south.

Figure 9.14: Healthy new growth.

Forest Regeneration

The way forests grow back after harvesting is different from the way they grow back after a forest fire.

In harvested areas, the forests that regenerate have much greater biodiversity at first than those forests that grow back in burned areas. However, over time the harvested forest regrowth becomes less diverse than the burned forest regrowth, as a single tree species gradually comes to dominate the harvested area.

Managing a Frontier Forest

"Frontier forests are defined as the world's remaining large intact natural forest ecosystems-undisturbed industrially and large enough to maintain all of their biodiversity. Labrador's forests represent some of the last frontier forests left in the world. This situation creates unique opportunities, as well as imposing unique obligations for planning. The value of Labrador's forests is also recognized as an important part of the Labradorian identity and heritage. Planning participants from Aboriginal and non-aboriginal communities alike highlighted the need for protection of intact forests as an important objective in the plan."

Forest Ecosystem Strategy Plan for Forest Management District 19, Labrador/Nitassinan, 2003-2023, page 34.

Intact is a term most often used to describe a forest that has reached its mature stage. An intact forest is also referred to as a **frontier forest**. Labrador's boreal forest is called intact because most of its 180,000 square kilometres of forest has not been divided or changed in major ways by human developments such as commercial forestry, agriculture, mining, power lines, settlement, or road building. It experiences natural disturbances such as fires, the impact of which can be widespread.

Several factors have influenced the evolution of Labrador's forest. These factors include the cold northern climate, local and regional topography, soil type, drainage, and forest fires. The fires are the main natural disturbance; however, there have been major human disturbances as well. The three most notable are:

- the flooding that created the Smallwood Reservoir;
- mining in Labrador West;
- logging near Port Hope-Simpson in the 1970s that supplied pulpwood for the Labrador Linerboard Company.

The harvested area near Port Hope-Simpson has since re-grown. Research in this area is gathering important information about how harvested areas in central Labrador regenerate. North of the few balsam and poplar groves in Saglek fiord, Labrador has no true forest. The climate is too cold. Even in Labrador's more southerly regions, the growing season lasts only 100 days. Precipitation is high—up to 1,300 mm annually in the south. Soils in Labrador are generally cold, thin, sandy, poorly drained, and lacking in nutrients.

These are harsh conditions for many tree species, but not the hardy black spruce. Not only do they tolerate these conditions, they thrive in here where competitive species grow slower and diseases and fungi are fewer. As a result, the central Labrador close-canopy forest is approximately two-thirds black spruce. This softwood grows in solid stands reaching heights of ten to fifteen metres at maturity. It also grows in mixed forests with other tree species—most often balsam fir (particularly forest that regenerate after being logged) or with the hardwoods white birch (*Betula papyrifera*), balsam poplar (*Populus balsamifera*), and trembling aspen (*Populus tremuloides*). Forests composed mainly of hardwood are relatively rare in Labrador, although stands of aspen and birch grow near Lake Melville where the soil is deeper and richer in nutrients and the growing season is as long as some forested areas of Newfoundland.

ENVIRO-FOCUS

The Tuckamore Forest

Tuckamore or "tuck," the Newfoundland term for dwarfed and twisted white spruce (*Picea glauca*) and balsam fir (*Abies balsamea*), grows in abundance on the coastal fringe.

Figure 9.15: Tuckamores, like these near Stephenville Crossing, are small stunted evergreens with gnarled, closely matted branches.
Photo courtesy C. White

These forests are subject to very adverse weather conditions and the exposed trees have been highly modified by prevailing winds and salt spray. Onshore winds hurl salt spray inland, blasting vegetation with ice crystals in the winter and grit in the summer. Exposed needles and buds dry up and die, weak branches break off and, over time, this coastal forest takes on a wind blasted appearance. W.E. Cormack wrote in 1822: "The spruce-fir thickets are often only a few inches in height, the trees hooked and entangled together in such a manner as to render it practicable to walk upon, but impossible to walk through."

Figure 9.16: Tuckamores are blasted with salt spray and high winds to give them their characteristic wind swept look. Depending on how exposed they are, tuckamores may form trailing mats that hug the ground or reach heights of 1 to 2 meters.
Photo courtesy C. White

The leading edge of the tuckamore forest is formed by tiny mat-like tuckamore trees that are so low their tallest branches are only centimetres above the soil. This low wedge-shaped leading edge deflects onshore winds up and over the trees' crowns, protecting those trees farther inland.

Any new exposed branches of the forest soon die in the harsh coastal winds. The surviving lower branches form a dense carpet of green boughs oriented perpendicular to the wind direction, with dead tips occasionally protruding above the dense living blanket.

Source: Where Continents Collide: An Outdoor Education Curriculum, School District 3, 1999

ENVIRO-FOCUS

The Plight of Boreal Birds

Canada's boreal forests provide breeding habitat for more than thirty per cent of North America's birds. More than 380 species of birds have been observed in Newfoundland and Labrador.

Approximately 165 of those species are passerines, or songbirds—an order of birds that are also known as perching birds. Of the 165 species, approximately 90 passerine and several woodpecker species regularly make Newfoundland and Labrador their home. The majority of these species visit in spring and summer to breed and raise young. Many others are permanent year-round residents. Together, they form the bird communities that you see and hear in our forests, fields, barrens, and bog lands.

Figure 9.17: Ovenbird *(Seiurus aurocapillus). Photo courtesy USFWS/S. Maslowski/ WO-4549-51*

Forest songbirds have evolved in the forest habitats over thousands of years by adapting to a niche of opportunity. Each have their own needs—some prefer mature forests, others are prefer bogs and wetlands, while still others seek out younger trees and "edge" habitat.

Figure 9.18: Boreal Chickadee *(Parus hudsonicus rabbitsi).*

The boreal forest landscape is naturally composed of many interconnected habitats, each with bird species adapted to that environment. This varied but interconnected natural habitat is essential for the stability of the forest ecosystem and enriches its biodiversity.

Figure 9.19: Hairy Woodpecker *(Dendrocopos villosus terraenovae).*

Forestry has the single largest industrial impact on forest habitats in our province. Forest harvesting practices have a huge impact on the landscape and on the various species of birds that live there. This may harm some bird species populations and may benefit others. Responsible forest management has as its goal, not only the sustainability of the forest industry, but also the maintenance of healthy populations of all the bird species and other wildlife that depend on the forest habitat for their survival.

To achieve this goal of responsible forest management, forest managers are developing ecologically based management strategies to help ensure that species have sufficient habitat distributed across the landscape to survive at sustainable levels.

Figure 9.20: Tennessee Warbler *(Vermivora peregrine).*

Figure 9.21: White-throated Sparrow *(Zonotrichia albicollis).*

Figure 9.22: Dark-eyed Junco *(Junco hyemalis).*

Figure 9.23: Pine Grosbeak *(Pinicola enucleator eschatosus).* *Photo courtesy Environment Canada/Peter Thomas*

Figure 9.24: Hooded Merganser *(Lophodytes cucullatus).*

Forest Bird Guilds

Birds have adapted to take advantage of all the stages of growth in the forest. The groups of bird species that take advantage of different habitat types are referred to as guilds. Some examples of the guilds and the habitat they are associated with are described below.

Open/Edge Guild

Natural open/edge habitat is common in forests in Newfoundland and Labrador, created by the many ponds, bogs and barrens found throughout the province. Clear-cutting artificially creates edge habitat by removing trees from large tracts of land. Some species are well adapted to these conditions. Two of the species within the open/edge habitat guild include the Tennessee warbler (*Vermivora peregrine)* and the mourning warbler (*Oporornis philadelphia*). These species benefit from the dense low vegetation that is found around natural edges. The white-throated sparrow (*Zonotrichia albicollis*) is particularly well adapted to the open aspect of this habitat, often found probing the ground in search of seeds and insects.

Forest Generalist Guild

Birds in this guild are adapted to a wide variety of different forest habitats types, including different tree species, ages and heights. They can live in forest interiors or near edges. This guild tends to do well in second growth forests. Two of the more common birds you can find in this habitat are the dark-eyed junco and the gray jay (*Perisoreus Canadensis sanfordi*).

Mature/Overmature Forest Guild

Mature/over-mature forests have unique characteristics that some bird species depend on for survival. For example, as trees age, they become more susceptible to insect infestations, such as bark beetles. These insects provide food for bark foragers, like brown creepers (*Certhia familiaris americana*), golden-crowned kinglets (*Regulus satrapa satrap*)and various species of woodpeckers.

Mature forests are also important for cavity-nesting birds—those species that build nests in tree holes, or cavities. Woodpeckers are the best known group of cavity-nesting birds, but there are many others including tree swallows (*Iridoprocne bicolour*), black-capped (*Parus atricapillus bartletti*) and boreal chickadees (*Parus hudsonicus rabbittsi*), red-breasted nuthatches (*Sitta Canadensis*) and winter wrens (*Troglodytes troglodytes aquilonaris*). Even some ducks, such as the common goldeneye (*Bucephala clangula Americana*) and hooded merganser (*Lophodytes cucullatus*), use tree cavities for nesting. Still other seed-eating species take advantage of good cone crop production in mature forests. Some examples that are found in our forests include pine grosbeaks (*Pinicola enucleator eschatosus*), purple finches (*Carpodacus purpureus nesophilus*) and white-winged crossbills (*Loxia leucoptera leucoptera*).

Species at Risk—Forest Birds

Despite the best efforts of forest managers in Canada, there are growing concerns for the survival of our forest songbirds. Monitoring programs have determined long-term declines in Canada's migrant songbirds over the last thirty years. Some of these declines have been so great that several bird species that inhabit our boreal forests have been designated as species at risk. Since 2004, the Committee on the Status for Endangered Wildlife in Canada (COSEWIC) has designated two boreal songbird species as At Risk in Newfoundland and Labrador – the Red Crossbill (*Loxia curvirostra pusilla*) (Newfoundland subspecies listed as Endangered) and the Rusty Blackbird (*Euphagus carolinus nigrans*) (listed as Special Concern). Also the gray-cheeked thrush (*Hylocichla minima minina*) was designated as a vulnerable species under the *Provincial Endangered Species Act*.

Figure 9.25: Tree Swallow in tree cavity *(Iridoprocne bicolour).*

Figure 9.26: Red Crossbill *(Loxia curvirostra). Photo courtesy Environment Canada/Peter Thomas*

Although we do not know exactly what is causing these population declines, it is clear that we do not have all the facts for sustainable forest management. A few of the many potential forest problems that must be factored into the complex management model are climate change, habitat loss or habitat fragmentation, release or accumulation of toxins, and invasion by alien or non-native species. The boreal bird species at risk may be an indication that we need to pay more attention to boreal forest management in Canada. A more complete understanding of how these birds use different habitats and how they move around within these habitat types would allow biologists and managers to make more informed decisions about how to use the resources of the forest in a way that sustains the biodiversity and health of all the native species of plants and animals.

MINI-LAB ACTIVITY

Trends in Gray-cheeked Thrush Populations

The population of the gray-cheeked thrush has declined in Newfoundland and Labrador over the last twenty five years. The data provided below were collected by a monitoring program known as a Breeding Bird Survey (BBS) – an annual, volunteer-based survey conducted along the same route every year.

Figure 9.27: Gray-cheeked Thrush *(Hylocichla minima minima).* Photo courtesy USFWS/ WV-Menke Birds1 - 7470

What do these data tell you about the trend of the gray-cheeked thrush along these seven BBS routes for insular Newfoundland? Unfortunately, as the table reveals, surveys are not always conducted along every route in every year.

Year	St. John's	Heart's Delight	Gander River	Burgeo Road	St. Paul's	St. Anthony	Port Saunders
1980	11	38	17	-	-	9	10
1981	10	17	3	14	1	8	11
1982	2	8	3	19	20	14	9
1983	5	33	0	6	6	14	8
1984	7	8	1	9	4	6	2
1985	-	-	2	-	-	-	-
1986	12	-	-	-	-	-	-
1987	1	-	0	-	-	-	-
1988	6	-	-	-	-	-	-
1989	-	-	0	-	-	-	-
1990	-	-	-	-	-	-	-
1991	-	-	1	-	-	-	-
1992	-	-	-	-	2	-	-
1993	-	-	-	2	0	-	-
1994	-	-	-	-	1	-	-
1995	-	-	-	-	0	-	0
1996	-	-	-	-	-	-	-
1997	-	-	-	-	2	-	-
1998	1	-	-	-	-	-	-
1999	0	-	-	-	-	-	-
2000	1	-	-	-	-	-	-
2001	0	0	-	-	-	-	-
2002	0	-	0	1	-	-	-
2003	0	-	0	3	-	3	-

Figure 9.28: Population counts of Grey-cheeked Thrush at selected locations on the island of Newfoundland.

CHECK your Understanding

1. List the characteristics of the Boreal Forest.
2. Briefly outline the extent of the Boreal Forest globally and nationally.

For Further Discussion and/or Research

3. The dominant trees in the Boreal Forest are conifers. How are these species adapted for the harsh northern environment?
4. Through research find out what animals are often found in boreal forests in Newfoundland and Labrador.
5. Use a camera to document the same species of trees growing under different environmental conditions.

FOREST SUCCESSION

The forest is always changing from season to season and over time. While the individual trees die, the boreal forest, as a living, self-sustaining community, will persist for many thousands of years. Two types of changes influence the nature of the boreal forest during its life cycle—seasonal changes and succession changes.

Figure 9.29: Balsam fir forest succession to savannah in Gros Morne National Park (GMNP). Browsing by moose, an introduced species has inhibited what would have been natural succession to another balsam fir forest. *Photo courtesy Parks Canada/Carson Wentzell*

Figure 9.30: Balsam fir regeneration on 30 year old disturbance in GMNP. The lack of significant regeneration is due to the overabundance of moose. *Photo courtesy Parks Canada/Carson Wentzell*

Seasonal changes are the short-term changes that occur over each twelve-month cycle. These changes include periodic loss of needles, reduction of tree sap in winter, loss of leaves in the fall, accumulation of snow and ice on the forest floor in the winter, internal and external changes in plants and animals, varying temperatures and changes in the length of day light.

A succession change occurs over a long time and includes two types: primary succession changes and secondary succession changes.

The Amazing Black Spruce Cone

Some tree species, such as the black spruce, depend on fire to help them reproduce. The black spruce produces two types of seed cones: closed cones and open cones. Open cones drop their seeds each year and sprout in any area where there is enough light to grow. Closed cones cannot release their seeds unless heated to a high temperature by fire. The heat of the fire melts the resin that acts like glue to keep the seed cone closed.

Try it for yourself. Put a black spruce cone in the microwave and watch what happens.

Primary succession begins with a barren area like sand or rock that does not support vegetation. On rock, succession begins with soil-building organisms such as lichen. These kinds of plants are called pioneering organisms because of their ability to slowly break down the rock and build pockets of soil that will support larger vegetation. As soil accumulates, new plants called colonizers germinate, grow, and reproduce thus beginning a new stage of succession.

Secondary succession occurs when vegetation is destroyed or removed by a disturbance. After a fire, insect damage, major blow-downs, or after forest harvesting, the forest regenerates in a gradual and complex way. Succession is also responsible for changes in the abiotic features of the forest such as microclimate, soil characteristics and height of the water table.

Forest Fire

Before humans appeared in North America, fires were controlled by the presence of trees and shrubs that fuel the fire, by weather, by topography, and by climate. Today, particularly on the island of Newfoundland, most forest fires are the result of human carelessness. These are deliberately suppressed to reduce property damage and protect forest resources.

Figure 9.31: A forest fire in Central Newfoundland.

Fire plays an important role in the life of a forest. Fire enriches the soil, limits disease, creates habitat for plants and animals and releases nutrients. Fire burns away most of the **overstory** vegetation and allows sunlight to reach the ground. There the sun's rays stimulate the germination of seeds from the fire hardy and pioneering species. In fact some tree species, such as black spruce and native pines, depend on fire to help them reproduce. See the sidebar for an explanation of how one species has evolved to take advantage of fire.

Did You Know?

Fire is as natural as the rains and winter snows in the boreal forest. It is essential to maintain forest health. In fact, the boreal forest has adapted to fires.

Today, many forest fires are suppressed to preserve valuable timber and property and to protect landscapes. But the prevention of forest fires can have negative effects on ecosystems in at least two ways. Forests protected from fire become older with little or no development of younger growth. Younger forests are more productive and have more food available for a variety of animals. Older forests create a build-up of broken limbs and other deadwood that fuels any fires which

may occur. This extra debris becomes fuel in the event of a forest fire, causing it to burn so hot it destroys the roots and seeds necessary for begin succession growth.

Did You Know?

Tens of thousands of hectares of productive forest on the Avalon Peninsula have been repeatedly burned and are now classified as "soil barren" even though this heath land is capable of supporting tree growth.

The heath land created as a result of the burning will only return to forest with human intervention such as scarification and planting.

Positive Effects	Negative Effects
• a natural event for the boreal forest • creates the conditions for regenerating the forest (e.g., creates large openings, destroys stands of old/unhealthy trees, prepares soils, releases nutrients) • creates a forest of differing stand types, ages and habitat - a healthy forest ecosystem • enhances the regeneration of black spruce and other fire adapted species	• consumes commercially valuable forest • may eliminate a preferred species for harvesting or may change the age and species mix of a forest • poses a threat to human communities • may have negative localized affects on fish and wildlife • disruption of silviculture planning

Figure 9.32: Forest Fires: The Good, the bad, and the ugly.

Source: Sustainable Forest Management Training for Front Line Forest Worker: Participant's Workbook, Western Newfoundland Model Forest, 1999

CHECK your Understanding

1. Distinguish between seasonal and successional changes in the boreal forest.
2. Define succession and give examples of primary and secondary succession.
3. What are two important roles of forest fire?
4. Forest fires are suppressed to protect valuable forest resources and property. What are some disadvantages of preventing forest fires?

For Further Discussion and/or Research

5. If there is a boreal forest next to your school, use a digital camera to take a photo of the same spot twice a week throughout the school year. Assemble a Power Point presentation and run it with a two-second transition between each shot. You may be surprised at the number of changes you observe.

OLD-GROWTH FORESTS

Trees can have a much longer lifespan than humans and the old growth forests persist for hundreds of years. But even those old-growth forests that are too remote or protected from human impact are subject to natural disturbances that can cause larger areas to be replaced by new forest growth. This natural cycle is unique for each forest type and location. For example, in most regions of Newfoundland and Labrador, naturally occurring disturbances will disrupt forest growth before it reaches its maximum age. However, there are forested areas that have avoided naturally occurring disturbances and are considered to be **old-growth**.

Figure 9.33: While they may not look like much to the casual observer, the trees in this area of Gros Morne National Park are very old. *Photo courtesy Parks Canada/ Rob Hingston*

The smallest Old-Growth Forest

Tucked away at the base of the Tablelands in Gros Morne National Park is one of Newfoundland and Labrador's oldest and "smallest" old-growth forests. Two different species of trees are evident within this forest. Towering an impressive 20 cm above the ground is the common juniper, which can attain ages up to 250 years. The common juniper struggles against the harsh elements of the Tablelands. Cold temperatures, poor soils, driving winds, and a lack of moisture have caused these trees to grow at a very slow rate. A typical age for larch is 50 years and they usually have a trunk diameter of 4 cm, which translates into a height of 1-1.5 m.

Old-growth forests are classified as primary or secondary old-growth. Primary old-growth forests have never been directly influenced by humans. They have ecological and scientific values that cannot be replaced or duplicated except by nature. Secondary old-growth forests have been disturbed by humans during their development. Occasionally though, some secondary forests may have recovered to the point where they resemble primary forests.

Characteristics of old-growth forests due to the lack of either human or natural disturbance include:

- A variety of tree species and other vegetation dominated by many trees near the age of the maximum life expectancy for their species, often at wide spacing;
- Presence of very old—not necessarily big—trees;
- No evidence of a major fire or insect infestation;
- Multi-layered forest with distinctive lower, middle, and upper levels of trees and vegetation;
- Rarely there may be multiple age trees if the forest has passed through a number of minor natural or human disturbances;
- Continuous vertical distribution of foliage with standing dead trees (snags) and large logs on the ground (woody debris or dead falls).

Did You Know?

Most of the forest of the Avalon Peninsula is secondary old-growth forest.

TREES

I think that I shall never see

A poem as lovely as a tree.

A tree whose hungry mouth is prest

Against the earth's sweet flowing breast;

A tree that looks at God all day,

And lifts her leafy arms to pray;

A tree that may in Summer wear

A nest of robins in her hair;

Upon whose bosom snow has lain;

Who intimately lives with rain.

Poems are made by fools like me,

But only God can make a tree.

Joyce Kilmer (1886-1918)

Value of Old-Growth Forests

It is wrong to place a dollar value on nature. This is especially true of old-growth forests. There are powerful reasons for conserving old-growth forests and allowing younger, natural origin stands to mature into old age:

- Natural, old-growth forests give scientists information to help understanding forest processes that humans have not influenced. By researching in old-growth forests and comparing the results to research in second growth forests, scientists can learn how human disturbances affect forest growth and development.
- Old-growth maintains unspoiled characteristics that contribute to spiritual value for Aboriginal people and others.
- Old-growth forests provide necessary habitat for the survival of habitat specialist species.
- Old-growth forests with large trees store carbon. Carbon storage in plants is greatest in large trees. Converting these trees into fuel and other products that may be burned or broken down quickly increases atmospheric carbon dioxide.
- Old-growth forests provide a source of genetic diversity that may be lacking in secondary forests.
- Old-growth forests are an important feature of the environment supporting ecotourism values.

Old-growth forests in Newfoundland and Labrador

Old-growth forests in Newfoundland and Labrador are classified as **wet boreal**. They are dominated by conifer species that receive moisture from precipitation and fog, especially during summer months. Because of high moisture levels, forest fires rarely occur in the wet boreal forest.

Various plant and animal species are distinct in the old-growth forest. These include species of flowering plants, beetles, Collembola (primitive wingless insects), oribatid mites which live in forest soils, mammals and birds. The Newfoundland marten is a suggested **indicator species** for the Newfoundland and Labrador old-growth

Indicator Species:
A species which is specific to the living conditions in a particular habitat is called an "indicator species."

forest. The Newfoundland marten however, is not distinct to old-growth forests and occupies a range of forest habitat in varying stages of succession.

Did You Know?

Balsam fir trees in Newfoundland and Labrador's old-growth forests range from 70 to 150 years in age but may infrequently reach 250 years in some areas.

The trees in the wet-boreal forest are replaced by either full-stand or gap (single tree) replacement. Full-stand replacement occurs when insects or wind destroy a large area of forest. Gap replacement occurs when the death of an individual tree or small group of trees allows more light to reach the forest floor so younger trees can grow.

A comparison of even aged mature and old-growth forests in Newfoundland has shown that old-growth balsam fir forests have a different structure than mature balsam fir forests. These differences are summarized below.

Old-growth balsam forest	Mature balsam forest
A range of tree ages if present from young to 100+ years resulting in a multi-tier tree canopy	60+ years
Lower tree density	High tree density
Trees of various heights	Trees of similar heights
More larger diameter trees	Smaller diameter trees
Lower diversity and density of deciduous shrubs	Higher diversity and density of deciduous shrubs
Greatest snag density	Few snags
Taller snags	Short snags
More logs on the ground	Few logs on the ground
More open canopy	More closed canopy
No disturbance by insects, wind, fire or humans during usual disturbance period	Disturbance by insects, wind, fire or cutting
More moss ground cover	Less moss ground cover

Figure 9.34: Comparison of old-growth and even-aged mature balsam fir forest.

The Main River Old-growth Forest

Figure 9.35: A section of the Main River, a river which was designated a Canadian Heritage River in 2001. *Photo courtesy Parks Canada*

One of the most studied tracts of Newfoundland old-growth forest is located in the Main River watershed. The forest in this area has been unaffected by major disturbances for several centuries, allowing it to reach maturity and take on old-growth characteristics. The forest in the Main River watershed continually undergoes **gap replacement** as old trees with their stems weakened by fungal infection succumb to the wind and other natural forces. The increased growing space and available light and nutrients allow small trees to develop and increase in size. This is called **release**. Balsam fir is a species that can survive in shady conditions for many decades until release.

Did You Know?

Recent research by Father John McCarthy indicates that the Main River boreal forest is among the oldest boreal forests in the world?

It is estimated the Island of Newfoundland has approximately 4,800 square kilometres of forests capable of supporting gap replacement. The area extends from Cloud River in the north, to Main River in the south. Many species of plants and animals contribute to the ecological diversity within the gap replacement forest.

When people visit the Main River old-growth forest they expect to see very large trees since trees tend to continue to grow throughout their life span. However, size is not always a true measure of old growth for several reasons.

First of all, large is a relative term. Some species can grow much larger size than other species in the same environment. Second, under difficult growing conditions, trees may grow very little in most years and not at all in others. For example, some trees in the Main River region have survived for many decades, perhaps even more than a century, but are less than ten metres tall. However, through gap replacement, these trees could undergo a period of more rapid growth.

Case Study

Logging the Main River Watershed

One of the most publicized examples of conflict between industry and public forest values is over logging in the Main River watershed.

Located on the lower east side of the Great Northern Peninsula, this watershed is one of the last old-growth forest areas on the island. The rights to the wood in the watershed are held by Kruger, the company that owns Corner Brook Pulp and Paper Company.

When Corner Brook Pulp and Paper planned to log this area, local environmentalists mobilized in opposition. As part of an environmental assessment, an **Environmental Preview Report (EPR)** was requested. The EPR supported claims of forest uniqueness. And while Corner Brook Pulp and Paper committed to a no clear-cutting policy, and accepted less access to the watershed than they wanted, environmentalists felt that even that among of harvesting was too much.

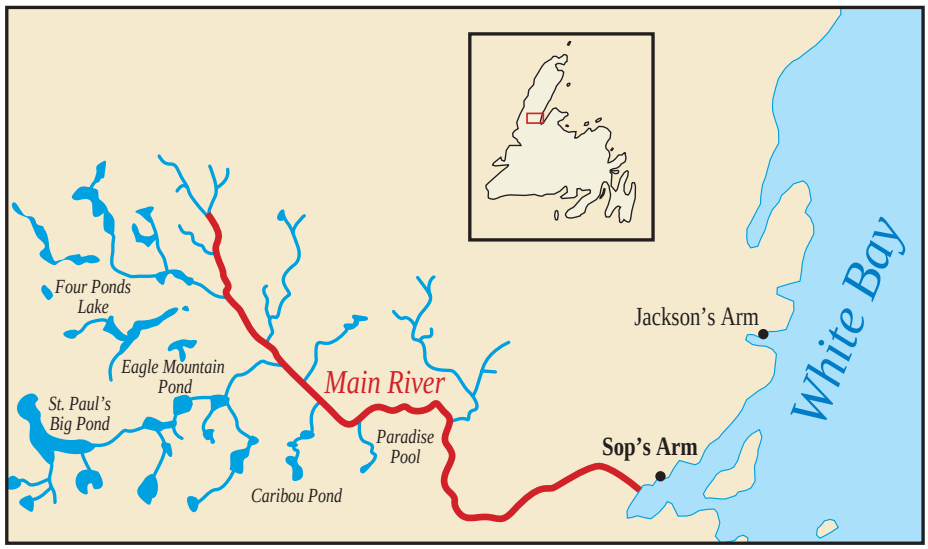
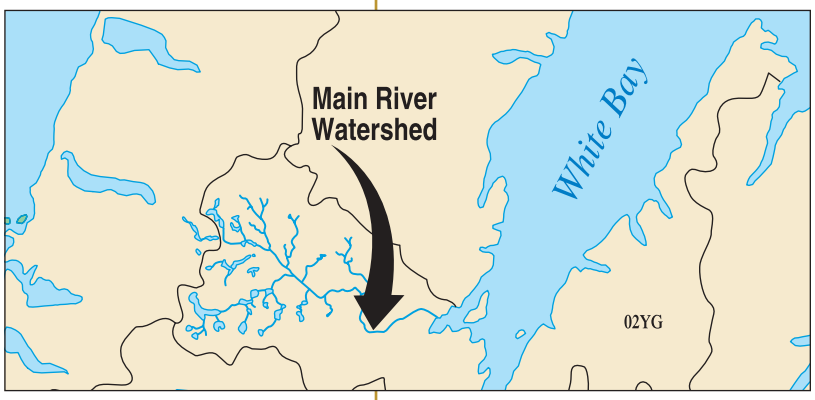


Figure 9.36: Main River watershed. *Map courtesy Department of Natural Resources*

The Main River Dispute

The Main River flows from the Long Range Mountains through a boreal forest and grassland before emptying into White Bay at Sop's Arm. Because of its inaccessibility the river was protected from significant human impact until 1986. It is one of the few rivers in Newfoundland and Labrador in which natural ecological features had remained untouched. For the past three decades, the Main River has generated much debate, both at the local level and beyond. The following timeline demonstrates the complexity of an environmental issues and the length of time required to resolve them.



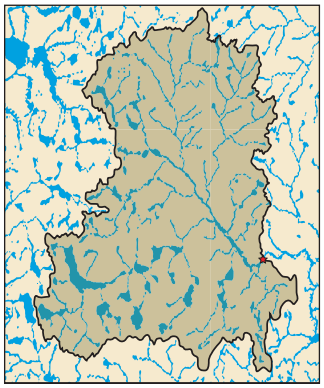


Figure 9.37: Main River watershed. *Photo courtesy Department of Natural Resources*

Figure 9.38: The Main River watershed. The black line defines the area within the watershed, which is defined by the high points of land that trap water within the watershed area. *Map courtesy Department of Natural Resources*

1972 Parks Canada began a wild river survey program. The program was designed to identify Canadian rivers that had recreational potential. The Main River was identified among the most outstanding rivers in the country.

1974 Newfoundland Hydro proposed to construct a transmission line from the Lower Churchill and across Main River at Big Steady, a unique and spectacular grassland zone. Opposition resulted in Newfoundland Hydro agreeing to change the route of the proposed transmission line. The transmission line was never built.

1982 The Wilderness and Ecological Reserves Advisory Council (WERAC) submitted a proposal to create a wilderness reserve to take in the entire Main River watershed. However, the Department of Forestry identified a major conflict with the proposal; the pulp and paper mill in Corner Brook held extensive timber rights within the Main River watershed that dated back to 1938.

1984 Kruger submitted a proposal to begin logging activities in the Humber/Main River watersheds. In response, WERAC requested a full environmental review. Permission to cut was granted on condition of an approved environmental impact statement and consultation with WERAC. Discussions began the following year, but no agreement could be reached. The provincial government approved construction of an access road and bridge over Main River.

1986 Kruger submitted its environmental impact statement in which it recommended a small ecological reserve at Big Steady and an uncut buffer zone along the remaining length of the river. The proposal was rejected by the Department of Environment because the minimum 100 metre buffer zone proposed by the Kruger did not provide adequate protection to preserve the river's natural state. A second environmental impact statement received approval, but discussions were ordered between WERAC and Kruger to resolve differences between the two parties.

1987 WERAC submitted a Cabinet paper that sought to establish an emergency ecological reserve totalling 10,300 hectares at Main River (this included 500,000 cubic metres of commercial timber). The Department of Environment recommended acceptance of Kruger's proposal. Cabinet agreed with the Department, resulting in a protected corridor along the Main River that encompassed 5,234 hectares at Big Steady. The protected zone along the river would be a minimum of 100 metres wide to reduce the environmental impact of harvesting. WERAC ceased to pursue the matter.

1987 Kruger began harvesting operations. However, shortly afterwards, the provincial government directed the company to move its logging operations to the Upper Humber.

1991 Government officially nominated Main River for heritage status. Soon after, public consultations and open house discussions started to develop a management plan for Main River. With so many competing interests, this process took more than a decade to complete.

1996 Kruger registered its harvesting plan for the Main River. The 1997-2001 plan and two changes were released from the Environmental Assessment process. A third change, which Corner Brook Pulp and Paper (CBPP) submitted in December 1999, was to harvest in two areas not originally included in its plan, near Main River North and the east side of Sheffield Lake. It was this third change that prompted a fresh wave of opposition.

2000 Main River Coalition of environmentalists was formed in St. John's. The coalition was formed because of concerns about Kruger's proposed change to harvest timber in the Main River-Sheffield Lake region. The Coalition argued that harvesting within the region would destroy tourism and recreation opportunities. Moreover, it felt that the proposal threatened the ecological integrity of Gros Morne National Park and would "destroy one of the last old-growth forests on the island." Also, the coalition expressed deep concern for the population of Newfoundland pine marten.

2001 Main River officially became a Canadian River Heritage System river.

2001 Kruger registered its new five-year plan for Management of District 16 (the Main River is included in this district). On 9 August 2002, the minister of Environment announced a conditional release of this plan from further assessment under the Environmental Protection Act. Despite protests of environmentalists, this meant logging could start. Kruger committed to no clear cutting in the Main River watershed where old-growth forest characteristics exist.

Logging the Main

Kruger's harvest plan stated that it will harvest up to 25,000 cubic metres per year from the watershed area using "selective harvesting techniques." Over the course of the five-year plan, logging activities within the watershed were to represent no more than 2.5 per cent of the total amount of merchantable timber in the area. As per Kruger's operating plan, it was required to develop and implement an environmental effects monitoring program. The program's objectives are:

- To confirm the accuracy of the environmental impact of harvesting in the watershed area;
- To establish the success of any measures taken to reduce environmental effects;
- To execute measures to alleviate any negative environmental effects that had been identified. Kruger must report annually, beginning with the operating plan for 2002;
- To address the impacts of harvesting in the Main River watershed on the Newfoundland marten, forest birds, on ecosystem connectivity to Gros Morne National Park and on the structures of the old-growth boreal ecosystem.

Source: Logging the Main River Watershed: Environmental Policy and Politics in Western Newfoundland, Honna Janes-Hodder and Peter R. Sinclair, Memorial University of Newfoundland, 2003

QUESTIONS

1. Why was Main River given the designation as a Canadian Heritage River?
2. Search the Web and determine where the other Canadian Heritage Rivers are located. Also, briefly describe what makes these rivers so special.
3. Since Corner Brook Pulp and Paper (CBPP) is harvesting in the Main River watershed, how might this affect the status of Main River as a Canadian Heritage River?
4. The endangered Newfoundland marten is found within the forests near Main River.
   a. How might logging affect marten population in this area?
   b. What measures are CBPP taking to minimize marten disruption?
   c. Should logging activities in this region be modified or suspended altogether because of the presence of marten?
5. If CBPP was forced to stop harvesting in the Main River area, what economic repercussions may result?
6. How might forest harvesting in the Main River area affect the ecological integrity of Gros Morne National Park?

7. After a long struggle with environmental activists (e.g. Main River Coalition), Kruger was obliged to accept less access to the watershed than the company desired, but most environmentalists feel they have lost the battle. Why?
8. The struggle over logging in the Main River watershed is a valuable illustration of power and politics. It pits a multinational corporation against citizen groups as they argue over the critical economic and environmental issues.
    a. Imagine you are an employee at Kruger's Corner Brook Pulp and Paper Mill, which side of the debate would you be on? Would you become an active supporter to lobby for your job? Or would you lobby to protect your natural heritage? Is it possible to balance these two needs?
    b. During this controversial period, the provincial government had to be very careful in making a decision for or against logging the Main River region. What types of economic, social, and political issues were they dealing with?
    c. Do you see the Main River Coalition as a well-informed group of concerned individuals doing their part to protect our natural environment? Or do you see them as a radical group with more concern for protecting trees than people's jobs.

For more information on their "Save the Main River" campaign contact the Protected Areas Association Newfoundland and Labrador

ECO SPOTLIGHT:

Father John McCarthy: *Canadian Geographic Magazine's* People's Choice Award

Figure 9.39:
Father John McCarthy.
Photo courtesy Parks and Natural Areas Division of the Department of Environment and Conservation/Erika Pittman

For a long time, Jesuit scholar Father John McCarthy thought it would have to be one thing or the other, either the priesthood or a career in ecology. Born in Newfoundland in 1958, Father McCarthy spent his formative years in St. John's. He soon discovered a love of the outdoors and developed a deep appreciation of the beauty of the province's forests and ecological systems. His boyhood enjoyment of forest hikes and water sports drew him to the study of ecology after high school. He graduated from the University of New Brunswick in 1980 with a Bachelor

of Science and Forestry degree and went on to earn a Masters in soil science at the University of Florida.

His journey on the way to a career in environmental concerns was interrupted when he began studies for the priesthood and was ordained for the Society of Jesus in 1994 in St. John's.

> *"I feel that we have opened up a new vision of the forest, not only in scientific terms, but also in terms of how we view forests from an affective, moral and spiritual perspective."*
>
> - Father John McCarthy

The Society of Jesus encouraged Father McCarthy to pursue a doctorate in ecology with a view to preparing him to help the Church and the world at large to question the role of faith in the environment. His doctoral thesis was on old-growth forests, particularly the boreal forest found on the Northern Peninsula of Newfoundland. This includes the watershed of the Main River, one of the province's two designated Canadian Heritage Rivers. The Main River watershed is part of one of the last remnants of primary old-growth forest on the island. When Father McCarthy first suggested that he wished to study the province's old-growth forests, he was told there were none left on the island. Thanks to his research that view has now changed.

"I feel that we have opened up a new vision of the forest, not only in scientific terms, but also in terms of how we view forests from an affective, moral and spiritual perspective. I think that both scientific research and social activism can serve to enlarge the context in which we can now talk publicly about our concern for the forests," says Father McCarthy.

"I think we must create a wider space for the conversation to happen around stewardship. There's only one world and we are here in it. How do we sustain our resources in the challenges that we face, such as the loss of the Atlantic fishery, which had a great impact on my home province? What do we feel when there is overcapitalization of certain industries in certain areas because political concerns have caused undue influence to be brought to bear?" he says.

In 2002 Father John McCarthy was honoured with the *Canadian Geographic Magazine's* People's Choice award for his efforts to promote the protection and restoration of Canada's environment, especially his work in Newfoundland's old-growth forests.

Source: BC Catholic, "Finding God in nature: Priest-ecologist honoured for environmental work," By Laureen McMahon

Case Study

Maintaining secondary mature forest in the Avalon forest.

Background

The Avalon Forest in the central region of the Avalon Peninsula is an area of approximately 50,000 hectares that is classified as ecologically different from the rest of the Avalon.

The Avalon Forest has been logged by operators from Conception Bay, St. Mary's Bay and Trinity Bay. Each of these operations had camps in the woods where up to 250 people at a time were engaged in logging. Shortly after Confederation, a dispute arose between two sawmillers about driving logs on the Colinet River. The dispute went to court and ended up in the Supreme Court of Canada in 1955. The case cited the construction of a dam at Ripple Pond in 1901 and a similar sized dam on Back River Pond in 1914. These river systems were used continuously for driving logs cut from all the reaches of the Colinet watershed. Forest access roads began to enter the area in 1974 and water driving ended in 1981.

Forest Succession

Meades and Moores (*Forest Site Classification Manual*, 1989) report that the Avalon Forest was spared the ravages of fire that decimated forests in the surrounding landscape. The Avalon Forest is recycled naturally by insect outbreaks and windstorms which produce stands of even age. Succession of forest cover types in the Avalon Forest is the same when it is cut as when it is disturbed by insects and blowdown. That is, after disturbance by either of these agents, the forests regenerate in the same way and grow toward the same species composition, notably balsam fir, yellow birch (*Betula lutea*), and white birch on better soils and growing conditions. Moose which were successfully introduced in the western part of the island in 1904 were first reported on the Avalon in 1941. Since that time moose have become the primary cause of vegetation change from the natural succession to fir and birch (which moose like to eat) to spruce forests or to open grasslike conditions.

Competing Land Uses

The Avalon Peninsula has fifty per cent of the human population of the province. There is tremendous pressure on forested areas for a number of competing uses such as recreation, cabin development, agriculture, protected areas, domestic and commercial wood cutting, residential expansion, roadways, and industry infrastructure. Many of these uses involve permanent removal of the forest.

Others involve removal of a portion of forest or a disruption of normal forest functioning for a period of time.

There are a number of protected areas on the Avalon, such as the Avalon Wilderness Area. It was established mainly for caribou management but also includes 5,000 hectares of Avalon Forest. In this area the protected can cycle naturally. Some biologists and others argue that there is not enough area under current protection and that this could undermine the efforts of forest managers to recognize all values and to have ample forest in all age-classes in order to ensure adequate habitat for various species such as arboreal lichen which rely on particular ages of forest or forest conditions.

Roads are a source of concern for many who see them as another step in the loss of an area's natural environment. Access roads constructed for cutting timber, silviculture, and forest protection work can also become avenues for cabin or agriculture development, illegal occupation, or even dumping by unscrupulous people. Forest operations are seen as a forerunner to loss of the forest by some. Others favour forest operations and subsequent decommissioning of forest access roads, replanting more area of growing forest and reducing pressure on forested areas for other land uses.

QUESTIONS

1. Outline the value of a mature forest on the Avalon Peninsula.
2. Identify competing land uses in the Avalon forest. How can these competing land uses be reconciled?
3. How can we be ensured of having a range of different age-classes of forest at any time?
4. How is the moose population impacting on forest succession in the Avalon forest?
5. Why is it important to maintain mature forests in the Avalon forest area?

CHECK your Understanding

1. What are the characteristics of an old-growth forest?
2. Compare and contrast a mature balsam fir forest with an old-growth balsam fir forest.
3. Would you recommend protecting a large tract of old-growth forest for 100 years? Support your answer.
4. The forest of the Main River watershed is considered "old growth." What makes this forest old growth? Give an argument for protecting it.

For Further Discussion and/or Research

5. Imagine that you are part of a group trying to preserve a portion of forest near your community. Design and produce a poster that communicates the value of this forest to the public.

Summary

Like the fishery, the forest has played an important role in the culture of the people of Newfoundland and Labrador. For many, lifestyle and life's work still revolve around the forest and its resources. The province is blessed with vast stands of forests that contribute globally to maintaining climate and balance. Today we use the forest primarily for wood fibre to make paper and saw logs for lumber to build homes. Secrets the forest holds for the future are unknown. Biofuels, new medicines and ecological relationships are yet to be discovered. On this alone we must work toward sustainable forest use to meet the needs of today's uses and users and more importantly those of tomorrow. A healthy forest maintains and sustains its ecosystem. Indicators of healthy forests include biodiversity change, resilience (the ability to recover after a disturbance), diverse wildlife habitat, aesthetic appeal, and resource sustainability. Both natural and human influences can impact these indicators in positive and negative ways. Some natural influences such as fire, insects, and disease may appear to have a negative impact. But these processes are actually essential for the regeneration and succession of healthy forests.

Over time, we have built up our knowledge about how best to manage our forests to maintain their health. As you can imagine, the way forests are managed today has changed a great deal since the early days of forest harvesting when the resource seemed unlimited and little thought was given to the impact of logging operations. Today we know that while this resource is renewable, we must respect nature's limits. Out of an estimated five million hectares of boreal forest in Newfoundland and Labrador, approximately three million hectares is available for wood production.

Chapter 10: Managing our Forests

A healthy forest maintains and sustains its ecosystem. Indicators of healthy forests include biodiversity change, resilience (the ability to recover after a disturbance), diverse wildlife habitat, aesthetic appeal, and resource sustainability. Both natural and human influences can impact these indicators in positive and negative ways. Some natural influences such as fire, insects, and disease may appear to have a negative impact. But these processes are actually essential for the regeneration and succession of healthy forests.

Did You Know?

The largest consumers of that wood are the two pulp and paper companies that operate on the island: Corner Brook Pulp and Paper (owned by Kruger) and Abitibi-Consolidated. Together they control 1.73 million hectares (fifty nine per cent) of productive forest land. Kruger alone controls thirty three per cent. Balsam fir and black spruce are the primary species harvested.

Over time, we have built up our knowledge about how best to manage our forests to maintain their health. As you can imagine, the way forests are managed today has changed a great deal since the early days of forest harvesting when the resource seemed unlimited and little thought was given to the impact of logging operations. Today we know that while this resource is renewable, we must respect nature's limits. Out of an estimated five million hectares of boreal forest in Newfoundland and Labrador, approximately three million hectares is available for wood production.

Figure 10.1: Corner Brook Pulp and Paper Facility. *Photo courtesy Department of Natural Resources*

HISTORY OF FOREST MANAGEMENT

Before European contact, Aboriginal peoples had, over thousands of years, evolved a hunter-gatherer lifestyle that allowed them to live in harmony with the forest ecosystem. For the first 400 years after European fishermen and settlers arrived in Newfoundland, they exploited the forest primarily to support their work in the fishery. Wood was used for the construction of buildings, boats, and for stages

and flakes on which the salted cod fish was dried before shipment overseas. Wood was also a primary source of fuel. By the late 1800s the Newfoundland railway opened up the interior of the island, providing access to its resources. Approximately 10,000 square kilometres of land was granted to R. G. Reid as partial payment for constructing the railway. Forests on this granted land would later provide much of the timber for a thriving pulp and paper industry. In the early 1900s additional timber leases were issued to pulp and paper mills in Grand Falls and in Corner Brook. Some of these grants and leases are still in existence today.

Figure 10.2: Domestic Logging, Trout River. *Photo courtesy Parks Canada*

By the beginning of the twentieth century, sawmilling, primarily of white pine, was a flourishing industry. But the demand for pulp and paper was growing rapidly. In 1909 the Anglo-Newfoundland Development Company started a pulp and paper mill in Grand Falls (owned today by Abitibi Consolidated Inc.). A second pulp and paper mill was opened in Corner Brook in 1923 by the Newfoundland Power and Paper Company Ltd. (owned today by Kruger Inc.). The Labrador Linerboard Mill was opened in 1972 in Stephenville. Abitibi Price Incorporated later purchased that mill and converted the facility to a pulp and paper mill until they closed it in 2006.

Before the early 1900s, it was not considered necessary to protect the forest resource. Basic forest protection from fire and insects was the primary role of forest managers from the early 1900s to as recently as 1975. However, the seeds of change were planted in 1972 when a Federal/Provincial task force on forest management made recommendations that, in 1974, shifted responsibility for forest management to the provincial Department of Forestry. As part of the provincial management strategy, companies involved in tree harvesting were required to submit forest management plans to government. During the 1980s, the practise of **silviculture** became an important tool in the management of Newfoundland and Labrador's forests.

Silviculture is the development, cultivation, and reproduction of trees.

Did You Know?

Each year silviculture programs include 3,600 hectares of planting and 4,700 hectares of pre-commercial thinning. In 2006, the two hundred millionths tree was planted in our province!

The *Forestry Act* of 1990 implemented new changes in forest management. Since then, forests must be managed not just for timber, but for all forest values. That includes environmental values that support the principle of sustainable development. To accomplish this, planning teams were established in forest management districts across the province. These teams consisted of forest industry representatives, government resource managers, non-government organizations, and the general public. The teams worked with the district managers to determine the forest values in the district and to prepare a forest management plan for the area.

PARADIGM SHIFTS IN FOREST MANAGEMENT PRACTICES

During the past two centuries, resource management approaches for our forests evolved from Exploitation through Utilitarian to an Ecosystem Based or Sustainable Approach.

Figure 10.3: Hauling wood in winter using traditional technology.
Photo courtesy Department of Natural Resources

Exploitation

This approach uses resources as intensively as possible to provide the greatest profit to the user with no consideration for the sustainability of the wood supply. Exploitation was practiced early in our history and continues today in some areas of the world in both developed and less developed countries. In the early days of forest harvesting there was little concern about effects on soil erosion, water quality, and wildlife habitats. If loggers in the 1800s had a slogan it would probably be something like: "Get in, log the trees, and get out." When the trees were gone, the loggers got out and repeated the process somewhere else.

Utilitarian

The utilitarian approach to forest management, beginning in the 1930s, was about sustained yield—managing the renewable resources (such as soil, forests, wildlife, and fisheries) so that they will never run out. One of the basic practises supported by this approach is that, once a forest has been logged using clear cutting, block cutting, strip cutting, or selective cutting, the site must be reforested to provide timber for future generations.

Ecosystem Based or Sustainable Approach

Approached from an ecosystem-based perspective, forest resource management includes the multiple uses that we make of a forest based on our values. A forest, for example, is not only a source of timber. It has many other values such as wildlife habitat, scenic beauty, flood and erosion control, and a preferred environment for many types of recreation. Forests must therefore be managed so all of these other values can be realized.

The ecosystem approach is sometimes called sustainable forest management. It includes the elements of social, ecological, and economic sustainability.

Foresters applying this management approach would consider in the timber harvesting phase:

- Will water runoff be increased? If so, will this result in flood damage?
- Will there be soil erosion that could destroy trout or salmon spawning beds in streams below the area that is harvested?
- Will soil fertility at the site be reduced because of erosion and affect the healthy development of seedlings on the harvested site?
- What will happen to moose, pine marten, birds, and other wildlife when the forest that provided food, cover and breeding sites is removed?
- What effect, if any, will this timber harvest have on the build-up of carbon dioxide in the global atmosphere and the warming of the planet?
- Will biodiversity and growth increase in a sustainable way after cutting mature timber?

In the ecosystem-based approach to conservation, forest resources are used without negatively affecting the physical and biological environments.

Ecosystem Based Management

Ecosystem-based management ensures the long-term health of forest ecosystems and provides ecological, social, and economic opportunities for the benefit of present and future generations. Forest mangers recognize that the forest consists not only of trees but of soils, waterways, wildlife, insects, diverse plant life, and even fungi and bacteria.

a) Ecosystem-based management supports multiple uses. Forest ecosystems are very complex and ecologists are just beginning to understand them.

Forests are important because they provide a vast range of services to society including clean water, employment, recreational opportunities, and a place to be alone with nature. Managing our forests sometimes requires actions that exclude or limit human activity. For example, in order for natural resources to regenerate naturally, it may be necessary in vulnerable places to establish protected areas.

b) Ecosystem-based management involves protecting and managing entire ecosystems—not just parts of it. Many species depend on two or more interconnected ecosystems to survive. Those connected ecosystems must all be protected to ensure the survival of the species in the area. For example, to protect a species of fish in a river or lake, ecosystem-based management demands that more be done than simply improving stream habitat. For the protection of the fish and the stream, steps must be taken to protect the surrounding watershed. That means management should include control of human activities many kilometres away from the stream. It would include measures to eliminate careless road building, to control sources of pollution, and to ensure that ecologically sound forestry is practised upstream from the fish habitat.

c) Ecosystem-based management requires good scientific information and constant monitoring of conditions. In this way management approaches that are not working can be adjusted, and those that are working can be adapted and used in other ecosystems.

CHECK your Understanding

1. What events or issues might be responsible for the shift in resource management approaches?
2. Are all of the above management approaches being practiced at the local, regional, and global levels? If so, give specific examples.
3. Has the view that Earth and all things on it "exist for the sole benefit of humans" changed? What ecosystem management practice might support or contradict your view?
4. Which non-government agencies (NGOs) might have influenced the move from traditional forest management practices to ecosystem-based practices?
5. Who is affected by paradigm shifts in forest management practices? How is the general public affected in the short and long term?

For Further Discussion and/or Research

6. Are we (individuals, provinces, countries, continents, the global community) now shifting toward the concept of sustainability? Is the shift real or perceived?
7. Write or invite a forest manager to visit your class and do a presentation on modern forest practices.

ENVIRO-FOCUS

Forest Management in Labrador - The Forest Process Agreement

In 2003, the Province released its Forest Ecosystem Strategy Plan for Forest Management District 19 Labrador/Nitassinan. This plan has been welcomed by many as a new and more balanced approach to forest management. The plan is one outcome of a process that began in 1995. Before it could be completed, this plan required the input and consensus of a variety of forest stakeholders.

One of the most important stakeholders in Labrador are the Innu. For more than 2,000 years, the Innu have used the forest of their homelands (which they call Nitassinan) for food, shelter, and protection, and as a resource for tools and medicine. It is a place of great cultural and spiritual importance to the Innu.

In 2001, the Province and the Innu Nation signed a historic agreement-the Forest Process Agreement. This agreement recognizes "the significance of the Innu land claim in this District, and how decisions made under this [forest strategy] plan could affect those interests." It laid out a process for communicating about the forest and for resolving issues that might arise from harvesting. It also described the process to involve the Innu Nation in the development of sustainable forestry practices and ecosystem-based management plans.

The first 20-year Forest Ecosystem Strategy Plan was released in 2003 for the central Labrador area. Contributing to this process were the following:

- The Forest Process Agreement
- The participation of the Innu
- The input of many other stakeholders from industry-in particular forestry and tourism
- The input of the provincial and Nunatsiavut governments, and the communities of Labrador

The Forest Ecosystem Strategy Plan was shaped by the principles of ecosystem-based planning (EBP), used elsewhere in the province. Significantly, the Labrador EBP process involved stakeholders-the Innu-who brought to the table their traditional knowledge of the forest and the clear alternative vision for managing sustainable harvesting of the forest that came out of that knowledge. Because the forest was relatively untouched by logging, there were opportunities to build in ecological considerations from the start.

Ecosystem-based planning is a relatively new approach right across Canada. It takes ecological, cultural, and economic values into account. As the Strategy Plan says, "It helps create a balance between timber and non-timber values." It puts these values in a hierarchy, and acknowledges that maintaining ecosystem health "is the basis for sustaining cultures, which in turn is the basis for sustaining economies."

According to the 2003 Strategy Plan, decision-making in based on three priorities:

1. Ecological responsibility: All activities will protect, maintain, and where necessary, restore fully functioning ecosystems at all levels of planning over long time frames.
2. Cultural responsibility: All activities will respect and protect Aboriginal and non-aboriginal cultural values.
3. Economic responsibility: All activities will strive for economically sound practices and products. Local communities and organizations will assist in decision-making and provide key direction in realizing economic opportunities.

The Labrador/Nitassinan Strategy Plan provides for the establishment of three levels of ecological protected areas in the forest management district:

1. Landscape level (required to preserve, for example, the important habitat of migrating caribou).
2. Watershed level and the stand level (which can protect rare plant communities or streams that are important for aquatic life).
3. Cultural protected areas level (to be developed to protect areas of important cultural significance and ensure they cannot be harvested).

The cultural imperatives that the Strategy Plan respects include:

- Cultural heritage values
- Landscape aesthetics
- Hunting and trapping
- Non-timber forest products (such as berries)
- Socio-economic factors
- Domestic forest products

The 2003 Labrador/Nitassinan Strategy Plan provides for an annual allowable cut of approximately 198,600 cubic metres of forest in central Labrador (District 19). This is about half the amount that previous planning efforts had considered acceptable.

The ecosystem-based approach requires participation of stakeholders not just for the 2003 Strategy Plan, but continuing over time.

The 2003 Strategy Plan for central Labrador addresses four ecological objectives:

1. Identification of species at risk
2. Wildlife and habitat management
3. Ecosystem health and water quality
4. Global implications

SUSTAINABLE FOREST MANAGEMENT

Ecosystem-based management requires that forests be managed to sustain forest values. That means forest managers must monitor and review what they are doing, compare the results of their actions against where they want to be going, and then use that information to learn from their successes and their mistakes. Criteria and indicators, developed by the Canadian Council of Forest Ministers, are used for determining changes in forest condition and as a basis for decision making.

The indicators are measurable and continually measuring indicators allows forest managers to record trends and changes in the forest over time.

The five criteria for sustainable forest management are:

1. Conservation of Biological Diversity

Managing forests to maintain biodiversity means that representative landscapes, special places, wildlife habitat, native and valued species, and genetic diversity are considered.

2. Maintenance of Forest Ecosystem

A healthy forest is an evolving forest. Forests are continually growing and changing. In fact, natural disturbances are a vital part of forest ecosystems. Insects, fires, and storms may damage or kill some trees, but that doesn't necessarily mean they are harming the forest. A healthy forest is a productive forest, with constant new growth of trees, other plants, and animals. A healthy forest can sustain change and disturbances without losing its productivity.

3. Conservation of Soil and Water

Soil and water are essential to life. The quantity and quality of water and soil affect forests. Forest practices, including logging and the construction of access roads, may impact on the quantity and quality of soil and water. Maintaining a consistent quantity and quality of water is a sign of sustainable forest management and is necessary if the forest is to continue to provide for current and future generations.

4. Contribution to Global Ecological Cycles

It's been said forests help the planet "breathe." Forests play a vital role in helping to regulate global biological cycles related to carbon and water. Forests store carbon in trees and in soil, and release carbon as the trees decompose, are burned and, as manufactured wood products, decay. Carbon dioxide is the most significant of the "greenhouse gases." These gases are an essential component of Earth's atmosphere, and they help keep the planet's temperatures within a liveable range. However, there is growing evidence that human activity may be causing the level of green house gasses to exceed the desired levels. This may be artificially increasing the temperatures experienced all over the planet (thus "global warming"). Healthy forests can help to store some of that carbon and therefore remove it from the atmosphere.

Did You Know?

Fires and insect infestations are natural to the forest. Think of the forest as a skin. When we get a skin infection or a burn it heals in a matter of days. Fires and insect infestation damage heals but it may take up to eighty or hundred years for all signs of the damage to disappear. That's normal and it seems a long time to us, that's because human time and forest time are different!

5. Economic and Social Benefits

Many benefits come from the forest for current and future generations including employment, recreation, personal use, heritage, and spiritual values. Forests are important to people for a wide variety of reasons. Good ecosystem management accepts the importance of all values and balances the sometimes-competing visions of the forest in a manner that attempts to accommodate all values

International and National Model Forest Network

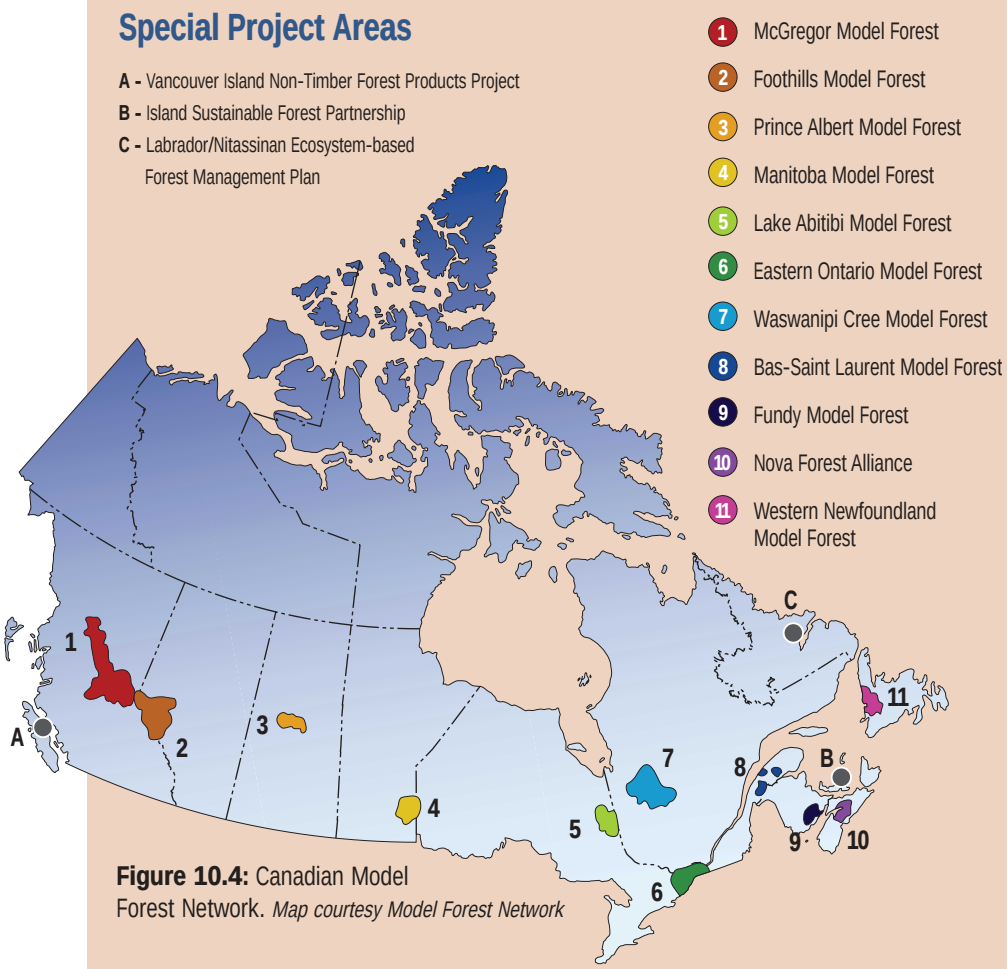


Figure 10.4: Canadian Model Forest Network. *Map courtesy Model Forest Network*

The International Model Forest Network is a Canadian success story that is reaching around the globe. Formed in 1992, the network is a group of volunteer partners working toward the goal of sustainable forest management.

The International Model Forest Network combines the social, cultural, and economic needs of local communities with the long-term sustainability of forest lands. There are more than thirty model forests in existence or under development.

The model forest is both a geographic area and a group of partners. Geographically, a model forest must include a land base large enough to represent all of the forest's uses and values. A model forest is a fully functioning landscape of forests and non-forest, farms, protected areas, rivers, and towns.

Model forest partners exchange knowledge that strengthens the policy, regulatory, and development framework at community, regional, and national levels. These partners typically include: industry, community groups, government agencies, non-government, environmental and forestry groups, academic and educational institutions, national parks, Aboriginal groups, and private landowners.

Within Canada there are eleven model forests. In Newfoundland and Labrador the model forest has undergone some changes and has evolved from the former Western Newfoundland Model Forest to its current status as the model forest for the entire province. The model forest's diverse range of projects includes biodiversity assessment, carbon stock assessment, watershed planning, water quality, wildlife, and education.

Source: Canadian Model Forest Network

THE SCIENCE OF FOREST MANAGEMENT

Accurate information about the province's forests must be gathered, verified, and processed so that the twenty-year strategies, five-year operating plans, and wood supply decisions made in Newfoundland and Labrador are realistic and practical.

The Ecosystem Management Division of the province's Natural Resources Department is responsible for doing this scientific work. It involves physical and computer sciences, many types of data collection, and several analysis tools.

One piece of basic information about our forests is created through aerial photographs. The forested region of the island is divided into twenty four forest management districts. Every year, the Ecosystem Management Division takes aerial photographs of the potentially merchantable forests in one or two of these districts—which means they photograph about a tenth of the forested area of the island annually in more than 5,000 images. These photos are printed and individually analyzed by trained interpreters, who identify the tree stands they see, their estimated heights and ages, and their crown density.

Interpreters can be very accurate in reading photographic images, but their readings must be verified and other forest characteristics measured by making observations on the ground. Therefore government observers are regularly sent to the field to study three types of ground plots:

Permanent sample plots —these plots vary in size and include a sample of at least seventy five trees. Trees are measured for height and age, factors that are used to determine growth and yield rates. Additional information that

cannot be collected from aerial photos is also measured, such as the trees' diameter at breast height (1.33 m off the ground). Each plot is checked every four or five years.

Temporary sample plots —these random, one-time plots are used to take a sample of various forest data including the volume of timber within a stand.

Ground-truthing plots—these are areas visited to confirm the accuracy of interpreters' estimations in specific locations.

The information measured in the field increases the accuracy of the forest inventory maps, and also helps interpreters improve their aerial photograph reading skills.

The next step in mapping forest inventory turns the interpreted photographs into a GIS (Geographic Information Systems) map. The resulting digital map is a powerful tool for forest management. Forest information from these maps can also be combined with data from other sources and shared. The accuracy of the digital maps and the various ways in which they can interface with other layers of data is expected to increase even more with the transition to computerized image interpretation.

This work provides a base inventory map for analyzing the timber supply and determining the Annual Allowable Cut.

Another important planning tool is the preparation of growth and yield curves. These help managers predict how forest stands in different ecoregions will change over time, and how much harvestable timber an area will produce over time. The data show that growth and yield curves for managed stands (trees that have been planted and thinned) and natural stands are different. Despite the long history of logging in this province, intensive silviculture only began in the late 1970s. The higher growth-yield results for managed stands lend support to industry investment in silviculture.

Managing the forest is a complex process and, in addition to GIS inventory maps and the growth/yield curves, managers must also take into account values and realities other than timber production. For example, management principles also include ensuring that:

- The timber supply will be sustainable over time (a 160-year projection is used)
- The forest will remain ecologically sound
- Sensitive or special features will be taken into account
- No-cut areas identified for ecological, economic, social, and other reason must be considered

Annual Allowable Cut
The Annual Allowable Cut is determined on a district-by-district basis. It is re-assessed every five years. A forest district's Annual Allowable Cut is the maximum sustainable amount of yearly harvesting that is permitted in the district.

Once these quantities are determined, the district forester allocates areas and harvest quantities among eligible harvesters.

Did You Know?

Geographic Information Systems (GIS) software is one of the most useful tools available to resources managers. The software enables the forester to compile all available data in a map format consisting of different layers. For example one layer might show all the lake, rivers and, wetlands and another layer might show all the trees in a specific age class. These data layer can be manipulated and used to help make wise management decisions for today and for tomorrow.

Applying this information to the calculation is called **management input**. Planners take three streams of information and use a computer model to create an initial numerical Annual Allowable Cut (measured in cubic metres). The three streams of information include:

1. Forest description (based on data and maps)
2. Forest growth projections (based on the growth/yield curves)
3. Management input

The model generated from this information also produces a rough map. The map is further modified using a computer model, which outlines a detailed, twenty five-year harvest schedule in five-year increments. Management objectives can also be factored into the process at this point, as well—for example, the 2006 analysis included a management objective of maintaining 15 to 20 per cent old growth forest across the landscape on a forest management district basis.

Even after these models are applied, the job is still not done. The map must now be examined and adjusted to take into account additional realities, such as the amount of wood that will not be used because of other factors, such as poor location or pest infestation. After these adjustments, the proposed Annual Allowable Cuts are available for public review. They can continue to be adjusted with additional input before being finalized.

Reasons Not to Cut

A bald eagle in a tree top in Newfoundland and Labrador.

Ecological: Could include riparian zones, eagle/osprey nests, ecological reserves (existing or proposed), old-growth areas, and other site specific or unique ecological factors.

Economic: Could include landscape management for important tourism areas.

Social: Could include no-cut buffers along popular hiking trails, popular cabin areas, and other high-use recreational areas.

CHECK your Understanding

1. What kinds of information can be collected from aerial photographs of a forest? What kinds of decisions might this information support?
2. What is the purpose of permanent sample plots and ground-truthing plots?
3. After all the data has been collected and analyzed for a specific forested area what factors might result in a decision not to harvest?

For Further Discussion and/or Research

4. Obtain a copy of a GIS map of a forest near your community. What types of information can you get from this map?

FOREST MANAGEMENT ISSUES

The Economic Value of Newfoundland and Labrador Forests

The value of Newfoundland and Labrador's forest industry, which directly employs more than 6,000 people, is more than $800 million per year. The industry is the backbone of more than eighty communities in the province. Added to these activities is the growing outfitting industry and outdoor adventure tourism, including snowmobiling and similar uses of forest lands.

Tourism is a major source of income for our province (see Recreation and the Environment). Sustainable and healthy forests are very important to keeping and growing this sector of the province's economy. Our forests are important to all of us whether we make our living from forestry, manufacturing, or tourism, or use the forest as a place of recreation or solace.

	Year									
	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Sawmill Production (million board feet)	75	92	118	125	134	144	144	96	121	123
Newsprint Shipments (thousands metric tonnes)	741	370	772	808	746	740	781	732	766	440[1]

Figure 10.5: Provincial Newsprint and Lumber Production.

[1]To end of 3rd quarter

Source: Department of Natural Resources

Public Planning and Forest Management

Figure 10.6: Members of the District 02 Planning team using GIS technology in decision making process. *Photo courtesy Department of Natural Resources*

To manage our forests, a twenty-year **provincial forest management strategy** has been developed. It is updated every five years. This plan includes a wood supply analysis for the province. This wood supply analysis determines the Annual Allowable Cut that can be harvested on a sustainable basis. This analysis is based on computer models. As described above, these models rely on information such as harvesting levels, planting and thinning activity, land available for forest production, and projected growth patterns.

Each of the twenty four forest management districts must submit a five-year operating plan and an annual work plan for all of the major land owners in the district.

Three levels of planning required within the Newfoundland and Labrador Forest Service

Twenty-year Provincial Forest Management Strategy

- It is created by the Newfoundland Forest Service with input from industry, government agencies, and other stakeholders.
- It is based on protection of natural ecosystems and sustainable forest management.
- It describes the government's forest management goals for the next twenty years.

Five-year Operating Plan

- Sets the goals and objectives of each management district based on forest values determined by the local public planning team
- This is a required planning document prepared for each management district and is submitted to the Newfoundland Forest Service for approval
- Public consultations are a necessary part of each plan's development
- It is registered for review under the Environmental Protection Act after the plan is approved by the Newfoundland Forest Service
- This plan proposes specific forestry activities for a five-year period including:
  - -Timber supply allocation
  - -Fuel wood and domestic cutting
  - -Silviculture
  - -Forest access roads and bridges
  - -Protected water supply areas
  - -Forest protection (fire, insects and disease, landscape, wildlife, ecosystem protection, environmental protection)
- The plan establishes criteria and indicators to be monitored as a check of sustainability

Annual Work Schedule

- The annual work schedule must be prepared by each forestry management district and approved by the Newfoundland Forest Service
- This schedule outlines detailed activities planned for the management district to accomplish it approved goals and objectives

Forest Management Problems

Past management practices, repeated insect infestation, and forest fires have created the current age-classes of our forest stands, most of which are either in the oldest or youngest age-classes. This presents problems in sustainable forest management. The older timber is susceptible to insects, disease, blowdown, and death from old age. Such damaged trees have little commercial value. Therefore harvesters want to log the older commercial stands as quickly as possible to reduce the loss. However, if

the older stands are logged before the new forest stands are old enough to be harvested, there will be a period of time when we will have a shortage of forest stands with trees in the age-classes necessary to provide (i) a continuous supply of timber, (ii) an unique habitats for plants and animals, and (iii) the other values associated with a healthy forest.

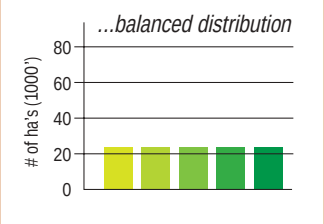
MINI- LAB ACTIVITY

Age-Class Distribution

Foresters often struggle with the questions, "Are our current practices sustainable?" and, "How do we measure sustainability?" One of the measures often used to help answer those questions is the age-class distribution of our forests. Forests are classified based on age groups or classes and the amount of forest in each age-class is measured. Common age-classes are

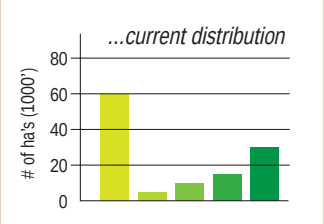
- 0–20 years old *(regeneration)*,
- 21– 40 *(immature)*,
- 41 – 60 *(immature)*,
- 61 – 80 *(mature)*
- and 81+ *(over-mature)*.

The premise is: if we have an equal amount of forest at various ages or stages of development, and only harvest at the mature or over-mature stage, then we will always have younger forest developing into later stages and, hence, sustainability. So, one measure of sustainability could be a **balanced age-class distribution**.



Balancing the Age-class

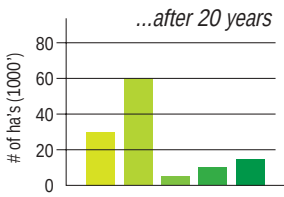
The following examples illustrate two options for balancing the age-class of a hypothetical forest with an age-class distribution similar to Newfoundland and Labrador's. Let's assume our theoretical forest has a total of 120,000 hectares of productive forest land. With five age-classes we would need 24,000 hectares in each class to balance the age distribution. Our current distribution in hectares is:



0 – 20	21 – 40	41 – 60	61 – 80	81+
60,000	5,000	10,000	15,000	30,000

Option # 1:

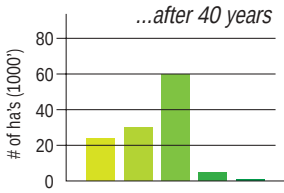
In Option # 1, we choose to focus our attention on removal of all overmature forest in order to create healthy, vigorously growing, young forest. We will continue this policy of oldest first until the ages have balanced. Because we are dealing with twenty-year age-classes, the overmature forest will be removed throughout a twenty-year period, giving all other classes the opportunity to advance one age-class. In the first twenty-year period



we will harvest all of the 30,000 hectares in the 81+ (overmature) category, resetting the ages back to the 0 – 20 (regenerating) category.

Our age-class distribution after 20 years would be:

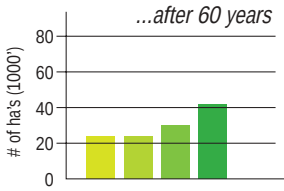
0 – 20	21 – 40	41 – 60	61 – 80	81+
30,000	60,000	5,000	10,000	15,000



In the second twenty-year period you will notice there is only 15,000 hectares of 81+ available for harvest, but we need 24,000 hectares to be reset to the 0 – 20 age-class in order to work towards balancing the distribution. So we must harvest 9,000 hectares from the next oldest age-class: 61 – 80.

Our age-class distribution after 40 years would be:

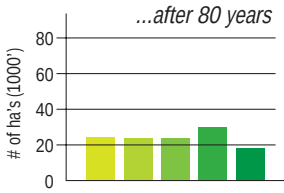
0 – 20	21 – 40	41 – 60	61 – 80	81+
24,000	30,000	60,000	5,000	1,000



Carrying on with our strategy, of oldest first but still maintaining 24,000 hectares of harvesting for the third twenty-year period will now mean harvesting from three different age-classes, including 41 – 60 (the oldest of the two immature age-classes).

Our age-class distribution after 60 years would be:

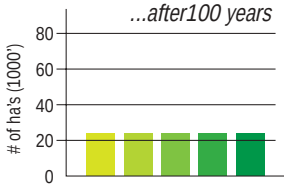
0 – 20	21 – 40	41 – 60	61 – 80	81+
24,000	24,000	30,000	42,000	0



In the fourth twenty-year period, there are no overmature trees left. We must harvest all 24,000 hectares from the mature category.

Our age-class distribution after 80 years would be:

0 – 20	21 – 40	41 – 60	61 – 80	81+
24,000	24,000	24,000	30,000	18,000



Throughout the fifth period we will be harvesting all 18,000 hectares of overmature and 6,000 hectares of mature, again resetting those to the 0 – 20 or regeneration class.

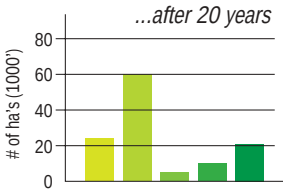
Our age-class distribution after 100 years would be:

0 – 20	21 – 40	41 – 60	61 – 80	81+
24,000	24,000	24,000	24,000	24,000

Finally, after one hundred years and the harvesting of 18,000 hectares of immature forest, the age-class distribution is balanced.

Option # 2:

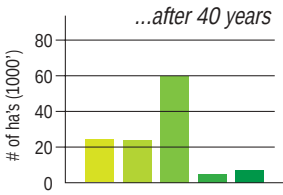
In Option #2, we again choose a harvest strategy of oldest first, but restrict our harvest over a twenty-year period to a maximum of 24,000 hectares (the amount required to balance each age-class). Remember there was initially 30,000 in the overmature category.



Our age-class distribution after 20 years would be:

0 – 20	21 – 40	41 – 60	61 – 80	81+
24,000	60,000	5,000	10,000	21,000

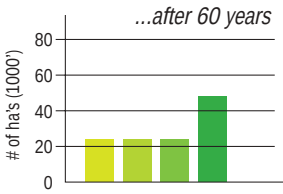
Throughout our second twenty-year period, along with the overmature, 3,000 hectares will have to be harvested in the mature category.



Our age-class distribution after 40 years would be:

0 – 20	21 – 40	41 – 60	61 – 80	81+
24,000	24,000	60,000	5,000	7,000

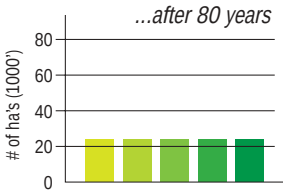
In the third twenty-year period, 12,000 hectares of 41 – 60 age-class will have to be harvested in order to maintain the 24,000 rule. Remember 41 – 60 is considered immature.



Our age-class distribution after 60 years would be:

0 – 20	21 – 40	41 – 60	61 – 80	81+
24,000	24,000	24,000	48,000	0

There is no overmature forest left to be harvested during the next 20 years so all harvesting will have to occur within the 61 – 80 (mature) age group.



Our age-class distribution after 80 years would be:

0 – 20	21 – 40	41 – 60	61 – 80	81+
24,000	24,000	24,000	24,000	24,000

By choosing to leave 6,000 hectares of overmature forest behind during the first twenty years in Option # 2 we actually balanced our age structure twenty years earlier and only harvested 12,000 hectares of immature forest.

Analyze and Conclude

1. Which of the above options would you prefer to balance an age-class distribution? Give your rationale.
2. Both options have a twenty-year period when there is no timber in the 81+ or overmature age-class. What are some of the advantages of not having overmature forests?

3. Forest stands on average produce about 100-120 cubic metres (m^3) of wood per hectare at maturity. What effect will harvesting immature timber have on the timber supply? What social and economic concerns might arise as a result of this impact on the timber supply?
4. These options demonstrate that it could take 80 – 100 years to balance an age-class distribution. Many things could change throughout this time frame. List some factors that may affect efforts to balance an age-class structure. Are these effects positive or negative?

ECO SPOTLIGHT:

Clarenville Forest Management District

Background

The Clarenville Forest Management District 02 is bounded on the north by Terra Nova National Park, and on the south and east by Swift Current and Sunnyside. It encompasses the entire Bonavista Peninsula and includes remote inland areas west of Clarenville.

The District has a long history of forest management problems, including poor logging practices, inaccessible areas, repeated insect infestations, poorly regenerating forests, a shrinking forest land base due to competing uses, and a widespread belief in the traditional right of access to timber resources.

Poor logging practices: The traditional method of harvest in the district is highgrading for sawlogs—a practice where the best quality trees in the best quality forest are harvested. While this may be profitable in the short-term, the long-term result is a substandard forest that does not reach its full potential and cannot properly regenerate. The unharvested substandard trees become the seed source for the forest, passing on substandard genes for the next generation of trees.

Inaccessible areas: Not all of the forest in a given area is available for forest management activities. Some areas are too remote or have ground conditions that restrict activities. Examples would be steep slopes, rugged countrysides, wet and boggy areas, and forest on islands in ponds and lakes.

Managing for other values: Some examples of managing for other values in this district include:

1. Wilderness trails are highly valued in the district. These include recreational hiking trails, cross-country ski trials, and ATV trails that have been developed. The district has a no-cut buffer zone added on both sides of these trails to maintain the natural appeal.
2. The protection of sensitive viewscapes is another high priority. Modified harvesting practises have been adopted in commercial and domestic harvesting blocks to protect viewscapes.
3. To conserve environmental values the district has committed to decommission some forest access roads.

Shrinking production forest land base: The production forest land base that is used to support commercial and domestic logging activity. In addition to the Class III restrictions, areas of productive forest land are constantly being converted to other land uses. These include agriculture developments, quarries, expanding towns, road construction, power lines and other developments. Production forest land has also become unavailable for logging for environmental reasons such as buffer zones around raptor nests and travel corridors for pine marten.

Insect infestations: The spruce budworm infested thousands of hectares of forest throughout the 1980s. The result is many dead and dying forest stands. This was followed by an outbreak of the eastern hemlock looper in the 1990s, again affecting thousands of hectares of production forest. Both insects attack balsam fir trees, the dominant species of the district. In addition, the balsam woolly adelgid has been infesting the same balsam fir. The adelgid is an indiscriminate insect. It affects trees of all ages including very young regenerating forests. Although the adelgid often does not kill the trees it infests, it severely stunts their growth and impairs fibre quality, thereby restricting a forest stand's ability to grow to its full potential. Bottom line: less wood available for future logging.

Poorly regenerating forests: One of the foundations of modern forest management is the ability of a healthy forest to regenerate itself. Once disturbed by fire, insects, or harvesting, trees will begin to grow again—naturally. Balsam fir will often regenerate more quickly than many other species of trees. This natural process has been impacted by two things:

1. The balsam woolly adelgid (formerly known as the balsam woolly aphid)
2. A healthy population of moose that eat trees (mostly young seedlings) at an alarming rate

Did You Know?

One moose consumes an amazing 18-28 kilograms of foliage every day. Ecologists are only now beginning to study the effects this can have on forest reproduction and development. A joint research project of Forest Management District 02, Terra Nova National Park, and Memorial University addresses this issue by constructing fences called **moose exclosures** at various locations in the forests. These **moose exclosure** fences keep moose out of certain areas. By measuring vegetation growth patterns inside and out, scientists can analyze the effects of moose browsing on forest growth and regeneration.

Black spruce is the other dominant tree species in the district and currently the most economically important. Meanwhile, natural regeneration of black spruce is impeded by a shrub known as sheep laurel (Kalmia angustifolia). An aggressive silviculture program (site preparation and reforestation) is required to combat the invasive characteristics of this plant.

Entrenched belief of traditional rights: The communities in the district have long depended on the forest for many social and economic values. Included in those values is commercial and domestic access to sawlogs and firewood. Such a tradition has helped to reinforce the belief among many people that they have an unrestricted right to cut their own wood. Although such traditional uses may conflict with other values, the current philosophy of ecosystem management demands that these traditions be respected.

Forest Management Activity *(Invite a local forest manager to lead this activity)*
Divide the class into groups and select a spokesperson. Each group will represent a particular forest user or interest group, such as the Department of Natural Resources, sawmill operators, domestic wood harvesters, environmentalists, pulp and paper companies, park planners, wildlife research biologists, tourism operators, farmers, hunters, and other groups whose values are important. Individual groups are to discuss what they want from the forest and set a list of goals. The groups will then come together to devise an ecosystem management plan that addresses the forest management problems discussed earlier and yet respects the values of all user groups. Keep in mind that no plan is more correct than any other. The plan must represent the collective values of all interest groups. Not everyone will get all they want—there will be trade offs.

Guiding principles

In devising the plan, there is much to consider. However you must follow three guiding principles

1. Everyone's values have merit, none should be dismissed
2. All decisions will have to be evaluated and results/effects measured
3. The role of the Department of Natural Resources is to address the forest issues as discussed in the Forest Management District 02 Case Study and to maintain forest sustainability (for economic as well as social values).

Figure 10.7: Pictures of moose exclosures five years after construction. Can you notice the difference? What does this mean for regenerating vegetation?
Photos courtesy Department of Natural Resources

Background information

The total area of Forest Management District 02 is 425,000 hectares with the following habitats:

- Productive forest land 170,000 ha
- Scrub forest 12,000 ha
- Non-forest 100,000 ha
- Water 33,000 ha

Each hectare of productive forest grows at a rate of 1.25 cubic metres of wood per year (m^3/yr) and will generate 100 m^3/ha at maturity. The rate of growth can be increased to 1.5 m^3/yr through silviculture. The balsam woolly adelgid will reduce the growth to 0.5 m^3/yr.

Forest Management District 02 looses 1 per cent of the production forest each year to fire and insects.

The District's productive forest has 70,000 ha of Class III land meaning only 100,000 hectares is currently available for commercial forest development. This is called the **production forest**.

The amount of production forest is decreased each year by 1% (100 ha) due to:

- Agriculture development—0.5%,
- Expansion of towns—0.25%
- Cabin development—0.25% (50 new cabins/year at 0.5 ha/cabin)

Figure 10.8: Town expansion is one of the reasons why a production forest decreases in size. *Photos courtesy Derek Peddle*

In 2005, the harvest level in the production forest was 75,000 m^3. This is broken down into 32,000 m^3 for domestic use and 43,000 m^3 for commercial use.

This commercial harvest level generated fulltime jobs for 78 people. The sawmilling industry generated an additional 68 jobs and another 64 came from the value-added industry (furniture, fencing, pallets, flooring, siding, mouldings, paneling, bagged firewood, etc). An additional 93 jobs are directly created from other aspects of the forest industry such as

forest management, trucking, and administration. From this information, we see that to generate one full time job in:

- Harvesting only, requires 551 m^3;
- Harvesting and sawmilling, requires 294 m^3
- Harvesting, sawmilling and value adding, requires 205 m^3

The provincial government of Newfoundland and Labrador is committed to protecting twelve per cent of all habitat types in the province. This commitment is to be maintained by Forest Management District 02.

Seventeen per cent of the entire zero to twenty age-classes is not regenerating due to moose browsing, insects, and competition from other vegetation.

The estimated moose density in the District is 1.5 moose per square kilometre (km^2).

The age-class distribution of the production forest in FMD02 is:

0 – 20	21 – 40	41 – 60	61 – 80	81+
25,000	7,000	12,000	30,000	9000

Figure 10.9: A harvested area in Forest Management District 02 that involved poor harvesting practices.

Surveys show that due to poor harvesting practices; nine per cent of the volume is left behind during harvesting. Also, an additional 17,000 hectares of production forest is occupied either by substandard trees, due to past poor logging practices, or by non-commercial species that have regenerated to the exclusion of commercial species so that the stand cannot be assigned an age-class designation.

In conjunction with Terra Nova National Park, a population of the endangered Newfoundland pine marten has been introduced to Forest Management District 02. The goal is to have a minimum of fifty pine marten living in and around Terra Nova National Park by 2010. An increase in this population Forest Management District 02 will require more mature forest habitat. This is because pine marten prefer older forests with trees greater than six metres tall, although they will use some younger forest habitat as well.

Evaluating decisions

There are many ways of evaluating decisions that have been made. You could take each goal, decide on a measurement for it, and monitor this measurement over time. For instance, to measure the goal of protecting twelve per cent of all habitats, you could map out what is currently protected in parks and reserves and then,

if necessary, add more habitat to that. This would be an area measurement and once you reach twelve per cent you have accomplished the goal.

If you set a goal to reduce the amount of area in the **not regenerating** category, you can measure this by the number of hectares planted each year as a percentage of the total non-regenerating.

The value of moose as a hunting resource is measured by big game surveys that give the number of moose/km^2.

But how do you measure sustainability? How do you know if your decisions are in the best interest of longterm ecosystem health? These are questions that forest managers must try to answer. They need to ask themselves "Are our current economic policies viable in the long term?" As you can see, these questions are not very easy to answer.

One way to answer them is to carefully select and evaluate potential indicators of success. As discussed earlier, we could select the age-class distribution as an indicator of forest health. We would then have to evaluate forest management decisions based on their effects on a balanced age-class. That then gives us criteria for evaluating decisions. For example, what does this balanced forest indicator tell us about the option of harvesting all of the overmature forest? Is it a healthy choice for the ecosystem? What does the need for a balanced age-class distribution tell you?

We could select the number of jobs in the forest industry to be our measure of economic success or failure. We may be losing production forest each year and, as a result, be forced to reduce harvesting, therefore reducing jobs. But can we increase employment in silviculture to offset this and have the added bonus of increasing the forest growth rate? Or, our economic measuring tool may be the number jobs/m^3 of wood harvested. Can we reduce the amount of harvesting in order to make more habitat available for the Newfoundland marten, and yet still maintain the current employment levels through increased production of value-added forest products?

Indicators and evaluating processes are all part of good ecosystem based management plans. The exact ones selected depend on the goals set. The goals set depend on the strength of the interest groups represented at the discussion table, and the ability of the forest managers to come up with a plan that balances all these values in a way that respects all groups and maintains a sustainable and healthy forest resource.

Figure 10.10: Mechanical Harvester. *Photo courtesy Department of Natural Resources*

Figure 10.11: Chainsaw Harvesting. *Photo courtesy Department of Natural Resources*

Harvesting Methods

Clear-cutting and selection cutting are two of the most common methods of harvesting timber. The biology of boreal overstory species (relatively short-lived, prolific seeders that grow best in full sunlight and which occur naturally as even-aged stands) suggests that clear-cutting, which involves the harvesting of all trees from a cutting block, is the preferred method for commercial harvesting of timber in these forests. Clear-cutting is also the economical method of harvesting for logging companies because they need to construct fewer roads than in less concentrated logging methods. And in even age-class stands there are no losses due to blowdown of remaining trees after harvesting. For these reasons, all wood harvested in Newfoundland and Labrador, and ninety per cent of wood harvested in Canada, is clear-cut.

Figure 10.12: Forwarder transporting wood from the stump to the landing, where the wood is loaded onto waiting tractor trailers. *Photo courtesy Department of Natural Resources*

Potential Problems

The loss of forest habitats, fragmentation of habitat, exposure of soil to erosion, the wastage of small trees, impacts on water quality and quantity, fish habitat and recreational opportunities, and unsightly appearance are some of the problems associated with this clear cutting.

Figure 10.13: Logging Adjacent to the Gros Morne National Park Boundary. *Photo courtesy Parks Canada*

To reduce negative impacts when a forested area is going to be clear-cut by harvesters, there are certain guidelines that should be met. Harvest cut blocks should:

- Be irregular in shape
- Leave non-merchantable timber in blocks or scattered green trees suitable for future snags
- Leave behind large diameter trees as green trees, seed source, snags for wildlife habitat, and as future source of coarse, woody debris
- Allow small amounts of woody debris to be left behind as habitat for small animals
- Allow corridors of vegetation between uncut forest stands to link forest habitat (this includes existing forest, "fringe wood" in wet areas, scrub forest, and buffers)
- Follow natural boundaries of stands and terrain. Harvester's should consider the location of water bodies, sensitive terrain, the potential for residual stands, difficult landscapes, and caring for environmentally sensitive areas such as salmon spawning areas, caribou calving areas, etc
- Be modified to protect environmentally sensitive areas
- Leave a minimum twenty metre no-cut buffer between operations and approved cabin development areas

Figure 10.14: While clear-cut areas do not look pretty they mimic natural disturbances such as wildfires, insect and disease outbreaks. As long as they follow sustainable harvesting practices, they are an acceptable harvesting strategy. *Photo courtesy APH*

Natural disturbance events, such as windstorms, wildfires, and insect and disease outbreaks may occur every few years or every several hundred years. They can affect small areas or large tracts of land. These natural disturbances often resemble cut-overs. By mimicking these natural disturbances, forest managers can help to maintain biodiversity and wildlife habitat.

Selection cutting is practised in young growing stands of similar age, or in uneven aged stands that contain at least three different age-classes intermingled. It involves the periodic removal of up to thirty per cent of the forest at one time and may be less disruptive to the forest ecosystem than clear-cutting. The condition and growth potential of the trees left after the cut is of primary importance. Partial cutting of an even-aged mature stand in a boreal forest is not recommended because this process leaves other mature trees standing that are usually unable to respond to improved conditions and frequently get blown over.

Selection cutting is recommended for environmentally sensitive areas such as stream margins and steep slopes. This method is used in the Main River watershed which has both steep terrain and trees of many different ages.

	Positive Effects	Negative Effects
Forests	• clearing tracts of forest can mimic the natural pattern • may allow the removal of insect-ridden, diseased or decaying trees	• alters the natural forest environment • too much coarse and woody debris removed can have a negative effect • some wildlife species require large areas of mature forest; careful planning is required
Water Quality and Protection	• a buffer strip can prevent many negative impacts on water • improves access for recreational opportunities such as fishing, hiking, etc.	• the removal of large tracts of forests can affect the groundwater table, run-off and stream flow • heavy equipment can damage streambeds • silt (from erosion) may change stream; affect fish
Land and Soil	• provides the advanced balsam fir and newly seeded black spruce regeneration more light allowing improved growth to start a new forest	• may cause erosion and soil loss • forestry operations can damage forest soils - for example, packing it down or removing it for fill
Fish and Wildlife	• species such as moose, snowshoe hare, song-birds and grouse benefit from new growth after harvesting • provides food and shelter for wildlife	• negatively affects species that are: - adapted for older age forest (e.g. marten, boreal owls) - are adapted for interior forests

Figure 10.15: Positive and Negative Effects of Forest Harvesting in the Boreal.

Source: Sustainable Forest Management Training for Front Line Forest Workers Participant's Workbook, Western Newfoundland Model Forest, 1999

ECO SPOTLIGHT:
Riparian Buffers

In Newfoundland and Labrador all water bodies visible on a 1:50,000 topographic maps must be given a minimum twenty-metre uncut buffer. In addition, district forest managers may increase buffers beyond the twenty metre minimum to protect values such as salmon spawning areas, cabin development areas, naturally beautiful areas, wildlife habitat, and outfitting camps. Riparian buffers filter runoff, provide nutrient uptake, provide canopy and shade, provide food to the stream, and help protect a transitional habitat that is rich in diversity.

Riparian buffers are areas of forested land next to streams, rivers, wetlands, or shoreline that form the transition between land and water environments. Buffers help maintain and preserve stream channels and shorelines.

Filtering runoff

Rain that runs off the land can be slowed and filtered in the forest, which helps settle out sediment and nutrients before they reach streams. In addition, the deep root systems of trees hold soil in place, stabilizing stream banks, and reducing erosion.

Nutrient uptake

Tree roots absorb fertilizers and other pollutants that originate on the land. Nutrients are stored in leaves, limbs, and roots instead of reaching the stream. Through a process called **denitrification**, bacteria in the riparian forest floor convert harmful nitrates to nitrogen gas, which is then harmlessly released into the air.

Figure 10.16: Tree canopy producing shade, which is important to fish survival.

Canopy and shade

Shading moderates water temperatures and protects against rapid changes that can harm stream health and reduce fish spawning and survival. Tree canopies also protect against elevated water temperatures that accelerate algae growth and reduce dissolved oxygen. In a small stream without the protective shade of trees, temperatures may rise 1.5° C in just thirty metres of exposure. Canopy cover also gives protection from predators.

Food

When leaves from the riparian forest fall into streams they are trapped on woody debris (fallen trees and limbs) and rocks where they provide food and habitat for small bottom dwelling creatures such as crustaceans, amphibians, insects, and small fish. These creatures are critical to the aquatic food chain. Insects dropping from the canopy are also a source of food.

Habitat

Riparian forests offer a tremendous diversity of habitat. The layers of habitat provided by trees, shrubs, and grasses, and the transition of habitats from aquatic to forest areas, create areas with the greatest biodiversity of the boreal forests.

Harvesting Technology

Harvesting technology has come a long way since the day of the buck saw and horse. Until the 1950s trees were cut in the winter time with axes and cross cut saws. Men, usually dressed in woollen shirts and pants, had to work in snow that was often chest high. They hauled the logs on horse-drawn sleds and stacked them on frozen ponds. When the ice melted in the spring the logs were flushed down stream by spring runoff to the mill. This method of transport had a tremendously negative impact on river habitat. But in those early years there was little concern for the environment. Oil was changed on site; operators drove equipment across streams and along streambeds. And there was little regard for sensitive areas such as young forest, wetlands, and riparian zones.

Figure 10.17:
Buck Saw Harvesting.
Photo courtesy Department of Natural Resources

As technology developed, horses were replaced by diesel tractors which in turn were replaced by skidders. And beginning in the 1980s, logs were no longer flushed through the waterways but were instead shipped by transport truck.

Figure 10.18:
Tracked feller buncher.
Photo courtesy deere.com

Today harvesting equipment is highly mechanized and can do many tasks once done by loggers. This reduces cost and, in some cases, environmental impact. Two harvesting systems are used today, **full-tree harvesting** and **shortwood harvesting**.

Full-tree harvesting systems involve the use of tracked feller bunchers with saw heads to cut the trees down. The trees are removed by grapple, clambunk, or cable skidding, depending on site conditions. Delimbing (removal of the limbs) and sorting is usually conducted at the roadside. This is a cost efficient harvesting method, because it produces more wood and leaves the site ready for natural regeneration or planting. However, because whole-tree harvesting leaves few of the branches, leaves, needles or other organic matter behind to decompose and enrich the soil, it results in nutrient losses and acidification of the soil, which in turn reduces site productivity.

The **shortwood method**, also called **cut to length**, is the preferred harvesting method in Newfoundland and Labrador. This method uses single grip harvesters, at the stump processors and forwarders. It has many advantages including low environmental impact and is suitable for use in selection cutting. With this method, branches and tops are left on site creating a protective bed for the harvester to travel on, reducing impact and leaving nutrients for the new forest. The stacked wood is picked up by a forwarder that takes the wood to the roadway where it is loaded on trucks for transportation to the mill.

Figure 10.19: Wheeled harvester. *Photo courtesy deere.com*

Other less common harvesting methods include cut and skid, cable yarding (use of a elevated cable to remove logs), and aerial logging (use of a helicopter to remove logs). Cut and skid is labour intensive. Trees are felled, limbed, and cut to length with a chain saw. Logs are stacked for pickup by a forwarder.

Figure 10.20: Wood hauling truck preparing for the highway. *Photo courtesy Abitibi Price Incorporated*

On hilly terrain, cable yarding and aerial logging (mostly by helicopters) are used for removing timber inaccessible by other means. These systems are very expensive and require high volume timber stands to be cost effective. Cable yarding is used on very steep slopes. It has been used by Corner Brook Pulp and Paper on a trial basis. In aerial logging, helicopters are used to airlift the logs to more accessible sites. Helicopter logging has not been cost effective in our province due to the small average piece size of our timber.

Regardless of how the wood is harvested, it is all transported by road to the mills. In fact, transport trucks hauling logs and wood chips along the Trans Canada Highway are a common sight in central and western Newfoundland.

Figure 10.21: Skidder transporting logs. *Photo courtesy Department of Natural Resources*

Did You Know?

The Wooddale Provincial Tree Nursery located between the towns of Grand Falls-Windsor and Bishop's Falls in central Newfoundland, officially opened in 1974. Four years later they shipped the first seedlings.

A satellite nursery facility was constructed in Goose Bay in the late 1970s to meet the reforestation needs in Labrador. Seedlings produced at both facilities target the twenty per cent of cutovers which failed to regenerate adequately.

In 2006, the 200 millionth tree was planted in Newfoundland and Labrador. If all these seedlings were planted on one site, the area covered would be in excess of 75,000 hectares.

Plantation survival is greater than ninety per cent due mainly to two important factors:

1. Newfoundland and Labrador's humid climate.
2. Use of only top quality genetic stock that is conditioned for the harsh environment.

SILVICULTURE

Silviculture is the development, cultivation, and reproduction of trees. Think in terms of a farmer who plants crops in the spring and cares for them until they are harvested in the fall. Preparing the land, weeding, and pest control, are all part of a farmer's annual cycle. Forest managers are applying this concept to harvested forest land that was formerly wild. The components of silviculture include:

Figure 10.22: Wooddale Provincial Tree Nursery.
Photo courtesy Department of Natural Resources

- Site preparation for regeneration or replanting
- Replanting of selected tree species
- Pre-commercial thinning
- Application of herbicides to remove weed species,
- Integrated pest management
- Salvaging forests that have been damaged by insects, blowdown, and fire

Site Preparation and Replanting

You need only to see the dense crops of seedlings sprouting up along the forest edge to realize how quickly the boreal forest begins to renew itself after natural disturbances such as fire, or human disturbances such as harvesting. Balsam fir forests rarely need site preparation and replanting since the balsam fir is the most prolific of all tree species in Newfoundland and Labrador. Natural regeneration can be helped by preparing the soil through **scarification**, by using prescribed burns, or using herbicides to suppress other plant species. Scarification opens up mineral soil allowing seedlings to take root. Burning removes logging debris and converts the debris to ash, which in turn lowers the acidity of the soil. The widespread application of herbicides (which some environmentalists question in terms of potential negative impacts

Figure 10.23: Thinned regeneration Forest.
Photo courtesy Department of Natural Resources

on the ecosystem) has the immediate effect of eliminating competing species such as grasses, shrubs, and hardwood species. Herbicides are not used on a broad-scale basis throughout forest sites in Newfoundland and Labrador. Many foresters now encourage a hardwood mix within the primarily softwood forest to increase biodiversity. Hardwoods, particularly white birch, are also important in providing fibre for the value-added forest products sector.

Natural regeneration is often assisted by planting. Whenever possible, seedlings grown from locally collected seed of native species are used. Generally black spruce or white spruce is the species replanted. Eventually the replanted or regenerated sites may have to be thinned to increase tree growth and yield, and to protect it from disease or insects. In 2005 – 2006, 12,470 hectares were silviculturally treated in this province. That included planting 8.9 million seedlings.

	Positive Effects	Negative Effects
Forests	• natural regeneration usually results in re-growth of same species • some species, for example moose, thrive in cut-over areas • other species re-grow naturally-helps maintain natural mix or diversity	• undesirable species may grow back • renewal activities may reduce diversity
Water Quality and Protection	• as forest regrows, natural drainage and water retention patterns are re-established	• chemical treatments (insecticides, herbicides) may damage water bodies and contaminate groundwater • scarification may cause erosion (soil runoff) which may inhibit fish breeding
Land and Soil	• re-growth helps to stabilize soils	• improper scarification may cause erosion and soil loss

Figure 10.24: Effects of Forest Renewal.

Source: Sustainable Forest Management Training for Front Line Forest Workers Participant's Workbook, Western Newfoundland Model Forest, 1999

Figure 10.25: Pre-commercial thinning permits the remaining trees to reach commercial size much faster than they would in an unmanaged forest.
Photo courtesy Department of Natural Resources

Pre-commercial Thinning

Pre-commercial thinning involves the removal of nonmarketable trees from forests between ten and fifteen years old. Harvesters leave approximately two-metre spacing between neighbouring trees. This reduces competition for light, nutrients, and water. These improved conditions allow the remaining trees to reach harvest levels twenty to thirty years earlier than a stand that is not thinned. Commercial thinning in intermediate aged forests involves the harvesting of marketable mature, diseased, and sub-quality trees. As in pre-commercial thinning, this reduces competition for light, nutrients, and water, and opens up the forest for better crop development of the remaining high quality trees.

CHECK your Understanding

1. Why is clear-cutting the preferred method of harvesting in Newfoundland and Labrador.
2. What are some potential problems associated with clear-cutting? Select two and outline how they can be overcome.
3. In what situations would selective cutting be used?
4. What are some of the positive effects of clear-cutting?
5. What are riparian buffers and what is their role in protecting aquatic ecosystems?
6. Distinguish between full-tree harvesting and shortwood harvesting method in terms of their impact on the forest environment.
7. Define siliviculture.
8. What does siliviculture and traditional farming practices have in common?

For Further Discussion and/or Research

9. Visit a cutover and use a digital camera to document the positive and negative effects of forest harvesting. Use Table 6 has your guide.
10. Write a one page speech that supports clear-cutting in Newfoundland and Labrador.
11. Write a one page speech that does not support clear-cutting in Newfoundland and Labrador.

ENVIRO-FOCUS

Re-greening the forest

Nursery production of trees for reforestation is at an all-time high in Newfoundland and Labrador. The Wooddale Tree Nursery, east of Grand Falls-Windsor, is capable of producing fifteen million trees a year.

A second tree nursery located in Happy Valley/Goose Bay supports these efforts by producing seedlings for reforestation in Labrador. These facilities are managed by the Forestry Branch of the provincial Department of Natural Resources.

Reforestation efforts in Newfoundland and Labrador have grown from about 6.0 million trees planted in 1991, to 12.5 million in 2006. The total planted in the province reached more than 200 million during 2006. (These young trees are always planted about 2 metres apart—a distance roughly equal to the span of your outstretched arms.) If planted in a straight line at the equator, the trees replanted in this province since 1978 would extend around the Earth more than eleven times.

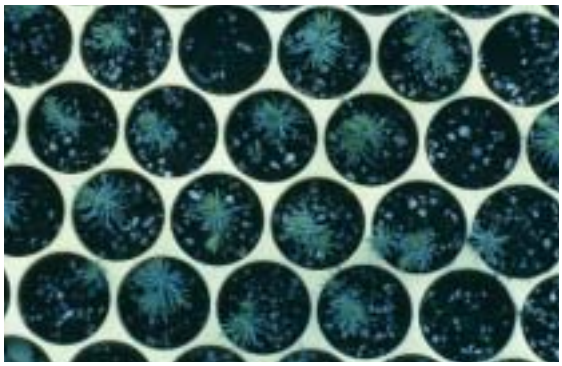


Figure 10.26: Spaces between trees, which in nature is done by pre-commercial thinning, allows them to reach commercial size much faster.
Photo courtesy Department of Natural Resources

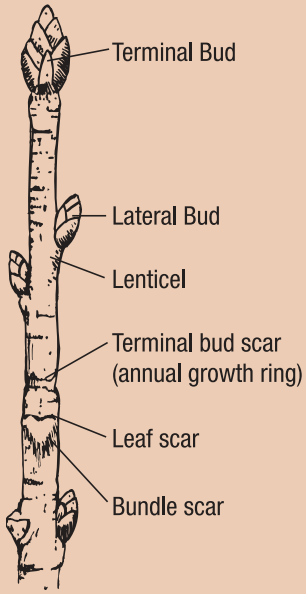
While planting levels are increasing, harvesting levels are decreasing from 3.0 million m^3 in 1991 to 2.5 million m^3 in 2006. The major forest tenure-holders in the province (Crown, Corner Brook Pulp and Paper, and Abitibi-Bowater) have increased planting levels. These shifts reflect efforts to build stronger forests. Replanting helps the forest re-establish itself more quickly after disturbance caused by harvesting. This, in turn, increases the stocking level on the forested land-base and improves its ability to store carbon. Some hold that this carbon storage will play a small role in mitigating climate change. Others argue that its impact is insignificant.

The total re-growth area of replanting efforts in the province since 1978 would cover an area of about 75,000 hectares—plus an additional 15,000 hectares that has been **gap-planted**. Gap-planted trees are seedlings sown in smaller un-stocked areas within larger blocks of forest that are regenerating either naturally, or following earlier re-planting.

Not all areas are replanted after commercial cutting. Areas that are expected to regenerate naturally are left to do so. One of the factors assessed when replanting is considered for any area is its **stocking level**. In managed forests, stocking level refers to the amount of productive forest land in a given area that is occupied by a desired crop tree. The stocking level is normally expressed in percentage. For example, if one hectare of managed forest in Newfoundland has about 2,500 evenly spaced spruce trees (each tree is about two metres or more apart), it is considered 100 per cent stocked. If a hectare has 2,000 evenly spaced trees, it is considered eighty per cent stocked. If the hectare of forest land has 2,500 evenly spaced trees that cover only half its area, then it is fifty per cent stocked. In that hectare, the empty half might be targeted for gap-planting, and the other, over-stocked half might be considered for thinning so that crop trees will have optimal growing space.

CORE LABORATORY ACTIVITY

How Fast Does This Tree Grow?



Outcomes

You will be able to:

- Evaluate data collected on trees
- Demonstrate that data reflects the accuracy of the measuring devices used
- Apply quantitative observational methods to accumulate precise data about trees
- Evaluate the interpretation of data collected during each experiment

Introduction

Perhaps it is the fact that trees grow slowly and live a long time, or perhaps it is the way they endure and change through the seasons, but whatever the reason, trees have inspired authors, poets, and composers from ancient times. They have even inspired scientists like Isaac Newton who "discovered" gravity while sitting under an apple tree. Trees affect our lives in more physical ways as well. Think about the trees in your neighbourhood when they bloom in spring or when, fleetingly, they take on their fall colours. Trees shade us in the summer, slow the wind in winter, and serve as a habitat for many types of small animals and insects. In the ever-changing urban landscape people are learning to select the trees that serve them best.

There are several different ways to evaluate the health of trees. The methods we are going to use here are just a few of the ways that growth data can be gathered.

You will use a few of the tools of a forester, plus others that you can find in any hardware stores. With these you can determine if a tree is growing well. We start with simple measurements of height, diameter at chest height, and twig growth.

Pre- Lab Question

How does the data collected about trees tell us more than just height, width, or growth pattern?

Hypothesis

Develop a hypothesis about the growth of trees before you continue.

Materials

- Metric ruler
- Stool
- Tree identification key
- Journal (logbook)
- Clinometer
- 35 metre tape
- Diameter tape
- Data tables as provided by your teacher

Procedure

Each group should prepare a checklist of materials and a data table. Students, in groups, should practice using all the tools before recording final data entries.

Trees Species

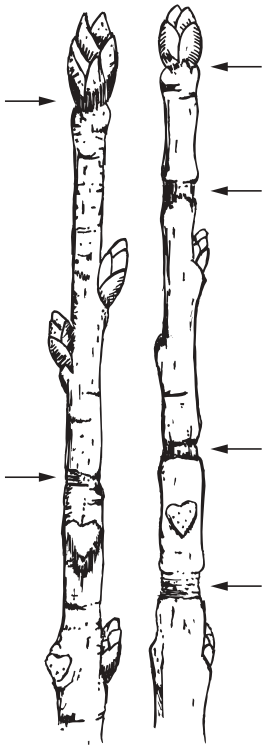
Record the species of your assigned tree.

Twig Growth

For the tree assigned, students will have to identify terminal bud scars, since these are the points that must be used to measure twig growth. Measure this length and record it in Table A for the year previous to this year. Continue moving down the twig until you find the previous terminal bud scar. Measure this length for the year previous to the last. Repeat this three more times to record a total of five growth lengths for the twig chosen. Record your data. You will collect the data from the other groups to complete the table your teacher provides.

Diameter at Breast Height (dbh)

Tree diameter at breast height has traditionally been the **sweet spot** on a tree where measurements are taken and a multitude of calculations are made to determine things like growth, volume, yield, and forest potential.



Tree dbh is outside bark diameter at breast height. Breast height is defined as 1.4 metres above the forest floor on the uphill side of the tree. For the purposes of determining breast height, the forest floor includes the duff layer that may be present, but does not include unincorporated woody debris that may rise above the ground line. Using the diameter tape, record the diameter of the tree at 1.4 meters above the ground. Record this in your tree data table.

Tree Height - Angle of Elevation Method

Your teacher will provide you with a method of calculating tree height. Record the value you calculate in your tree data table. To complete Table B, add data from other groups.

Data Tables: Your data should be compiled in tables similar to the following:

Table A: Tree Twig Length

			Twig Growth by Year					
Tree No.	Tree Species	Direction N/S/E/W	20 ☐	20 ☐	20 ☐	20 ☐	20 ☐	AVG

Table B: Tree Data

Tree No.	Tree Species	Tree Height	Tree Diameter

Analyze and Conclude

1. Which tree species had the greatest twig growth last year? Which tree species had the greatest average twig growth over the last five years? Why?
2. Is there a pattern to the data? What is the pattern that your group sees? Give three reasons for this pattern.
3. Were any of your trees planted in the last five years? Which ones? Why?
4. What are two other methods or instruments that could be used for this exercise? Explain why they may be useful.
5. If you were to do this exercise again, what technique would you change? Why?

6. What other data would you need to make an accurate estimate of the health condition of the trees you used for this exercise?
7. Based on your observations, what conclusion can you make about tree growth in your area?

Extensions

8. Do the trees in urban areas following typical growth patterns?
9. What problems does the Urban Forest (forests in cities and towns) have to contend with, in order to survive?
10. Using a tree bore, compare the growth in years by counting rings with the age determined using twig growth.
11. What advantages in age determination does the tree bore provide compared to observing twig growth?

This lab is based on an activity developed by the USDA Forest Service available at http://na.fs.fed.us/spfo/ce/content/for_teachers/curriculum/index.cfm?TitleToView=16

PEST MANAGEMENT

Figure 10.27: Hemlock Looper Larvae *Lambdina fiscellaria fiscellaria (Guenée) Larva(e).* *Photo by Pennsylvania Department of Conservation and Natural Resources - Forestry Archive, Bugwood.org*

Pests reduce the availability, quality, or value of useful resources such as trees. Insect pests have plagued forests for thousands of years but are normally kept in check by weather, parasites, predators, and disease. Like fire, they play a vital role in forest renewal and are one of natures many cycles. The ideal way to control pests, including the ones that plague our forest, is through **integrated pest management**. Integrated pest management requires an understanding of:

- Each pest species' life cycle and conditions that impact upon it such as temperature and humidity
- An understanding of the conditions that bring on an infestation
- The selection of appropriate control measures
- Monitoring the effectiveness of the program

Over the years, three forest pests have had a considerable impact on stands of black spruce and balsam fir in Newfoundland and Labrador. Between 1966 and 1971 the eastern hemlock looper *(Lambdina fiscellaria fiscellaria)* destroyed 11.5 million cubic metres of balsam fir timber. An effort to spray 400,000 hectares of forest saved 85 million cubic metres of wood. The balsam wooly adelgid *(Adelges piceae)* and the spruce budworm *(Choristoneura fumiferana)* had impacts on our forests in the mid-1970s and early-1980s.

Figure 10.28: Balsam Wooly Adelgid. *Photo courtesy Department of Natural Resources*

As we learned earlier, balsam woolly adelgid attacks balsam fir stands at various stages of development. It often does not kill trees, but reduces growth, yield, and quality of fibre from the forest. The woolly adelgid continues to spread throughout many regions of insular Newfoundland. It has become a serious threat to a number of forest management districts. Also affecting forest management on the island are on-going infestations of the hemlock looper and the balsam fir sawfly at various locations.

One important question facing foresters today relates to climate change. How will warming temperatures affect the spread of pests including insects, viruses, bacteria, and fungi?

Figure 10.29: Spruce budworm *Choristoneura fumiferana (Clemens) Larva(e).*
Photo by Jerald E. Dewey, USDA Forest Service

Chemical insecticides, such as fenitrothion, have been used to control forest pests in the past. Today, **biological control agents** are more common. Biological controls include viruses which exist naturally in the target organism and are usually specific to it. Pheromones, which interfere with the organism's reproductive cycle, are also used. Two biological controls that are being used in forests today are *Bacillus thuringeinsis* (often referred to as BT) and the nucleopolyhedrovirus (NeabNPV) virus. These insecticides have minimal impact on the environment.

Bacillus thuringiensis (BTK)

Bacillus thuringiensis is a naturally occurring bacterium that can kill the larvae of selected butterflies and moths, including the gypsy moth, spruce budworm, and hemlock looper. The larvae must eat BTK—usually on plant material sprayed with the bacteria. For the spray program to be effective, it must take place during the time when the insects are feeding most actively and are therefore most susceptible to the insecticide. It takes two to three litres of spray per hectare of forest to have

Figure 10.30: Spruce budworm control. *Photo courtesy Bernard J. Raimo*

the desired effect. But, because the caterpillars may hatch at different times, two applications may be necessary to give the best control.

BTK is naturally occurring and can be found in the soil, water, and on plants around the world. BTK does not kill other types of insects, such as honeybees, helpful insect predators, or parasites. BTK has no impact when eaten by fish, earthworms, frogs, birds, mammals, or humans. None of these organisms have the alkaline gut necessary to activate BTK. Because it is sensitive to sunlight, BTK breaks down quickly in the environment. Several days of sunlight or heavy rain can cause the BTK spray to become ineffective.

Figure 10.31: Balsam fir sawfly larva. *Photo courtesy Department of Natural Resources*

Balsam Fir Sawfly (NeabNPV) Virus

The NeabNPV virus naturally exists in the balsam fir sawfly *(Neodiprion abietis)* population. The virus is very specific as it only affects sawfly species, with no negative impact on non-target species. In the laboratory, the virus is actually extracted from the sawfly and then produced in a form that can be applied to trees infested by the pest balsam fir sawfly. Much of the research completed to date with this virus has been conducted in western Newfoundland.

A new biocontrol agent has now been registered for use in Newfoundland and Labrador. It is an agent known as Abeitiv. Abeitiv is a form of the naturally occurring nucleopolyhedrovirus (NeabNPV) virus.

As part of an integrated pest management approach, the Forestry Services Branch carried out an operational control program in 2003 against the hemlock looper using

the approved biological agents Mimic (tebufenozide) and BTK. A total of 61,635 hectares were treated with Mimic and BTK, from a proposed treatment area of approximately 100,000 hectares. The hemlock looper control program addressed the on-going outbreak of this insect by carrying out treatment on valuable stands forecast to receive moderate and severe defoliation. Emphasis was placed on young forest stands, particularly those that have received silviculture treatment.

For the balsam fir sawfly, the Canadian Forest Service, in cooperation with the department, continues work on the naturally occurring balsam fir sawfly virus to better develop this as an operational control tool. This is an on-going effort that has met with some success in the past and continues to be the focus of discussions at both the federal and provincial regulatory levels.

Positive Effects	Negative Effects
Insects and disease: • many insects are a natural part of the forest ecosystem • provide food for insect-eating birds (for example songbirds and woodpeckers) and other wildlife • part of decay process-break down wood fibre, creates nest cavities, and provides soil nutrients • regenerates over-mature forests • fungus and other forest diseases are part of the natural ecosystem and help in the recycling of nutrients	**Insects and disease:** • insect infestations kill large tracts of forest in Newfoundland in the past thirty years, insects have affected all mature softwood species (spruce budworm, hemlock looper, balsam fir sawfly, larch sawfly *(Pristiphora erichsonii))* • insects can cause reduced growth, stunted trees, loss of branches • forest diseases (for example, fungus, viruses) reduce quality of wood and cause loss of wood fibre
Controlling insects and disease: • may protect overall forest health - both short-term and long-term • improves growth and health of individual trees • improves quality of harvested timber	**Controlling insects and disease:** • improper use and handling of pesticides or overuse or use of improper pesticides may: - have negative effects on forest health - can affect fish and wildlife - can affect water quality - have serious short-term and/or long-term effects on human health

Figure 10.32: Dealing with insects and Pesticides in the Boreal Forest.

Source: Sustainable Forest Management Training for Front Line Forest Workers Participant's Workbook, Western Newfoundland Model Forest, 1999

CASE STUDY

Managing Balsam Fir Stands Infested by Balsam Woolly Adelgid

Background:

Balsam fir is Newfoundland and Labrador's most abundant and economically important tree species. It is also the most vulnerable to infestation from a number of insect pests.

Figure 10.33: *Adelges piceae (Ratzeburg)* - Infestation. *Citation: William A. Carothers, USDA Forest Service, Bugwood.org*

The most pernicious and pervasive of these insects are the hemlock looper and the spruce budworm. These are native defoliating insects that generally infest older stands inflicting high rates of mortality. The infestation effects are visually dramatic because chewed, dying needles turn reddish-brown (blasty). With early detection, these sporadic infestations can be controlled by the aerial application of insecticides. In older fir stands, where pesticide control opportunities are missed or ineffective, the merchantable timber can be harvested in a **salvage cut**.

Figure 10.34: Balsam woolly adelgid *Adelges piceae (Ratzeburg)* Damage. *Photo by USDA Forest Service - Region 8 Archive, USDA Forest Service*

Another very significant insect pest, exclusive to balsam fir in Newfoundland, is the balsam woolly adelgid. Adelgid were accidentally introduced to Newfoundland from Europe in the 1920s or 1930s. In the early years, infestations were scattered near the coast at low elevations in the more southerly portions of the Island where winter temperatures are mild. More recently, particularly over the past twenty years, the geographic range and damage severity has increased. Today, adelgid are found throughout Newfoundland, with the exception of the Northern Peninsula.

The balsam woolly adelgid, unlike the defoliating looper and budworm, is a sucking insect. Adelgids insert a feeding tube into the thin bark of newly formed branches. As part of this feeding process, the adelgid secretes a substance toxic to fir. This toxin disrupts normal growth, particularly in the upper crown, resulting in grouting, deformities, and a diminishing of branch elongation.

Adelgids can infest trees of any age, and persist throughout the remainder of the tree's life. Adelgids rarely cause mortality. The damaging impact of adelgids on timber management is slowing of forest volume by reducing or stopping height growth which, when combined with diameter, determines total volume.

In the late 1970s, the province embarked on a high investment, large- scale operational silviculture program. The Newfoundland Forest Service Program, in Forest Management District 14, was concentrated on Crown Land near

the coast where adelgid damage was severe. The strategy was to clear cut the damaged stands, to prepare sites by prescribed burning or slash raking, and to plant native spruce species.

At the same time, Bowater Newfoundland Limited (now Corner Brook Pulp and Paper Limited) concentrated their program on its inland timber licences where adelgid damage was light and broadly scattered. Their strategy was pre-commercial thinning (PCT) in 10 – 20 year-old naturally regenerated balsam fir stands. The objective of thinning is to accelerate crop tree growth to achieve a shorter harvest rotation time and increase stand merchantable volume yield. The PCT program is ongoing and to date over 13,000 hectares have been treated.

Another initiative of the silviculture program has been research and development with fast growing exotic species. In several comparative trials, Norway spruce has out performed native species by as much as fifty per cent in tree volume. Another aspect is the tree improvement program where native trees with genetically superior growing traits are bred to produce seed for the production of improved planting stock.

Problem:
Particularly in the past decade, a non-native, severe growth stunting adelgid infestation has been expanding geographically in PCTs. This is causing great concern because thinning volume yield projections and other PCT benefits are being drastically eroded. This will reduce future annual allowable cut levels. The increasing damage severity may restrict a number of PCT stands from reaching commercial harvest viability. It appears obvious that a strategy of corrective action is required to maintain a viable and productive forest.

QUESTIONS

These cannot be answered directly from the passage above and will require independent research.

1. What is the biology of the balsam woolly adelgid?
2. What are the effective control measures for balsam woolly adelgid?
3. Should fast growing exotic tree species be used to regain fir volume losses to adelgids?
4. Discuss the socio/economic impacts of a reduced Annual Allowable Cut.
5. Develop a timber management strategy to deal with:
    a) Current cutovers in predominately high risk zones for balsam woolly adelgid.
    b) PCT stands severely infested with balsam woolly adelgid.

CHECK your Understanding

1. What are the three components of integrated pest management?
2. What are two advantages of biological control agents for controlling forest pests over traditional chemical use?
3. List two positive and two negative effects of dealing with insects in the boreal forest.
4. Were there forest insect outbreaks before Europeans settled in Newfoundland and Labrador? If so why were they of little or no concern to the aboriginal peoples?

For Further Discussion and/or Research

5. Climate change will have significant impact on our forests. Through research find out how warmer temperature may effect the types and ranges of forest pests.
6. Visit a site of insect damage. How does it compare to a forest that has been:
   a) Damaged by fire
   b) Harvested

Each year Newfoundlanders and Labradorians harvest 400,000 cubic metres of wood for personal use.

DOMESTIC HARVESTING

Each year Newfoundlanders and Labradorians harvest 400,000 cubic metres of wood for personal use. Domestic wood harvesting still continues within the boundary of Gros Morne National Park. Here residents of communities within the Park have access to one quarter of the Park as part of their traditional right to cut wood for personal use. Since 1983, over 60,000 cubic metres of wood have been harvested from Park lands for fuel wood and for saw logs which may be used for a new shed or timber to repair the few remaining wooden boats. In the past there was little legislation to control domestic harvest. As a result, wood nearest to the community was taken, clearing accessible river valleys and leaving scars on hillsides. Today, permits are required to harvest wood for domestic use. The Forest Service attempts to strike a balance between sustainable, environmentally friendly domestic cutting, and the traditional right of residents to cut wood for their personal use.

MINI- LAB ACTIVITY

Domestic fuelwood/sawlog survey

Background

Cutting firewood and logs for wood has long been part of our culture. For many, the annual firewood cut is as much a recreational activity as hunting or fishing. Forest managers have long considered the domestic harvest as an uncontrolled use of a valuable resource. In this activity you will have the opportunity to learn about the domestic harvest in your community.

Part One: Wood-cutting Practices

Review the activity **Participation rates in Nature-related activities in your community** in the Recreation and the Environment chapter of this text. Prepare the following questionnaire and distribute it to members of your community.

1. In the last twelve months, have you cut any wood (fuel wood, scraps or sawlog)?

   ☐ Yes ☐ No

2. What kind of wood did you cut?

   ☐ hardwood ☐ softwood ☐ slabs ☐ burned wood

3. How far did you travel to obtain fuel wood (km)

   ☐ less than 5 ☐ 6 -15 ☐ 16 – 26

4. How did you transport the wood (Check all that apply)

   ☐ truck ☐ snowmobile ☐ ATV

   ☐ other What were they? _____

5. Generally, in what months do you cut wood? (Circle all that apply)

J	F	M	A	M	J
J	A	S	O	N	D

6. In the last 12 months, how much time have you spent collecting wood? (Indicate the time spent preparing trails, cutting and hauling wood, and splitting and stacking).

7. How much wood have you cut in the last 12 months?

Amount Cut

1 Cord = Stacked Wood (4 feet high X 4 feet wide X 8 feet long)

1 Pickup load = ½ Cord

Land tenure:

A - Crown Land

B - Company Land

C - Private Land

Harvest Codes

1 – Cutover

2 - Green standing timber - mature forest

3 - Green standing timber - immature forest

4 - Dead standing timber

5 – Scrub

Type	Species	Amount Cut (cords)	Land Tenure	Harvest Code	Amount Bought (cords)
Hardwood					
Softwood					
Mill slabs					
Sawlogs					
Burned timber					

Part Two: Analyze your results

1. Make a graph displaying the type of wood harvested and the amount cut.
2. What is the average number of cords used by households in your community?
3. Harvesting firewood is also a recreational activity. Survey ten individuals in your community and have them rate the recreational value of this activity on a scale of 1 – 10, where ten represents high recreational value and one represents no recreational value.

Part Three: Collect pictures and evaluate domestic cutting sites around your community.

Domestic harvesting has been an ongoing activity for many years around most rural Newfoundland and Labrador communities. Use a digital camera to document domestic harvesting activity around your community.

NEW TECHNOLOGY IN FOREST HARVESTING

It wasn't that long ago that logging was a hard and gruelling job. Today, depending on the logging operation, there are technological breakthroughs in harvester technology making the work much less physically demanding and reduces the impact on the environment. But some of the most exciting innovations are in other areas such as global positioning and mapping.

Innovation in Harvesting Technology

Today operators of mechanical harvesters can work in their slippers with the air conditioning on and listening to their favourite band on the CD player! They have a GIS (Geographic Information System) and a GPS Global Positioning System) to process data for harvesting precision and efficiency, and they have a cell phone for communication.

When operating a mechanical harvester, the operator uses routine, repetitive actions to control the equipment. Automation of these repetitive functions greatly enhances work quality and productivity, while reducing fatigue of the operator. Some of these new innovations include:

- Coordinated motion control for single joystick operation
- Self-learning machines that automate repetitive actions
- Sensors to monitor external conditions and adjust machine operation in response

Training simulators help deal with the growing complexity of forest equipment, reduce the cost of training, and ensure that operators use the machines in a way that reduces the impact on the environment.

Although current harvesting machinery uses hydraulic oils, chain oils, antifreeze, and other petroleum-based fuels and lubricants, environmental concerns and regulations are forcing the introduction of biodegradable alternatives. For instance, new walking harvesters use biodegradable vegetable oil instead of hydraulic oils!

Ground disturbance is an important component of environmental concerns. Government regulation is focusing on soil compaction and rutting, and on

Walking Technology

Figure 10.35: Walking Mechanical Harvester.
Photo courtesy Plustech

Walking technology harvesters and forwarders, which are modelled after biotic examples such as mammals and insects, have little impact on the forest floor. This technology enables operation in difficult terrain, like steep slopes where conventional methods fail or cause extensive damage. It is also an environmentally friendly way of operating in thinned and young stands.

The agility and flexibility of a walking machine is most obvious on irregular ground. The positive points of walking technology in forest applications include the following advantages:

1. Spot contact with the ground which leaves no continuous tract behind
2. Minimum risk of soil erosion on steep slopes
3. Optimum distribution of ground pressure
4. Minimum damage on tree roots
5. High variable ground clearance
6. Easy to manoeuvre in difficult terrain; move in all directions and turn on the spot without damaging the ground

sedimentation in water. Limitations on the areas of disturbance, the depth of rutting, and the period of operation, if properly enforced, can help to lessen this impact. The best solution to these problems is equipment that leaves a softer imprint on the forest floor. This includes a wide range of technological options, such as high flotation equipment, variable tire pressures, pendulum wheel arms, anti-slip systems and walking technology. The ground pressure of a wide tire harvester must be very low to minimize effects on the ground below. Newer harvesters are designed so that the operator cannot spin the tries in one place. This is one of the major causes of deep rutting.

Global Positioning Systems (GPS)

GPS uses a network of satellites to locate precise coordinates on the Earth's surface. This system greatly facilitates the ability to survey and navigate, which is very important in forest management and forest operations. For example, the use of GPS technology mounted on forest machines enables the updating of maps continuously, navigating machines along boundary lines, monitoring trucks and equipment.

Figure 10.36:
Staff using GPS unit.

Computerized Decision Support Tools

Digital technology is revolutionizing our approach to forest management and operations. The opportunities are virtually unlimited. For example, foresters must handle tremendous volumes of numerical and area-related information. The planning, controlling, and reporting phases of forest operations now span many parameters, including those that are ecological, technical, regulatory, and worker related. Computerized tools manage these data and can help managers to base their decisions on more information.

But some limitations still remain. While extensive computing power is available, the software developed for computing in this area is limited. Some efforts are aimed at correcting this, including the work of FERIC (Forest Engineering Research Institute of Canada). For example, the institute is developing an integrated computerized costing model for harvesting and silviculture. But there are many other areas of the modern forestry industry that require computing programs. There are specific opportunities related to managing the resource and landscapes, managing truck fleets, and designing, constructing, and rehabilitating roads. In fact, computerized planning tools will help integrate all forest management and operational objectives and values. This is an excellent opportunity for Canadian software development.

Geographic Information Systems (GIS) are spatial modeling and forecasting applications. As a versatile analytical tool, this technology allows resource managers to evaluate impacts of land use strategies. The Newfoundland and Labrador Forest Service uses satellite imagery and patented GIS software to conduct regular inventory updates for planning, and regular wood supply analyses. These tools are essential to assist in decision making to support the development and implementation of forest ecosystem plans.

Remote Sensing

Remote sensing is the science of acquiring information about Earth's surface without actually being on location. There are a variety of methods used to remotely sense and record reflected or emitted energy. These include ground-based sensors, aircraft, satellites, and even the space station. This information is processed, analysed, and used in a variety of fields including forestry.

Applications of remote sensing in forestry include the following:

- Reconnaissance mapping:
  This application includes mapping of forest cover and type, depletion monitoring, and measurement of biophysical properties of forest stands.

- Commercial forestry:
  The commercial forest industry is interested in inventory and mapping application. The most important applications are:
  - Clear cut mapping
  - Mapping cut areas or silviculture areas
  - Updating forest inventory
  - Information on timber supply
  - Insect and disease occurrence
  - Burn delineation

- Other applications
  - Infrastructure mapping (access roads, etc.)
  - Collecting harvest information
  - Forest type
  - Species inventory
  - Vegetation, density, and biomass measurement

- Environmental monitoring
  Foresters are concerned about monitoring the quantity, health, and diversity (biodiversity) of Earth's forests. Remote sensing can be used to measure and monitor:
  - Deforestation
  - Species inventory
  - Wildlife habitat assessments
  - Watershed protection (riparian strips)
  - Coastal protection (mangrove forests)
  - Forest health

Summary

Few things can rival the solitude of a healthy boreal forest on a hot summer's day with the pungent smell of pine and spruce and the splashes of colour from forest wild flowers as the call of a chickadee echoes under the canopy. Some of our best memories may be of blueberry picking in late summer. For many, moose hunting in the fall is a time of great enjoyment—not to mention a source of food. Others like to cut the winter's wood in March when the days are getting longer but the nights are still cold enough so everything freezes over and they can haul a few loads of wood before lunch. A lucky few may have the chance to run the rapids on the Main River in early June when the spring runoff is still high enough to make the trip a real adventure.

Anyone who spends time in the forest often learns to love it as a place of constant change, a place to play, and a place to work. In Newfoundland and Labrador we have strong links to the forest. It is part of our culture and our economy. We need healthy forests locally and globally if humans are to survive as a species on this planet.

When we learn that half the wood harvested on Earth is burned for heating and cooking, and that the loss of forest means a loss of biodiversity, we soon begin to realize the complexity of the problems we must face in good forest management. Sound management practices are important at the local, provincial, national, and international levels. Increased focus on some of the global issues such as poverty, limited energy supplies, and education will help to reduce pressures on our forests. There is no doubt that forest management in some parts of the world has come a long way from the approaches of our ancestors. However, to ensure that our forests continue to provide sustainable benefits for future generations, it is vital that we continue to improve our understanding of forest ecosystems, and how best to protect and manage them while at the same time improving our ability to develop and implement wise management plans based on that knowledge.

CHECK your Understanding

1. Why do modern mechanical wheel harvesters have very low air pressure in their tires?
2. What are some of the positive features of "walking forest harvesters" over wheeled harvesters?
3. What is remote sensing? What are some forestry applications of remote sensing?
4. How do you value the forests of this province? What types of activities do you participate in that involve the use of our forests?

CAREERS IN FORESTRY

Forest Industry Worker

If you have a love for the outdoors, enjoy growing things, or like working with your hands, there can be a healthy career waiting for you as a forest industry worker. Forest industry workers are employed by government and by private industry. Most government forestry workers work on silviculture projects such as reforestation and thinning, or at one of the two provincial tree nurseries. In the past, the Department of Natural Resources has piloted programs to expose young people to forestry. For example, in 2006, they piloted a silviculture program aimed at hiring young Newfoundlanders and Labradorians to reforest previously harvested areas that have inadequate or unacceptable regeneration.

Figure 10.37: Planting Seedlings.

Forestry workers may be involved in harvesting trees; in silviculture; or in an industrial setting. Traditionally, loggers used chainsaws to fell the commercial trees. This method is rapidly being replaced by modern mechanical harvesters operated by heavy equipment operators. There are also employment opportunities in forwarding (logs from forest to landings), trucking (logs from landing to the mill), and in other aspects of the harvesting industry. The Corner Brook Pulp and Paper company has a large silviculture program and plants millions of new seedlings each year. This company also conducts large pre-commercial thinning programs. There are industrial jobs inside the pulp and paper mill as well, such as machine operators, millwrights, and support jobs.

Figure 10.38: Inside mechanical harvester cab. *Photo Courtesy: Department of Natural Resources*

Millwrights also work in the numerous sawmills that have been developed in rural Newfoundland since 1996. Many of these mills face a shortage of skilled and unskilled workers.

Figure 10.39: Inside a modern sawmill located in Bloomfield NL. *Photo courtesy Department of Natural Resources*

The production of value-added forest products such as log siding, hardwood flooring, guitars, and furniture is expanding and creating additional opportunity for new employment in rural Newfoundland.

To work in the forestry sector people need a minimum of a grade 12 education. Skilled workers need additional qualifications such as a traction engine license to operate a wood harvester, and a Class 1 driver's license to drive a wood-hauling truck. Just as there is a wide range of job opportunities in this sector, there is also a wide range in the salary paid to forestry workers. Pay scales can range from $1,600/month for seasonal silviculture

Figure 10.40: Firefighter.

employment to $60,000 per year for unionized jobs associated with the pulp and paper industry. Most wood truck drivers are owner-operators. These drivers' pay is based on the volume of wood they transport. And because there is a shortage of people available to fill forestry worker jobs, there are opportunities for young Newfoundlanders and Labradorians to find a career in the rural areas of their province.

Forest Fire Fighter

Fighting forest fires requires special training. Forest fire fighters are on the front line fighting flames and smoke with pumps and hoses, or directing air support from water bombers and helicopters. The province's fire fighters are instrumental in protecting human life, property, and natural resources from the destruction by wildfire. This job is physically demanding and often includes long hours of work in extreme heat and very rough terrain. Because of the physical and mental demands of their work, and the responsibility for safety and protection that lies with them, most fire fighters take great pride in their work and their ability to help protect the forests. As a fire-fighter you would be a member of a close-knit team that, together with similar teams based elsewhere, make up an experienced and well trained fire-fighting organization. Qualified forest fire fighters from this province have traveled throughout North America to combat major wildfire outbreaks in other jurisdictions (under a national fire-fighting resource sharing agreement).

Figure 10.41: Air support to battle a forest fire.

The forest fire fighter is an entry-level position with the provincial Department of Natural Resources. The pay scale for this position starts at $2,500 a month (but can be much higher during major wildfire events). In order to become a forest fire fighter, you must, at a minimum, complete a two-year forest related course at a technical training institute recognized by the department. This is a great starting point for a rewarding career as a provincial conservation officer.

Conservation Officer

Figure 10.42: Conservation officer conducting an inspection of hunter's license and fire arm. *Photo courtesy Department of Natural Resources*

Figure 10.43: Conservation Officer. *Photo courtesy Department of Natural Resources*

Figure 10.44 Conservation Officer conducting a sawmill inspection. *Photo courtesy Department of Natural Resources*

Figure 10.45: Conservation Officer conducting forest inventory in a hardwood stand. *Photo courtesy Department of Natural Resources*

Figure 10.46: Conservation Officer involved in the Newfoundland Marten recovery program, student job shadowing the capture and collaring work. *Photo courtesy Department of Natural Resources*

Conservation officers are guardians on the front lines in the protection and preservation of our natural resources. They participate in a variety of resource management programs aimed at the sustainable development of forest and wildlife values. Duties vary from assisting in the development of strategic ecosystem management plans, to implementing forest renewal, resource access road development, and timber harvesting programs. Conservation officers also assist in the delivery of wildlife management programs such as the endangered Newfoundland marten recovery program, bald eagle *(Haliaeetus leucocephalus)* banding/monitoring program, a variety of big and small game population surveys, and in handling human/animal interface issues. Working with a fire management team to combat wildfires is often necessary during the summer season.

Conservation officers are responsible for ensuring that resource users obey the acts and regulations in place to protect the environment, including the *Forestry Act and Regulations*, the *Wildlife Act and Regulations* and *ATV Regulations*. They may also be cross-appointed to enforce other legislation such as the *Migratory Bird Regulations* and the *Newfoundland Fisheries Regulations*. Conservation officers work in a high-tech environment and rely on such things as GIS and GPS to perform many aspects of their jobs.

Keeping the public informed about proposed changes and bringing the opinions of the public back to government is also an important part of their work.

As a highly trained professional group, with a salary ranging from $30,000 to $50,000, conservation officers are expected, at a minimum, to complete a two-year course in a recognized natural resources program. Extensive on-the-job training is also provided by the Department of Natural Resources. The opportunities within the department as of 2006, identified the need for major recruitment during the following decade. And while the total number of jobs may be limited, this could be an exciting career choice for you if you have a love for the outdoors and a desire to join a professional team committed to educate people and protect our natural heritage.

Forester

Foresters face the challenging job of developing and implementing plans to manage the forest ecosystem. That is no small task in the twenty-first century. Public and private interests depend on foresters to help lead the way to healthy and sustainable forest management. Employed by industry and by government, foresters draft plans that provide for sustainable development of forest resources that are in harmony with other values intrinsic to the forest ecosystem.

As part of this process, foresters consult broadly with other people who often have competing land-use issues. For example, they would work with people in tourism and in agricultural development. They consult with cottage development groups and urban planners.

When foresters develop forest ecosystem plans, they have to reflect ecological values such as habitat protection for endangered species, or sensitive wildlife habitat such as that of the woodland caribou calving grounds. Following an intensive planning process, forest ecosystem plans must be registered under the province's environmental assessment legislation before they can be implemented. And before that can happen, the plans must undergo full public review.

Foresters face the challenging job of developing and implementing plans to manage the forest ecosystem.

As with conservation officers, the forester's work environment includes modern technology. They might, for example, conduct a wood-supply analyses using complex computer modeling programs that track timber harvest schedules through the rotation age (80 – 100 years) of a forest. HSI (Habitat Suitability Index) models are used to predict landscape carrying capacity of target wildlife species, and to evaluate the long term impact of management strategies.

Foresters develop and monitor the implementation of various other ecosystem management programs, such as resource road development, forest renewal, forest ecosystem inventory, and forest ecosystem protection. Foresters decide who gets how much of the province's timber supply. Public relations and supervision of a

professional conservation officer corps are key functions of many Crown forester positions in Newfoundland and Labrador. Foresters in the private sector might work as logging superintendents on major logging operations.

A bachelor of science degree in forestry/forest engineering from an accredited university is essential for most forester positions in the province. Salary ranges from $45,000 to $70,000 for government foresters, but generally tends to be higher in industry positions.

Forestry Researcher

A forestry researcher develops and conducts research to test and observe patterns in forest science. Many researchers design and test experiments in the field and in the laboratory to find out more information about a specific forest ecosystem problem or issue.

Researchers collect and analyze data, and then publish the results as scientific reports and journals. Forest researchers have well-developed analytical skills and an in-depth knowledge of the theories and main principles in the field of forest science. The two types of career opportunities in forest research include research scientist and scientific support technician.

Figure 10.47: Forest researcher collecting data. *Photo courtesy Department of Natural Resources*

A research scientist conducts research to advance knowledge and develop new technology. They do this by creating new theories in forest science and then testing those theories to determine whether or not they are correct. As a science researcher, you would have very specialized knowledge in a particular area of forestry. Based on your area of expertise, you would help improve the knowledge base of the forestry community. You would provide leadership on forest science panels and on committees.

In order to become a research scientist you would require a PhD in your field of expertise from a recognized university. Salary ranges from $35,000 a year for a research officer to $100,000 a year for an experienced forest researcher.

A scientific support technician prepares work sites and equipment needed in conducting experiments. They calibrate and maintain equipment used in the field and the laboratory, collect data samples, and compile data in graphic and narrative form. A two-year natural resource course from a technical training institute is required to begin a working career as a research technician. The salary ranges from $30,000 to $60,000.

Chapter 11: Agriculture in Newfoundland and Labrador

INTRODUCTION TO AGRICULTURE

Figure 11.1: A farm and agricultural land.

Most of what we eat and drink comes from cultivated plants and domesticated animals.

Humans have been growing plants and herding animals in some parts of the world for as long as 10,000 years. In other places the development is more recent. It is only in a few isolated places on Earth that some tribes still live as hunters and gatherers, the way our ancient ancestors did. The vast majority of people on Earth today rely on agriculture for part or all of their food.

Despite the growth of human population, now estimated to be 6.8 billion and climbing, the world's food production has kept pace. The Earth's agricultural lands actually produce enough food to meet the needs of all people on the planet, but this production is unevenly distributed due to such factors as climate, soil, and available technology.

The expansion of the agricultural industry to meet the ever expanding demand for food puts pressure on the environment. Most of the world's deforestation is a result of the need for more agricultural land. Farm runoff impacts water

quality in rivers and lakes. Livestock are a major source of methane, a greenhouse gas. Yet in spite of these and other impacts, the world's population could not be fed without agriculture. In fact it is human kind's ability to grow its own food that is contributing to the rapid growth of the human population.

In this chapter you will learn about the relationships between agriculture and the environment and how science can help to overcome problems associated with food production.

A definition of agriculture:

The land-based cultivation of living organisms for the benefit of humans. This includes the production of crops, and the rearing and management of livestock.

The development of agriculture over many thousands of years enabled humans to slowly adapt their nomadic way of life as hunters and gatherers to a more settled and stable lifestyle.

This allowed people to live together in larger and larger communities, and enabled them to specialize in various kinds of labour. It also fostered the flowering of art and science and the development of centralized religion and government. So it could be said that agriculture has fed the minds as well as the bodies of humans and is, therefore, an essential part of human civilization as we know it today.

Agriculture encompasses such subjects as animal husbandry, horticulture, and even aquaculture, which itself is thousands of years old.

Agriculture relies on numerous fields of science to address such issues as soil management and fertility, pest control, crop and animal production, as well as improving yields of cultivated plants and animals.

CHECK your Understanding

1. Make a list of everything you ate yesterday. Next to each item in your list, make another list that traces back to the food's origin (see the example below).

   Milk . . . . . cow
   Cheese . . . . . milk . . . . . cow
   Bread . . . . . flour . . . . . wheat

2. Is there anything that you ate or drank that could not be traced back to its agricultural roots? If yes, then you should ask yourself "Why"
3. Identify those food items on your list that you ate that were produced in Newfoundland and Labrador. You may have to go back and check the produce labels to find this information.

For Further Discussion and/or Research

4. Research the relationship between human population and the world's food supply. Will the food supply keep pace with the growing population? How can we increase food distribution around the planet?
5. Interview an older member of a rural community to learn about the role that agriculture played in their community in the past.
6. Interview a current farmer to learn about their farming operation, farming products, and farming impact on the local economy and prospects for the future.

Agriculture in Newfoundland and Labrador

Gross domestic product is the total market value of all the goods and services produced.

In 2004, farming in Newfoundland and Labrador contributed approximately 0.5 per cent of the province's annual gross domestic product. For every one hundred dollars made in this province, fifty cents came from agriculture. However, while in most Canadian provinces agricultural activity is decreasing, Newfoundland and Labrador is experiencing growth in the sector.

Figure 11.2: Pynns Brook Farm.
Photo courtesy Department of Natural Resources

During the last ice age, over 10,000 years ago, glaciers scraped off most of the surface soil of Newfoundland and Labrador. Our shallow and stony soils in the province today developed after the ice age ended.

Just one per cent of the island's land (that is 100,000 hectares) is suitable for agriculture. There are also 1.3 million hectares of peatland that can grow a wide variety of crops including vegetables, turf grass (sods for lawns and golf courses), forage (food for cattle), and cranberries. Peatlands can also be used as pasture lands. Approximately 8,000 hectares have the potential to support a variety of berry crops.

Newfoundland and Labrador's soil and cool climate have limited agricultural production in our province. However, Newfoundland and Labrador is one of the few areas in North America where land is still being cleared for agriculture. Most of the province's 640 farms are located on the island and they average sixty five hectares in size.

Did You Know?

In the metric system, the hectare (ha) is used to measure land for agriculture. One hectare equals 10,000 square metres.

One hectare is equal to 2.47 acres in the Imperial system used in the United States.

Growing crops and raising livestock has been part of the Newfoundland way of life since the first European settlers arrived over 500 years ago. The main crops produced in the province include berries, greenhouse products, and vegetables such as turnips, cabbage, carrots, and potatoes. In addition to crops, other principal agricultural products include livestock, dairy, poultry, and eggs.

History of Agriculture in Newfoundland and Labrador

Figure 11.3: In early settlements, making hay was a job taken on by women.
Photo courtesy Provincial Archives of Newfoundland and Labrador (PANL a12-122), St. John's, Newfoundland

Humans have inhabited Newfoundland and Labrador for more than 8,000 years. Maritime Archaic Indian, Paleo Eskimo, Beothuk and subsequent aboriginal cultures were hunter-gathers. They depended on the resources of the land and sea to meet their basic needs for food, water, and shelter.

Agrifoods is a term that is used to describe foods produced through an agricultural process as opposed to hunting, fishing, etc. The term also applies to the industries that are involved in the production, processing, and inspection of food products made from agricultural materials.

In Labrador, the Innu and Inuit relied totally on hunting and gathering. In the 1700s, Moravian missionaries introduced agriculture. However, this was not passed on to the nomadic population of Labrador, who had no need for cultivated crops on a commercial scale. However the Grenfell Mission successfully introduced agriculture to Labrador with the much smaller scale kitchen gardens.

It was not until the arrival of other Europeans cultures that agriculture became a common feature of the Newfoundland and Labrador landscape.

Figure 11.4: Bee hives. *Photo courtesy Department of Natural Resources*

Apiculture

Apiculture or "bee keeping" is the commercial raising of bees (Apis mellifera). Bee keeping is a small agricultural industry in Newfoundland and Labrador. In 2004 there were eleven commercial producers marketing approximately 2,500 kilograms of honey annually.

Honeybees in Newfoundland and Labrador are unique. They are free from parasites common to the rest of North America. The *Varroa* mite (*Varroa destructo)* lays its eggs in the brood cells of bee hives. The honeybee tracheal mite (*Acarapis woodi)* invades the trachea of honeybees and feeds on body fluids. These bee parasites are a significant challenge to beekeepers throughout North America. Because our bees are mite free they are prized for seed stock. Queen bees raised in Newfoundland sell for as much as $100 each. The only other places where mite-free bees are available are New Zealand and Hawaii!

Source: Department of Natural Resources

PRESENT LEVEL OF PLANT FARMING IN NEWFOUNDLAND AND LABRADOR

In 2004, the agrifoods industry employed more than 6,200 people in this province and had sales of approximately $500 million annually. The agrifoods industry consists of 643 producing farms and over 100 food manufacturers. Primary production includes dairy, eggs, poultry, red meats, vegetables, fruits, greenhouse products, and fur.

Crop Farming

Figure 11.5: A healthy field of potatoes. *Photo courtesy Department of Natural Resources*

When it comes to growing crops Newfoundland and Labrador farmers have shown innovation and adaptability in producing many different crops including vegetables, berries, forage (grass and legumes used for animal feed), grains, turf grass, and Christmas trees. Crop choice depends on environmental and market factors:

- Environmental factors include climate, weather, soil type, and soil quality.
- Market factors include the cost of production, distance to potential markets, and consumer demand.

Many crops are harvested from the wild. In the past, blueberries (*Vaccinium cyanococcus*), partridgeberries (*Mitchella Repens*), bakeapples (*Rubus chamamorus*), and other berries were primarily harvested for personal use. Many are now grown commercially or picked from the wild for market. Traditional garden vegetables like potatoes (*Solanum tuberosum*), carrots (*Daucus carota*), turnips *(Brassica*), and cabbages (*Brassica oleracea*) are now grown commercially.

Berries

The berries harvested commercially in the province include blueberries, raspberries, strawberries, partridgeberries, cranberries, and bakeapples. The Department of Natural Resources is also investigating the possibility of introducing new berries such as Sea Buckthorn. Like all plants, each species of berry requires specific soil and climatic conditions to flourish.

Berry Pests

Figure 11.6: Raspberry Crane Borer. *Photo courtesy Department of Natural Resources*

Walk through the forest in late August or early September and you will notice leaves are chewed up, curled up, and spotted black and brown. There has been a feast in the forest and if you want your share, you will have to outsmart all the others at the table. For example, who is chowing down on the raspberry bush? We call them pests and diseases but when you think about it, all they want is their fair share! For information on other agricultural pests, see the section on Pest Control.

Source: *Raspberry Pest Management Guide*

- **Blueberries** are native to Newfoundland and Labrador and were used by Aboriginal peoples for food and medicine. Today blueberries are picked in late summer and early fall for use in jellies, jams, and wines as well as in baked goods. The first plants to repopulate areas burnt in forest fires, blueberries have been grown commercially since the 1940s. In 2003, approximately one million kilograms of both wild and cultivated berries were produced from more than 485 hectares in Newfoundland. Major production areas include Conception Bay North, Bonavista North, and Central Newfoundland.

Figure 11.7: Blueberries.

- Although **strawberries** (*Psidium cattleianum*) are native to Newfoundland and Labrador, the commercial varieties are imported hybrids. Strawberry production increased from 52,000 litres in 1980 to approximately 190,000 litres in 2003, and then fluctuated down to 170,000 litres in 2005. With forty three commercial strawberry producers in the province, most of the production takes place in the Humber Valley, Campbellton, and Clarenville—Musgravetown areas.

Figure 11.8: Strawberries. *Photo courtesy Department of Natural Resources*

- **Partridgeberries** and **bakeapples** are also harvested in Newfoundland and Labrador. Our province is Canada's largest producer of partridgeberries. The bakeapple is popular with berry connoisseurs, fetching up to $8 – $12 per litre. This berry is valued for its unique flavoured tarts, jams and jellies. It is estimated that approximately 28,000 hectares of productive partridgeberry land are available. Bakeapples are found throughout the province but southern Labrador has the most productive bakeapple land.

Figure 11.9: Partridgeberries. *Photo courtesy Department of Natural Resources*

Figure 11.10: Bakeapples.

To flourish, each species of berry requires a specific soil type, pH, hours of light, and amount of moisture. The table below compares non-living (abiotic) factors specific to common berry types harvested in Newfoundland and Labrador.

Common Raspberry Pests of NL

Virus	Mosaic, Leaf Curl, Crumbly Berry
Mildew	Powdery Mildew *(Sphaerotheca Macularis)*
Galls	Crown Gall
Rusts & Blights	Late Yellow Rust *(Pucciniastrum americanum)*, Fireblight *(erwinia amylovora)*
Worms	White Grubs, Wireworms, Nematodes *(phylum Nematoda)*
Insects	Raspberry Cane Borer *(Oberea bimaculata)*, Raspberry Crown Borer, Root Weevils, Raspberry Sawfly *(Priophorus morio)*, Raspberry Bud Moth

Berry	Soil	pH	Day length	Moisture
Partridgeberries	Moist rich soil	4.5 - 5.5		Well drained soil
Blueberries	Well drained	4.5 - 5.5	Controls the conversion of vegetative buds to flower buds	Require lots of moisture
Bakeapples	Boggy land with ground water 40 - 50 cm below the surface	3.5 - 4.5		Require lots of moisture
Strawberries	Deep sandy loam soils	5.5 - 6.5	Short day plants	Well drained soil

Figure 11.11: Environmental conditions for selected Newfoundland berries.

ENVIRO-FOCUS

Creating growing environments for cranberries

Agricultural specialists from outside Newfoundland and Labrador predicted that cranberries could not be grown commercially in the province because the growing season was too short and the weather was too cold for the berries to ripen. Walter Calloway proved the experts wrong. His cranberry farm in Terra Nova is one of five commercial farms in the province.

Since 1996, the Department of Natural Resources has been fostering the development of a commercial cranberry industry in Newfoundland and Labrador. As part of this project, the department tested seven different varieties of cranberries and established five commercial cranberry operations at Frenchman' Cove, Deadman's Bay, Stephenville Crossing, Stephenville, and Terra Nova. Stephenville Crossing produced the first commercial harvest. In 2004, there were approximately thirteen hectares in production on five sites, of which eight hectares commercially produced over 72,570 kilograms of fruit. Researchers at the Agriculture and Agrifoods Canada Research Centre in St. John's are evaluating other varieties that may be well suited to the province's climate.

Figure 11.12: Cranberry farmer with harvest. *Photo courtesy www.centennialcranberry.com*

With eleven per cent of the Island being comprised of bog, one would think that there are plenty of prime cranberry growing areas. However, natural bogs are not suitable sites for cranberries. In a natural bog it is difficult to control water levels (used for flooding and harvesting) and difficult to construct growing sites (dikes and ponds). An ideal site for the construction of a cranberry bog has the following characteristics;

- A water table 0.5 metres below the surface
- A nearby source of the right type of sand and other materials used in construction
- Reasonably level land which lessens the need for earth moving
- An available source of fresh water, (usually this is a constructed pond beside the bog)
- Environmentally friendly in that there is no negative impact on the environment
- A climate free of late spring frosts and early fall frosts
- Easily accessible to the grower
- A large enough site to accommodate supporting structures including dikes and ponds, and to allow for future expansion

There are seven different varieties of cranberries grown on the island of Newfoundland.

Cranberry Bog Construction—When a suitable site is chosen for a cranberry growing operation and all the necessary construction and environmental permits are in place, construction may begin. After the construction is completed, cranberry vines are normally planted. In Newfoundland and Labrador, however, because the industry is being developed with superior stock—cranberry plants from selected tissue culture—fingerprinted material is used for establishing fields in the province. Using a specialized transplanter, cranberry shoots are planted at a rate of 50,000 per acre in the spring and the early summer.

There are seven different varieties of cranberries grown on the island of Newfoundland. These varieties are selected based on their genetic yield potential, suitability to local climate, and intended use for the product (for example fresh juice, dried fruit, and other uses).

After planting, the vines need proper fertilizing and watering through an irrigation system. In the first year no fruit is produced. The goal is to ensure that the plants become established and that the bog fills in with cranberry plants as quickly as possible. A well-rooted cranberry plant is more tolerant of changes in moisture and other conditions. A filled in bog makes it difficult for weeds to take root and will maximize future yields. Weeding during this crucial first year is often done by hand.

The second year will usually yield a crop that is harvested by flooding the field, releasing the berries by mechanically beating the plants and then scooping the berries off the surface of the water.

Cranberry Pests—The cranberry plant has its fair share of pests. Two major cranberry pests occur in Newfoundland and Labrador: the cranberry fruit worm, and the cranberry girdler. Cranberry fruit worm is present in Terra Nova, Deadman's Bay, Grand Falls, Flat Bay, Stephenville, and on the Avalon Peninsula. The larvae of the fruit worm burrow into the berry at the stem and consume the inner flesh. Less destructive than the fruit worm, the cranberry girdler feeds on the roots and runners of the cranberry bush. It is found across the island, although it is less common than the fruit worm. In addition, there are several other species of insects with diets that include cranberries. These include the false armyworm, the blossom worm, the cranberry white grub, the strawberry root weevil, and the black vine weevil.

CHECK your Understanding

1. What factors limit the range of agriculture in Newfoundland and Labrador?
2. Why are the soils of Newfoundland and Labrador shallow and stony?
3. Define subsistence and give an example.
4. What common crops are raised in this province? Based on today's data, what is the economic value of these crops?
5. Every summer Newfoundlanders and Labradorians go berry picking. Why is it not possible to find one spot where you can pick blueberries and bakeapples at the same time?

For Further Discussion and/or Research

6. Blueberries are one of the first berries to appear after a forest fire. What changes occur in the forest soil and surrounding environment that favour blueberries?
7. Find out how commercial blueberry farms prepare the soil so that it accepts and produces blueberry crops.
8. In the past, Newfoundland and Labrador berries have been used for more than food. Find out about other uses of berries in our province through research on the web or by interviewing older members of your community.
9. Apples and plums are commercially grown on the west coast and by hobby farmers elsewhere on the island. What environmental factors limit fruit production in Newfoundland and Labrador?
10. Find out more about the importance of berries in First Nations cultures.

Vegetables


Figure 11.13: Carrots and cabbage. *Photos courtesy Department of Natural Resources*

Vegetable production was probably the first type of agriculture in Newfoundland. Early settlers depended on a supply of vegetables to survive. For many, the vegetable garden also served as a source of income, especially from the 1930s to the 1950s. Local produce is currently available at farmers' markets and grocery stores.

Current production focuses on vegetables that are suited to our soil and climate conditions. In the past, the most important crops were potato, turnip, parsnip cabbage, carrot, and beet. Newfoundland and Labrador producers are changing to suit the market and are using the latest technology to stay competitive. Among the vegetables more recently added to the agricultural crop mix in the province are broccoli, cauliflower, corn, iceberg lettuce, leafy lettuce, romaine lettuce, tomato, and onion.

Crop farming involves planning, financing, marketing, accounting, labour management, mechanization, pest control, harvesting, cooling, storage, grading, packaging, and shipping. Current technology includes precision seeders, mechanical transplanters and harvesters, greenhouses, row cover, and refrigerated, jacketed, and ice-bank cooled storages.

Potato
Solanum tuberasum

Turnip
Brassica compestris var. rapa L.

Parsnip
Pastinaca sativa

Cabbage
Brassica oleracea var. capitata L.

Carrot
Daucas carota L.

Beet
Beta vulgaris

Broccoli
Brassica oleracea var. italica L.

Cauliflower
Brassica oleracea var. botrytis L.

Corn
Zea mays L.

Iceberg Lettuce
Lactuca sativa var. capitata

Leafy Lettuce
Lactuca sativa

Romaine Lettuce
(Lactuca sativa L. var. longifolia)

Tomato
Lycopersicon esculentum L.

Onion
Allium cepa L.

Commodity	Local Supply of Total Consumption	Annual Volume (kg)
Beet	56.9%	7,881
Broccoli	25.9%	109,604
Cabbage	22.7%	301,975
Carrot	16.6%	237,512
Cauliflower	11.6%	25,791
Corn	18.1%	34,506
Greenhouse Lettuce (Leafy)	22.1%	43,227
Greenhouse Tomato	3.7%	17,814
Lettuce - Head (Iceberg)	9.6%	26,973
Lettuce - Romaine	10.3%	26,494
Onion - Yellow	2.8%	51,029
Parsnip	25.9%	22,199
Potato - All Varieties	7.1%	885,513
Turnip (Rutabaga)	32.9%	494,149
Tomato - Field	15.9%	17,814
Potatoes		
White	7.6%	773,901
Red	5.0%	100,730
Yellow	1.7%	5,670
Blue	59.7%	5,213

Turf grass and Peatlands

Newfoundland and Labrador has 6.4 million hectares of peatlands, approximately seventeen per cent of the province's total land area. On the island there are 1.1 million hectares of peatland, or eleven per cent of the island.

Figure 11.14: Turf grass. *Photo courtesy Department of Natural Resources*

In a previous chapter, you learned that peatlands provide habitat for many species of animals and plants. Peat bogs are naturally acidic, infertile, and saturated with water. With good agricultural techniques, these qualities can be overcome. And the result is a stone-free growing medium ideal for vegetables and turf grass.

The first of two major steps in the agricultural development of a peat bog is proper drainage. Ditches and drains remove water from the peat, lowering the water table and drawing air into the peat soil (aeration). The oxygen content of the air speeds the process of decomposition and increases the release of nutrients.

The second major step before vegetable or turf grass production begins, is adjusting the pH and fertility of the peat soil. (This will be discussed later in this chapter).

With these two factors under control, farmers can grow the cleanest vegetables on the market and the highest quality turf grass. In fact, of the more than 150 hectares of land are now under turf grass production, ninety per cent of that is peatland. Less than ten per cent is mineral soil.

Christmas Tree Farming and Wreath Making

Figure 11.15: Christmas tree farming takes years to produce a crop. *Photo courtesy Department of Natural Resources*

With the Canadian Christmas tree market valued at $ 95 million, there are commercial opportunities in this market locally, nationally, and globally. Production of balsam fir wreaths can also be profitable. Recent figures indicate that New Brunswick—currently the largest producer in Canada—turns out 4.1 million wreaths annually with an estimated value of $20.5 million dollars.

Newfoundland and Labrador has thirty Christmas tree farms which produced 5,000 trees in 2004. The majority of sites for this developing industry are on cutovers which are well suited to the growth of balsam fir. Many challenges face the Christmas tree and wreath industry in the province. These include a lack of technical expertise, the problem of fir and pine insect pests not the least of which is the voracious moose.

ENVIRO-FOCUS

Moose and Christmas tree/wreath grower Conflicts

Moose eat 15 – 20 kilograms of food daily. In winter, their food consists mainly of deciduous tree shoots and balsam fir. In summer they eat deciduous shoots and leaves, aquatic vegetation, and shrubs. Like seasoned restaurateurs, moose tend to select from the top of the menu. Moose are attracted to fruit, vegetables, quality balsam fir plantations, and silviculture stands.

Conflict

Grazing moose can cause serious damage to both vegetable and Christmas tree farms. Vegetable farm problems occur mainly in late summer when moose can be removed by licensed hunters. On the other hand, moose dine on balsam fir all year and hunting season is closed for most of that time.

Figure 11.16: Tree damaged by moose. *Photo courtesy Department of Natural Resources*

Balsam fir is the tree of choice for most Christmas tree growers, but browsing moose create serious problems when their grazing detracts from the physical appearance of the trees. Conflicts may be especially severe when operations are established in moose habitats. Pruning and fertilizing balsam make the fir more tempting for moose—especially in winter when food is scarce.

Some Christmas tree growers have requested to be included in the moose removal program currently provided to vegetable farm operations. However, Christmas tree operations differ from vegetable farms in that they require year-round protection from moose. Christmas tree farmers have to find alternative methods of reducing loss from moose. These methods are outlined below.

Reducing Moose conflicts:

- Level of Human Activity—Generally, moose avoid communities and other areas of concentrated human activity. Wherever possible, Christmas tree farms should be located in such areas.
- Moose Occupancy—Christmas tree growing operations should be located away from winter moose yards or summer habitat.
- Dominant Forest Type Surrounding the Site—A balsam fir plantation should not be placed near a black spruce-dominated forest. Since moose will not eat black spruce, any animals in the area will be attracted to the balsam.

- Control Measures—Fencing and scare devices can be used to keep moose out or to scare them away.

- Hunter Co-operation—As a means to reduce numbers of local moose in close proximity to the operation, farmers should record the time, dates, location, and number of moose sightings. Collected over time, this information will often show a predictable pattern that licensed hunters can use to get a moose and also benefit the farmer by removing pest and discouraging others.

Source: Department of Natural Resources.

Figure 11.17: Forage field.
Photo courtesy Department of Natural Resources

Forage

Forage is animal food such as clover, timothy, red top fescues, alfalfa, and more recently, silage corn. In 2006, the province was eighty per cent self-sufficient in forage production with the western and central areas almost completely self-sufficient. Silage corn is used primarily as forage for the dairy industry and yields approximately twice as much forage as does traditional hay. In 2001, there were approximately 930 hectares in production producing 35,000 tonnes of forage.

Source: Newfoundland and Labrador: Department of Natural Resources

ENVIRO-FOCUS

Growing Silage Corn in Newfoundland

Silage corn is grown in Musgravetown, Cormack, Hughes Brook, Codroy, Daniels Harbour, Wooddale, and in various locations on the Avalon Peninsula. Silage corn is more desirable than the small grains (barley, wheat, and oats) as a feed for dairy cows because it is high in total digestible nutrients and digestible energy.

Successful corn production depends on hybrid selection, accumulation of corn heat units (CHU), soil conditions, and climate. Under normal conditions it is difficult to grow corn in most areas of the province. Growers risk total crop failure eight out of every ten years if they do not use plastic mulch (see below for more information on plastic mulch). The number of frost-free

Figure 11.18: Silage corn yields twice as much forage per acre as does traditional hay.
Photo courtesy Department of Natural Resources

days and total degree days (heat units) are the main impediments to growing corn in Newfoundland. New hybrids and new technology make growing silage corn possible, and thus a very important component of the Newfoundland dairy industry. Producing silage corn decreases the farmer's dependency on out-of-province feed sources. Silage corn is very high in energy, and this improves milk production for dairy farmers.

New technology, such as the Samco three-in-one corn seeder, is helping farmers to become more self-sufficient in producing a high yield, high energy crop. The new seeder uses mulch made from biodegradable or photodegradable plastic fibres ranging from six to twenty microns in thickness. The mulch covers young seeds and plants to protect them from the cold, and captures solar energy to encourage an early seeding date and rapid early plant growth, which are very important to silage corn production.

Each year the amount of silage corn being planted is steadily increasing. Production for silage corn has grown from none grown in 1995 to 600 hectares in 2004, to 800 hectares in 2005 and to 920 hectares in 2006—the province's highest acreage to date.

Source: Newfoundland and Labrador Department of Natural Resources

CHECK your Understanding

1. What is forage? Give examples of common forage grown in Newfoundland and Labrador.
2. What environmental factors limit the growth of certain types of forage in this province?
3. Corn is the ideal silage for dairy cattle. What environmental challenges had to be overcome to get corn to grow in the province?
4. Peatlands are valuable resources for habitat, energy, and agriculture. What advantages do peatlands have over traditional crop lands for growing crops such as vegetables? What are the disadvantages?
5. Since their introduction in the late 1800s and early 1900s, moose have become formidable pests in the forests, along our highways, and in agricultural operations. What solutions can be put in place to reduce the impact of moose on the agricultural sector?

For Further Discussion and/or Research

6. Peatland is not just common to Newfoundland and Labrador. Find out how other northern countries are using peatland for agriculture.
7. Technology plays a major role in agriculture today. Find out how the following work:
    - Precision seeders
    - Mechanical transplanters
    - Jacketed and ice bank cooled storage
    - Mechanical harvesters

CORE LABORATORY ACTIVITY

Testing the Effectiveness of Plastic Mulch

Background

Plastics have been used for years to cover greenhouses. They are now also used as a mulch to increase and retain soil heat. In this activity you will try to find out how plastic colour and thickness influence soil temperature.

Materials

- Plastic growing trays (approximately 30 cm by 40 cm)
- Potting soil
- Plastic (black or clear—different thicknesses available from your local department store)
- Thermometers
- Desk lamps or access to south facing window

Figure 11.19: By germinating corn under plastic farmers increase the number of corn heat units in a given season (See Agrometeorology section later in this chapter). *Photo courtesy Department of Natural Resources*

Procedure

1. Fill each tray with potting soil.
2. Cover each tray with plastic mulch. Leave one uncovered as the control.
3. Make a small hole in the plastic mulch and carefully insert a thermometer in each tray to a depth of 1 cm.
4. Place each tray under an individual desk lamp or near a south facing window (on a sunny day).
5. Record the soil temperature every 10 min for one hour in a table similar to the one below.

	Soil Temperature (˚C)					
Plastic Type	10 mins	20 mins	30 mins	40 mins	50 mins	60 mins

Analyze and Conclude

1. Display your results in a graph.
2. What colour of plastic mulch produced the greatest change in soil temperature?
3. What colour of plastic mulch produced the greatest rate of temperature change? (Hint: Look at the slope of the line.)
4. Does the thickness of the plastic have any effect on the rate of temperature change? Explain your answer.

LIVESTOCK AND POULTRY PRODUCTION

Figure 11.20: Dairy production is the largest agricultural sector in the province.

Livestock

Livestock production is the raising of animals for use by humans. This usually means raising animals for food, whether in the form of eggs, milk, or meat. But livestock production also includes raising animals for leather, wool, fur, or even feathers. In a livestock operation, farmers are responsible for feeding, sheltering, and tending to the health of their animals. That means feeding them, protecting them from the weather, and managing their health.

Feed for livestock depends on the type of animals being raised. For most animals raised in Newfoundland and Labrador, feed usually consists of forage, which provides animals with roughage that they transform into proteins and other nutrients. Animals such as cattle and sheep can live on a diet of forage by grazing in grassy fields. If access to fields is limited, farmers supply hay or silage as forage, and further balance this diet by providing feed concentrates made from ingredients such as soybean meal or corn meal. This balanced diet is necessary to ensure that the animals receive the right nutrients needed to produce milk, eggs, and meat. To give the livestock producers a return on their investment, the correct quality and quantity of feed is important.

Livestock operations also provide shelter to protect animals against extreme weather, although many breeds of sheep and cattle are hardy enough to endure a wide range of weather conditions. No matter how hardy a breed of animals may be, they are vulnerable to illness. To reduce the risk of livestock disease, farmers vaccinate their animals. When animals do become sick they may be given antibiotics. There are regulatory safeguards in place to reduce human exposure to these antibiotics. They are designed to prevent the animals from going to slaughter until the antibiotics are eliminated from their bodies.

Livestock farmers in Newfoundland and Labrador raise dairy and beef cattle, goats, sheep, pigs or swine, and a variety of species used for fur. These include fox, mink, lynx, and sable.

- Cattle: The dairy industry is the largest agricultural sector in the province with forty three producers generating more than thirty five million litres of milk each year from more than 4,000 cows. As the industry grows, secondary production of cheese, butter, fresh cream, yogurt, and ice cream is increasing.

  Dairy farms are very expensive to start and operate. In addition to the costs of land and animals, farmers also need to pay for feed, barns, equipment, and a share of the provincial quota for dairy production.

  Raising cattle for beef can be difficult for many of the same reasons. Newfoundland beef farms, most of which are in western Newfoundland, are usually part time operations. Locally grown beef accounts for less than five per cent of the beef consumed in the province.

- Goats: Interest in commercial goat farming is growing. Both goat milk and goat meat have an expanding market. Lactose-intolerant people (unable to drink cow's milk) can drink goat milk. Feta cheese, a popular ingredient in Greek and Turkish food, is made from goat milk. Goat meat,

though not a traditional Newfoundland staple, is becoming more common as the province's population enjoys greater ethnic diversity. Production and processing on a small scale is relatively inexpensive for both start-up and established businesses. A great advantage of raising goats compared with raising cattle is that goats require much smaller land areas. However, strong animal husbandry skills (agricultural practice of breeding and raising livestock) are just as essential to goat farming as any other livestock operation.

- Sheep: Sheep were the first livestock raised on the island of Newfoundland, providing wool and meat to outport families. The local variety is a hardy breed that can withstand the island's challenging climate. For many years they roamed freely in most rural communities. Poor land can serve as pasture for these sheep, which can derive as much as eighty per cent of their nutritional needs from forage. That means the animals require less of the expensive imported feed than other livestock. And that means sheep can be raised at a minimal cost in comparison with other livestock.

Figure 11.21: Pig farm.

- Swine: Newfoundland and Labrador swine farms are small scale by modern standards. These farms are located throughout the province to provide for local markets. A great advantage for Newfoundland's swine producers is their ability to move meat to market quickly. For this reason, local pork is often fresher and has a longer shelf life than imported products. There is also a strong market for secondary pork products, including bacon, ham, sausages, and deli meats.

- Fur species: In 2007, there were thirty fur ranches in Newfoundland and Labrador ranging in size from 25 to 15,000 female breeders. Species produced include fox, mink, lynx, and sable (marten). The estimated pelt production for 2007 is 270,000 pelts—almost doubles the estimated production from 2006. Fur pelts are marketed and sold through major auction houses primarily for use in garment manufacturing.

  Fur production tends to rise and fall according to trends in the global market. Feed, as in most other livestock industries, is a major factor in the cost of production. Fur producers must try to keep costs low in order to compete in a fluctuating market. Ranched fur animals recycle waste products because their diets are comprised of fish offal, spent hens, red meat, and chicken by-products, which would otherwise be rendered or disposed of in the ocean or in landfill sites. Like all farms, fur farms have an impact on the environment, and proper waste management is vital to control disease, odour, and pests. The recent emergence of the Aleutian virus in the mink population may have an impact on the industry.

Livestock and the Environment

Livestock, primarily cattle, use more than one-quarter of the world's croplands for grazing. One fifth of the world's arable land is used for growing crops for livestock feed. Livestock produces over thirteen billion tonnes of waste globally each year. A large part of this is recycled, since manure is an important source of fertilizer. Waste still poses an environmental hazard if not properly managed. On the other hand, livestock provides human food. Livestock production is the sole source of income for many people around the world.

Livestock production impacts water quality, biodiversity, and climate:

- Water can be greatly affected by livestock production. Pollution from wastes and livestock wading in streams and ponds can reduce water quality.

- Another concern is the impact of livestock on biodiversity. For instance, thousands of hectares of rain forest have been cleared to make way for livestock production in South America.

About five to ten per cent of greenhouse gases are produced by livestock and livestock waste. This contributes to global warming. However, farm activities can be modified to reduce the release of greenhouse gases. One way this can be done is by injecting manure into the soil instead of spraying it on the soil surface.

Manure storage at a livestock operation.

Livestock Waste – Manure

Agricultural wastes include manure, animal parts, and crop residue. Manure can improve crop productivity when used as a fertilizer. However, environmental damage can follow from poor disposal of large quantities of manure. In some developing nations cattle and other animals' manure is a traditional building material. It is mixed with grasses, and dried to make bricks.

Manure can also be used as a source of fuel called biogas. Biogas consists of fifty to sixty per cent methane and carbon dioxide and is a by-product of the anaerobic digestion of manure. Anaerobic digestion is a digestive process that takes place in the absence of oxygen (anaerobic means without oxygen). The biogas yield varies with the quality of material. Animal manure has four to five times the yield of a similar volume of municipal solid waste. Biogas can be burned in combustion engines to produce electrical power and heat.

Did You Know?

Other Livestock Species

In addition to the more common livestock and poultry listed above, newer alternative species of animals can be raised in Newfoundland and Labrador. These include ratites, rabbits, and bison:

- Ratites are flightless birds like ostrich, emu, and rhea. A few small ratite productions have started in Newfoundland. Ratites can be used for meat, feathers, and oil.
- Rabbits can be raised for meat. This animal is still being evaluated for commercial development in Newfoundland and Labrador.
- Bison are raised for meat in western Canada. Bison production has not started in Newfoundland and Labrador, though it is possible for interested parties with sufficient pastureland to apply for import licences.

Figure 11.22: While manure, such as this piled outside a barn, can be used as a natural fertilizer, it can also be a source of contaminants that may lead to ground water pollution.
Photo courtesy Department of Natural Resources

Biogas production has many benefits:

- It provides a way of managing manure, especially in large beef or dairy operations.
- It provides an alternative source of energy.
- It reduces odours from manure.
- Fibre from digested manure can be used as a peat moss replacement.
- Anaerobic digestion destroys harmful bacteria in manure and reduces land and water pollution.

Positive Effects	Negative Effects
• Reduces the requirements for artificial fertilizer • Improves soil fertility • Improves soil structure by increasing organic content	• Ammonia emissions before and during storage, and during application in the field • Emission of NO_2, formed as a by-product of the denitrification process • Emission of methane, formed by the decomposition of manure under anaerobic conditions • Run off of manure into surface water, contributing to water pollution • Leaching of nitrate and phosphorus into the ground water, contributing to groundwater pollution

Figure 11.23: Positive and negative environmental impacts of manure.

Methane Gas (CH_4)

The global average methane concentration is about 1.7 ppmv (parts per million by volume) and is increasing by about 0.8 per cent per year. This is a result of human activities such as producing livestock, managing manure, cultivating rice, producing and distributing oil and gas, mining coal, and operating landfills. Livestock and manure contribute about sixteen per cent of a total annual production of 550 million tonnes. Methane is a greenhouse gas with about twenty three times the potency of carbon dioxide to contribute to global warming.

During the process of digesting grasses, ruminant livestock like cattle, sheep, and goats "emit" methane. This gas is a result of the activity of anaerobic digestion in their stomachs (called rumen) where bacteria ferment and digest the grass cellulose. As part of this chemical process, large amounts of methane are produced per unit of feed energy consumed. Pigs and poultry do not have the same digestive process and so have low methane "emissions."

Figure 11.24: A healthy herd of cattle.

When large numbers of animals live together diseases can spread quickly from animal to animal, as for example, in the case of foot and mouth disease. Diseases can seriously reduce the productivity of a herd and in some cases may seriously impact a whole livestock industry. Even though Mad Cow Disease (bovine spongiform encephalopathy) is not passed from animal to animal, one infected cow can have a tremendous impact on the beef industry.

A **prion** is an infectious protein molecule similar to a virus but lacking genetic material. Prions are transmissible agents that are able to induce abnormal folding of normal cellular proteins in the brain, leading to brain damage. Prion-caused diseases are usually rapidly progressive and always fatal.

Livestock diseases are caused by viruses, fungi, prions, and parasites. Parasites are spread in many different ways. They can be introduced to a farm through diseased livestock animals, contaminated feed, rodents, birds, insects, and the shoes and clothing of farmers.

Diseases caused by parasites are common in domestic animals. Parasites may be internal or external. Internal parasites range from single-celled organisms to larger parasites such as roundworm, tapeworm, and fluke. External parasites live or feed on the surface of the animal's body. This group includes bloodsucking insects, such as mosquitoes, gnats, some flies, fleas, and some lice.

Animal	Disease	Means of Spreading	Symptoms
Poultry & Swine	Salmonellosis	Contact with birds or manure	Diarrhea
Cattle	Ringworm (fungus disease)	Contact with contaminated skin or objects Contact with contaminated animals or bedding, inhaling contaminated air.	Itchy, red, dry, scaly circular patches on skin (on the animals they often appear as crusty, bald patches)
Sheep & Goats	Q-fever	Cats can also carry this disease and in a barn situation may be significant in maintaining infection.	Fever, headache, weakness, sometimes pneumonia
All fur-bearing animals	Rabies	Bite from a sick animal	Fatal infection of the brain

Figure 11.25: Examples of Animal Diseases in Newfoundland and Labrador.

Source: Provincial Veterinarian Dr. Hugh Whitney, Director, Animal Health Division

Poultry

The poultry industry in Newfoundland and Labrador is strong and is expected to grow in coming years. The industry includes both broilers (chickens raised for meat) and layers (chickens that provide eggs). There are eight chicken producers in the province. One of Newfoundland's poultry farms is the largest in Canada. The poultry industry in Newfoundland benefits from a mild climate, which is conducive to chicken production. At the same time, feed is very expensive and out-of-province competition for Newfoundland and Labrador markets is intense.

Figure 11.26: Chicken farm.

Chicken producers provide safe, high quality food. Chickens are raised in clean, modern barns that are well heated and ventilated to ensure the right temperature, heat, and air circulation. Broilers are allowed to range freely around the barn.

The Newfoundland and Labrador poultry industry has three parts:

- **Broiler chickens** are grown for meat. Broiler chickens are raised indoors, and take food and water from automated dispensers. They are kept on a floor covered with litter usually made from hay or wood shavings. The litter absorbs moisture, helping to keep the birds dry and clean.

- **Layers** provide eggs. They are usually kept in cages with sloped floors. And while the situation may not be ideal from a layer's point of view,

the result of this method of containment is higher sanitation levels, as the eggs roll away from the chickens and up to the front collection area. Young layers are called pullets— these are hens less than one year old. After one or two seasons, layers are no longer used to produce eggs and are replaced with new pullets.

- **Turkeys** are grown by six main farms and by many smaller operations in Newfoundland and Labrador. Fresh turkey sells for a premium price during traditional holidays like Thanksgiving and Christmas. However, many people buy frozen turkeys that can be imported from out-of-province suppliers. This means that there is strong competition for shares in the provincial market.

Poultry feed usually consists of grains like corn or wheat, mixed with protein supplements like soy meal. Vitamins and minerals are also added. Like livestock, poultry is vaccinated and kept very clean to prevent disease. This is especially important since poultry flocks can be very large, with birds kept in close proximity to one another.

Poultry health and food safety

Federal and provincial governments have primary responsibility for safeguarding the health of food and animals. However, the management of poultry health is a coordinated effort between government, Country Ribbon Chicken Incorporated, and the Egg Producers of Newfoundland and Labrador. Laboratory analysis of feed, water, eggs, tissues, and serum are carried out along with analyses of data on production, environment, and mortality. Bird health is closely monitored and controlled.

CHECK your Understanding

1. What group of animals raised for meat have had the greatest impact on the planet? Should their impacts be considered negative or positive?
2. Sheep were much more important than cattle to the early settlers on the island of Newfoundland. Why was this true?
3. Describe one common livestock disease found in Newfoundland and Labrador.

For Further Discussion and/or Research

4. In many parts of the world manure is the major energy source for cooking. Find out two ways that manure is used to produce energy for cooking.
5. Find out more about Mad Cow Disease and the measures that have been but in place to completely eliminate it from Canada.

ENVIRO-FOCUS

Horticulture in Newfoundland and Labrador

Horticulture is the growing of fruit, flowers, ornamental plants, and vegetables in small gardens or greenhouses. Horticulture includes the following:

Figure 11.27: Inside a modern greenhouse. *Photo courtesy aesop.rutgers.edu/~horteng/images/openroof/inside%20open-roof.jpg*

- **Floriculture**: the production and marketing of floral crops
- **Landscape horticulture**: the production, marketing and maintenance of landscape plants
- **Olericulture**: the production and marketing of vegetables
- **Pomology**: the production and marketing of fruits
- **Post-harvest physiology**: this involves maintaining the quality of horticultural crops

In 2003, there were seventy five greenhouse operations in the province with 59,177 square metres of space. Main crops include ornamental bedding plants, potted plants, and vegetable transplants. In Newfoundland and Labrador, we produce close to ninety per cent of the province's bedding plants and one hundred per cent of the vegetable transplants.

Soilless versus hydroponic horticulture

Soilless growing methods use an inert (non-reactive) medium such as sand, gravel, peat, or vermiculite for a root environment. All the nutrients required for plant growth are provided in water solution. These Soilless cultures are **not** hydroponic in the strict sense of the word, since the roots are embedded in the medium rather than suspended in the water and nutrient solution.

- **Science of Greenhouses**: As controlled growing environments, greenhouses work on the principle that glass and plastics are transparent to solar radiation—the form of energy essential to plant growth. When the sun shines on a greenhouse most of the solar radiation passes through the building envelope, providing plants with energy for photosynthesis and heating up the air inside the structure.

- **Hydroponics**: Hydroponics is a technique for supplying nutrients and water directly to the roots of plants without soil or other media. In hydroponic culture, precise control of the pH and the concentrations

of elements in the solution are critical; all essential elements must be provided and in the correct ratios for plant growth (see also plant mineral nutrition).

Hydroponic systems offer a number of advantages over soil culture. They reduce water, pH, and nutrient stress, yield clean roots and leaves, and facilitate rapid crop turnaround and automation. The disadvantages are that disease may spread more rapidly, pH and nutrient control are required, and initial set-up expenses are higher.

CHALLENGES OF AGRICULTURE IN A NORTHERN CLIMATE

Figure 11.28: Frost on berries.

Climate

Frost

Frost forms when the local air temperature falls below freezing. During the day the planet is like a greenhouse. The sunlight heats up the surface of the Earth and unabsorbed energy is reflected back. At night with no sunlight to provide additional warmth, the energy reflected back by the Earth results in loss of heat. This loss is slowed by the presence of clouds at night which re-reflect heat back to the Earth, reducing the possibility of frost. Frost is more likely to form on clear, calm nights when heat loss is greatest and there is less mixing of cooled air with warm air.

Fruits and berries are very sensitive to frost. It can damage flower buds, blossoms, and fruit. The damage, if widespread, may destroy a whole season's crop. Frost damage is a major threat to farmers in Newfoundland and Labrador.

A **frost-free** day is a day when the temperature does not fall below 0° C.

The average number of frost-free days in the province varies from more than 180 on the west coast and the Avalon Peninsula, to 100 in southern Labrador, to as low as 40 in northern Labrador and central Newfoundland. This is clear evidence that the number of frost-free days is influenced by the farm's location. And this includes how close it is to large bodies of water such as lakes or the ocean. The closer they are to the water, the more frost-free days they are likely to have because of the water's moderating influence on the air temperature. On the other hand, crops in valleys (like the Humber River Valley) or in other low-lying areas are at higher risk of frosts. Because cold air is denser than warm air, it sinks, through warmer air, flowing like invisible water and collecting at the bottom of slopes or in other low-lying areas.

Preventing Frost Damage: The best way to prevent frost damage is to plant crops on less vulnerable sites. Avoid depressions where cold air can gather, plant on south-facing slopes, and make sure that there are no barriers to the free flow of cold air.

Figure 11.29: Using sprinklers for frost control.

Other methods of protecting crop from frost damage are expensive and are usually done only with valuable crops like fruits and vegetables. Protection methods include using heaters or open fires to counteract radiant heat loss, covering individual plants with insulating materials, using fans to mix air near the ground with warmer air above, and using water sprinklers. Sprinklers are used in the Humber Valley to irrigate valuable strawberry crops and to prevent frost damage.

When the temperature reaches 0°C, water sprinklers are turned on to spray the plants and prevent them from freezing—even though ice may form. This method works because when the spray hits the plant surface it freezes before the plant does. The reason is simple. The liquids in the plant cells contain a variety of dissolved materials that act as a natural anti freeze. The water being sprayed on the plants has fewer materials dissolved in it and freezes first. As water is continually sprayed on the plant it continues to freeze and thus protects the plant which is below the ice. However, this is only a short-term solution because if too much water freezes on the plant, the weight of the ice will crush or break the plant.

CHECK your Understanding

1. What three factors influence the potential of a crop to be frost damaged?
2. What are the four methods used to prevent frost damage? What method is preferred in Newfoundland and Labrador?
3. Explain how spraying water on a crop can prevent frost damage, even when the air temperature dips below zero.
4. What factors besides soil quality should you consider when selecting a site for an apple orchard?

Figure 11.30: Data logger in field. *Photo courtesy Department of Natural Resources*

Agrometeorology

The word Agrometeorology combines "agro", meaning "field" or "soil", with "meteorology", which is the study of weather and the atmosphere. Agrometeorology is therefore the study of the interaction between meteorology and agriculture.

While many factors determine what crops can be grown in an area, moisture and temperature are the most important. Normally, the lack of moisture is not a major concern for agricultural crops grown in Newfoundland, although there are some exceptions. For example, cole crops often require irrigation in August, which is typically a dry month in Newfoundland. A more important issue in our province is the amount of heat a crop requires to reach maturity.

"Cole crop" is a general term used to describe several crops of the mustard family including: broccoli, brussel sprouts, cabbage, and cauliflower.

These cool season vegetables grow best in a temperature range of 15 - 20ºC and can withstand light frosts without injury.

Temperature affects plant growth and development. One method to determine the suitability of a crop for the temperature range of an area is to measure the amount of heat available during the growing season. The greater the amount of heat available, to a maximum unique to each plant species, the faster the growth. There is also a minimum heat accumulation level below which no growth will occur. This method of calculating the heat available for plant growth is called the growing degree-day (GDD). GDD is calculated by taking the average daily maximum and minimum temperatures compared to a base temperature. The average temperature for a day is simply the maximum temperature plus the minimum temperature divided by two:

FORMULA

$$\text{Daily GDD} = ((T_{max} + T_{min})/2) - T_{base}$$

Where:

T_{max} = the daily maximum air temperature
T_{min} = the daily minimum air temperature
T_{base} = the GDD base temperature for the plant being grown

The base temperature is often determined by trial and error based on the optimal growing of the plant in question. Using potatoes as an example, we can see how growing degree-day data can be used.

For example, in the summer, the average temperature (Tmax +Tmin)/2) might be 20°C on the island of Newfoundland. The baseline temperature for potatoes (Tbase) is 5°C. On a day like this the daily GDD 20°C - 5°C or 15 GDDs. Potatoes, like other crops that grow well in the mid-latitude areas, need an accumulated minimum of 1,000 to 1,100 GDD to be ready for harvest. If the potatoes accumulated an average of 15 GDD per day during the course of the summer, then potatoes planted in mid-May would be ready to harvest within 74 days (1,100GDD/15 GDD) which would be around the end of July.

But, as you can see in the table below, in Newfoundland it takes an entire growing season to accumulate 1,100 to 1,200 GDD. As a result, potatoes planted in mid-May are usually not ready to be harvested until October (approximately 160 days).

There is a special calculation of GDD for corn, called corn heat units (CHU). For corn, the accumulation of GDDs begins on the day in spring when the average temperature rises above 10°C and ends on the last day in the fall when the average temperature drops to 10°C (10°C is the base or minimum temperature required for the growth of corn).

Location	Average	Highest on record	Lowest on Record
Corner Brook	1364	1627	1149
Grand Falls-Windsor	1353	1619	1146
Seal Cove	1353	1598	1132
Terra Nova Park	1245	1532	880
Buchans	1183	1364	998
St. John's Airport	1155	1420	933
Goose Bay	996	1250	853
St. Lawrence	950	1214	797

Figure 11.31: Growing degree-days (base 5°C) accumulated from April 1 to October 31.

Source: Memorial University of Newfoundland and Atlantic Provinces Field Crop Guide, 1991. Atlantic Provinces Agricultural Services Coordinating Committee, Publication No. 100, Agdex No. 100.32. Data from Gordon, R., and Bootsma, A., Risk analyses of growing degree-days in Atlantic Canada, Research Branch, Agriculture Canada; Technical Bulletin 1993-5E. ©1993 - 2000, Newfoundland and Labrador Heritage Web Site Project

CHECK your Understanding

1. Define the term Agrometeorology and give some examples of how climate influences agriculture.
2. What is a growing degree day? How are growing degree days used to determine the following:
   a.) What crops can be grown in a specific area
   b.) Predicting harvest time
3. Describe the possible effects of climate change on agriculture in Newfoundland and Labrador.

For Further Discussion and/or Research

4. Study the map showing growing degree days in Newfoundland and Labrador. Find out what crops could be grown in your region. What other factors might influence your decision to grow this crop?
5. New insects are extending their range into Newfoundland and Labrador. Find an example of an insect pest and determine its possible impacts on agriculture.

AGRICULTURAL PRODUCTION AND THE ENVIRONMENT

While Newfoundland and Labrador has only a relatively small number of farms spread over a large geographic area, environmental safeguards in farm operations are essential. An environmental certificate of approval specifies rules for livestock operations greater than five animal units. It also provides rules for other specialties like cranberry farms on peat bogs. Certificates are also required to carry out farming activities in protected water supply areas. According to the terms of these certificates, agricultural leases are not permitted within fifteen metres of water bodies, and contain the following standard environmental conditions:

Figure 11.32: Good agricultural practises are usually rewarded with a bountiful harvest.

- Thirty metres of undisturbed buffers must be placed along streams and other watercourses.
- Pesticides and herbicides must only be applied by a licensed pesticide applicator.
- Manure must be spread according to soil testing.
- Livestock operations must have at least six months approved manure pits for winter storage.
- Manure must not be spread on frozen ground.

Environmental Farm Plans

Environmental farm plans help farmers to apply a sustainable environmental management perspective to their land, buildings, and work materials. Through environmental farm plans, farmers assess their operations to identify areas of risk to the environment.

The process begins with a rough map of the farm, including farmstead sites and fields (or field groups, depending on the size and physical layout of the operation). From this information, potential for soil erosion, water contamination, and other forms of resource degradation are evaluated.

The environmental farm plan itself consists of two parts:

1.) The farm review
2.) The action plan

The **Farm Review** is divided into four major sections:

- Farm buildings
- Livestock and manure management
- Soil and crop management
- Sensitive ecological areas

A Farm Review workbook is used to identify farm activities with an environmental risk potential. The workbook helps farmers assess the degree of risk associated with these activities.

Figure 11.33: Today's farmers need many skills to keep a farm running smoothly. *Photo courtesy Department of Natural Resources*

Based on the Farm Review, the farmer can then develop an **Action Plan**. It will help them to set realistic goals to minimize environmental risks from their farming activities. For those areas identified as having a potential risk, it is up to the farmer to decide what (if any) action needs to be taken, and how long such action will take. And, since the action plan is designed by the farmer, it can take into account the needs and situations unique to each farm.

- Composting of manure and other organic materials, such as fish offal, is encouraged to reduce waste and to improve land fertility.

Applications for land clearing in excess of fifty hectares, and agricultural development in designated areas require registration under the *Environmental Protection Act*.

Environmental farm plans and other environmental initiatives form one of the principal elements of the Canada-Newfoundland and Labrador Agricultural Policy Framework agreement. In a special project, the provincial department responsible for agriculture has worked closely with the Newfoundland and Labrador Federation of Agriculture to help farmers develop and follow through on environmental farm plans for their operations. With government assistance, the farmers conduct a confidential environmental audit of their farm to identify areas where they can improve their performance. Based on their findings, they draft a plan to improve the environmentally sustainable operation of the farm.

Another initiative coordinated by the province is the Environmental Farm Practice Guidelines for Livestock, Horticultural, and Poultry Producers in Newfoundland and Labrador. These guidelines illustrate acceptable farming practices. The *Farm Practices Protection Act*, proclaimed in May 2003, protects responsible farmers from nuisance complaints related to farm odours, noise, and dust

Source: Department of Natural Resources

SOILS: A RENEWABLE RESOURCE

Figure 11.34:
Ploughing mixes the soil layers below which increases the decomposition of organic material.

Since the dawn of agriculture 10,000 years ago, soil has been one of the most important sources of nutrients at the base of the terrestrial food chain. With water and energy from the sun, plants take nutrients from the soil to grow and provide the vegetation that feeds countless organisms.

Because the number of plants cultivated by humans is so limited, and we have transplanted these to so many different corners of the earth, the local soil conditions may or may not favour farming of those plants, depending on a number of conditions such as soil pH, presence of sand, organic material, ability to hold water, presence of trace minerals, porosity, and a range of other conditions.

In order to protect good soil and prevent the depletion of that soil, farmers and other agricultural specialists have developed a range of measures to conserve and improve soils. And it all begins with an understanding of soil composition.

Soil Formation and Composition

Composition

Soils are composed of four parts:

1. Mineral particles
2. Organic particles
3. Water
4. Air

A healthy, balanced soil is approximately forty five per cent mineral, twenty five per cent water, twenty five per cent air, and five per cent organic material. Soils also contain complex ecosystems that contribute to the soil's chemical and structural characteristics.

- Mineral particles, usually composed of sand, silt, and clay, provide plants with essential nutrients.

- Organic content comes from decaying plant and animal material. As it is mixed with water, this organic material forms a dark, heavy substance called humus, which enriches the soil and supports plant and micro organism life. Soils rich in humus tend to be very fertile.

- The soil is also home to many living organisms. Plant roots, worms, insects, small burrowing mammals, and microbes all play important roles in healthy soils. Microbes, like fungi and bacteria, help break down and release nutrients from dead organic material. Worms, insects, and animals help to aerate the soil by breaking apart the humus, making the soil porous.

- The air and water content of a soil is measured as porosity. The spaces or pores between soil particles are important. They allow oxygen and water to mix with the soil and help sustain the microbes which need air and water to break down organic material. Water in the soil dissolves nutrients into a soil solution, some of which drains away, and some of which is taken up by roots to help fuel the growth of plants.

Formation

Soils are formed over vast periods of time. Environmental processes, like glaciers, erosion, and freeze thaw cycles, break down surface rocks into smaller and smaller particles. In the course of millennia, these particles mix with organic material.

Soil formation is influenced by factors such as:

- Parent material—Comes from the break-up or weathering of rocks early in the soil formation process. As the rock mixes with organic materials, it loses resemblance to the original parent material.

- Climate—Weathers the rock and affects the number and types of organisms found in the soil, the rate of organic matter decay, moisture content, and temperature range. Hot and humid climates speed decomposition, helping the organic content of soils to form quickly compared to cold climates, where decomposition and the natural development of organic content in soil takes much longer.

Figure 11.35: One of many peatlands in Newfoundland and Labrador, a rich agricultural resource when properly managed. *Photo courtesy Doyle Wells, Forestry Canada, 1999*

PEAT

A Special Kind of Soil

Soils on peatlands can be quite productive with proper cultivation and management practices. Besides the production of crops and landscaping sods, peatlands have great potential for the production of horticultural peat as a growing medium.

Source: Government of Newfoundland and Labrador: Agrifoods

- Drainage and Topography—Drainage, or the movement of water through soil, determines many characteristics of the soil including horizon development (specific layer structure of soil), colour, and chemical composition. Topography is the shape and size of features on the surface of the land. They affect the distribution and accumulation of soil. Slope will also affect the amount of water in the soil. Erosion removes weathered soil products nearly as fast as they form on steep slopes and causes the eroded soil products to accumulate in valleys and other low lying areas.

- Time—Soils improve with age. Soils that resist erosion and undergo formation processes over long periods of time tend to become fertile, deep, and mature. Soils that erode quickly and are slower to form are usually shallow and infertile.

- Living Organisms—Plants and animals affect the chemistry and organic content of soil. The accumulation of decomposed matter from plants, animals, and other organisms, eventually forms humus and releases nutrients into a fertile environment that favours the growth of plants. A healthy, fertile soil has an abundance of microscopic organisms including bacteria, fungi, protozoa, and others. Earthworms and arthropods such as millipedesare also characteristic of healthy soils.

- Cultivation—Humans can improve or deplete the soil depending on the farming techniques they employ. For example, ploughing mixes the soil layers and increases the rate of decomposition of organic material. In turn, this increases compaction, runoff, and soil erosion. Humans can also alter the pH and chemical composition of the soil with the addition of lime, manure, and artificial fertilizers.

Newfoundland and Labrador soils

Despite the 10,000 years since the last ice age, Newfoundland and Labrador's soils still have characteristics that challenge agriculture. The primary weathering agent was the enormous glaciers that dragged their slow length south over land, grinding up surface rock rich in iron.

Today, almost all of the province's soils are sandy loam. This means they are high in silt and sand, but low in clay. Because of this sandy quality, the pores of Newfoundland soils tend to be quite large, allowing for easier passage of water than in clay soils. This means that there is less water erosion of soils in Newfoundland than in other parts of Canada.

Because of Newfoundland and Labrador's cool climate, organic material decays slowly compared to the rate of plant decay in warmed southern climates.

Figure 11.36: This soil is rich in organic materials.

Uncultivated or virgin soils in Newfoundland and Labrador have 9 – 11 per cent organic material. Cultivated soils range between 4 – 11 per cent organic materials. The sandy, virgin soils tend to have a pH between 4.5 and 4.7, while peat has a pH of around 3.8.

Some plants grow very well in acidic conditions, but many crops do not. In order for agriculture to succeed in the soils of this province, the pH has to be increased. The normal way to do this is through the addition of lime to the soil. Ashes and decomposed seaweed can also increase the pH of soils to which they are added.

CHECK your Understanding

1. Why are most soils in Newfoundland and Labrador no more than 10,000 years old?
2. What are the five factors that influence soil formation? Use a table to summarize these factors.
3. Would the soil horizons in a forest and in a field be the same or different? Explain.
4. What are the four components of soil? What is required to make a well-balanced soil?
5. How do sandy and clay soils differ in terms of their inability to hold water?

For Further Discussion and/or Research

6. If your family has a vegetable garden find out what steps they have taken to improve the soil quality of the garden.
7. Research how you can use local materials (for example peat or sand) to create an ideal growing medium for vegetables. Compare your mixture with off the shelf soils that can be purchased at local hardware stores.

MINI- LAB ACTIVITY

Introduction

Although Newfoundland and Labrador is known as the Rock, we have plenty of soil to support our forests and an expanding agriculture industry. In this activity you will have an opportunity to explore an amazing soil. This layer, called the **pedosphere**, is a mixture of the biosphere, atmosphere, hydrosphere, and lithosphere. If time permits you might use this activity to compare cultivated soils with forest soils.

Part 1: Soil Profile

Choose a 50 cm × 50 cm square of soil as your study area. Dig a hole. With the back of the shovel, slice a straight wall down one side of the pit. Record the following on your work sheet:

1. The depth of the humus and other soil layers.
2. Make a careful sketch of the soil profile showing the layers of soil, location of stones, animal life, and plant roots.
3. Carry out the following for each soil layer. Record the information in the table below.

   Colour: Describe the soil colour.
   Moisture: Use a soil moisture meter to measure soil moisture.
   Texture: Use the key provided to determine the soil type.
   Temperature: Using a nail, make 5 cm holes in each soil layer. Insert the stem of the soil thermometer into each hole in turn, packing soil loosely around the mouth of the hole. After two minutes, remove the thermometer and record the soil temperature. Unless using a fresh hole, soil temperature will not differ since the exposed edge of the pit will allow warming of all layers

Soil Layer	Depth	Colour	Texture	Moisture	Temperature

Part 2: Soil Mechanics

Select a test area and perform the following tests.

Percolation Rate: Percolation rate is the rate at which water moves through soil. The rate is an indicator of available space between soil particles. Use a tin can that has both ends removed. Insert it into the soil so that the lower lip is just under the surface. Pour exactly one full can of water into the

buried can. Use a stopwatch to record the time taken for the water to soak into the ground. Repeat this test another two times at different locations in the study area.

Soil Compactness: At the first location, hammer a stake into the ground with three equal blows. Mark the depth on the stake. Pull it out and measure how far the stake went into the ground. Record this depth as Trial # 1 on your worksheet. The same person will repeat this procedure at two other nearby locations using the same effort to hammer the stake. Record the results.

Soil Temperature: Make a 5 cm hole in the ground with the nail. Insert the stem of a soil thermometer and wait two minutes. Record the temperature on your worksheet as Trial # 1. Repeat this procedure at two nearby spots. Record the results.

pH - Place 1–2 cm of soil in a test tube and then add an equal amount of barium sulphate. Fill the tube with distilled water and shake vigorously. The barium sulphate makes the clay settle, leaving a clear solution. Test this clear solution with universal pH paper or with a pH meter.

Trial	Initial water level (cm)	End water level (cm)	Water Drained (cm)	Start time	Finish time	Percolation time	Percolation rate (cm/time)
						Average	

SOIL CONSERVATION

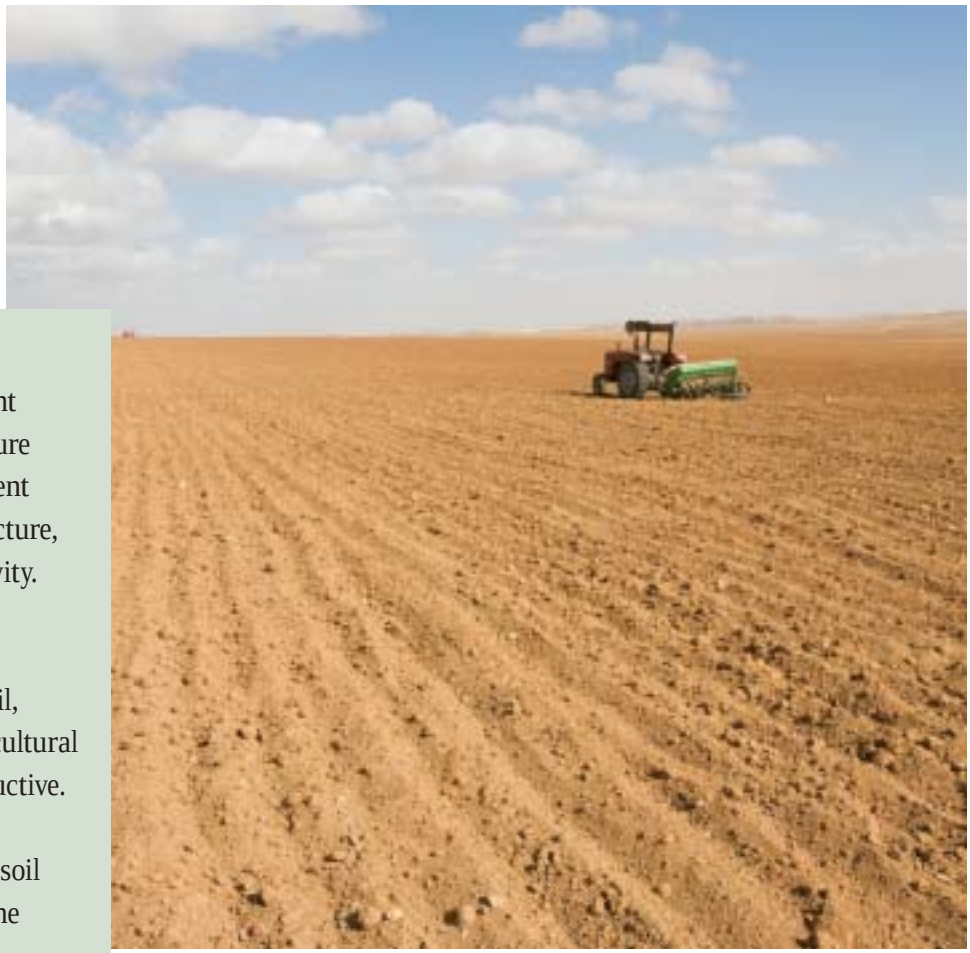


Figure 11.37: Tilling soil to meet the seed.

Soil management and conservation is an important part of sustainable agriculture and involves the improvement or maintenance of soil structure, fertility, and biological activity.

Effective soil management practices ensure that the soil, which is necessary for agricultural practices, will remain productive.

Depending on the location, soil management may involve the following practices:

- Application of fertilizers
- Prevention of erosion
- Reducing compacting by ploughing/tilling or other mixing practices
- Application of lime or other pH raising chemicals
- Addition of organic material
- Drainage improvements

Tilling the Soil

Soil management includes tillage, fertilization, and pest control. Tillage, or cultivation, prepares soil for seeding. It also helps control weeds. It includes breaking up the soil, adding fertilizers or plant material, and sometimes shaping soil into rows for planting. Years ago soil was tilled by hand or by horse drawn ploughs. Today this heavy tillage is done using tractors to pull disk ploughs, harrows, and rotary tillers.

Every time the soil is broken there is increased potential of soil loss through erosion by wind and water. It also hastens moisture loss through evaporation. The use of herbicides and avoidance of perennial crops (crops that can be grown for several years without any tillage) eliminates the need for traditional tillage, thus reducing soil loss by wind and water.

Tilling soil has agricultural advantages and disadvantages. Advantages include the preparation of soil for seeds and weed control. Crop residues that are ploughed under decompose faster and release nutrients into the soil. Disadvantages include increases in soil erosion, loss of soil moisture, increased costs, and a reduction in the organic content of the soil from erosion and leaching.

Nitrogen Fixation and Bacteria

Nitrogen is an important mineral nutrient on which all living organisms depend. It is a vital component of many plant cell parts, including proteins and nucleic acids. So, for crops to be successful, farmers must add nitrogen to the soil.

But why should they have to add nitrogen to the soil when seventy eight per cent of air is nitrogen? The problem is that the nitrogen in the air is N_2—two atoms of nitrogen bonded tightly bonded together in a form that most plants cannot use. However, nitrogen can be combined with oxygen in the form of nitrate (NO_2), or with hydrogen in the form of ammonium (NH_4). When this happens, nitrogen is said to be "fixed" and it can be used to build cellular components.

And what is amazing is that plants and certain bacteria have formed a symbiotic relationship to fix nitrogen. The bacteria live in tiny external sac-like structures called nodules on the roots of the plants. There, in the process of their life cycle, they convert the N_2 into ammonium which the plant absorbs.

Plants that have the ammonium producing nodules are called **nitrogen fixing plants**. Among the cultivated plants, nitrogen fixing species include legumes such as clovers, alfalfa, beans, soybeans, and peas. Among wild plants, the pioneer species alder and the introduced wildflower, lupine, grow well in poor soils because of their ability to fix nitrogen.

Improving Soil pH

Newfoundland soils tend to be acidic (low pH), a condition that hinders the growth of most cultivated plants. To increase crop production farmers must raise the pH of the soil. They do this by adding limestone. Limestone returns minerals such as calcium and magnesium to the soil thereby raising the pH. The higher pH promotes micro-organism activity, which in turn causes organic material to decompose more quickly. Limestone also improves the uptake of artificial fertilizers by plants and reduces their uptake of toxic aluminum.

Increasing Soil Fertility

As with any living thing, plants have a complex range of needs for healthy growth and reproduction. They need water, sun, and carbon dioxide. They also need minerals like nitrogen, potassium, phosphorus, calcium, magnesium, and sulphur. Nitrogen, phosphorous, and potassium are called **macronutrients** because plants require large amounts of them. When macronutrients are lacking, or at low levels, they are artificially supplied to the soil with fertilizer. Calcium and magnesium are usually supplied by the addition of lime.

Fertilizers are either organic or inorganic. **Inorganic fertilizers** contain three macronutrients: nitrogen, phosphorus, and potassium. Before being applied to soil these macronutrients are chemically combined with other elements. Fertilizers are sold with the percentages of the chemicals listed on the bag. If a bag lists 10-12-10, it has four components:

- Ten per cent nitrogen in a chemical form that is absorbable by the plants
- Twelve per cent phosphoric acid
- Ten per cent potassium oxide (potash)
- Sixty eight per cent ballast, which is filler made from crushed stone. Ballast has no nutrient value to the soil (except, occasionally it may contain some trace elements). Its purpose is to mix and spread the three macronutrients.

Organic fertilizers commonly include manure, compost, ground bones, and seaweed. Historically, Newfoundlanders and Labradorians used local organic matter on their vegetable gardens, including sea weed, capelin, and fish remains (offal). Organic fertilizers have several advantages over inorganic fertilizers. They are cheaper, have less impact on the environment, help maintain soil moisture, and release nutrients slowly so that they are available over the life cycle of the plants.

Another method used to improve soil fertility is to **rotate crops.** That means on successive years farmers will first plant a field or field group with the primary crop followed the next year by a crop of nitrogen-fixing legumes. (See side panel: Nitrogen Fixation and Bacteria)

LAND DEGRADATION PROCESSES

Figure 11.38: Once it begins, the degradation of good farm land can quickly rob the land of its productivity.

Over time poor agricultural practices will degrade soils and make them unsuitable for agriculture. This degradation includes a loss of organic content, erosion of the topsoil, compaction, and acidification. Unless corrected, the result is always the same—declining crop production.

Most farmland was originally forestland. In a forest ecosystem, dead and decaying vegetation constantly increases available organic matter on the forest floor. This organic decay supports soil organisms, which provide the vegetation and trees with a constant slow release of nutrients. The trees in turn hold the soil together with their roots and protect the surface from the full force of rain, wind, and sun. When the trees are cleared for agriculture, the sustainable source of organic matter is removed and the soil is no longer protected from the elements, which can quickly degrade the soil. Certain types of soil degradation will also impact surrounding areas. For example, wind blown soil can be carried great distances in the form of dust. Silt runoff into streams can reduce fish habitat. However, such degradation and the negative environmental impact can be kept to a minimum with good land management practices, which include:

- Seasonally appropriate cultivation
- Crop rotation
- Leaving crop wastes to cover soils during the winter
- Use of machinery suited to soil conditions

Soil Erosion

Erosion caused by water runoff and wind is the most serious form of soil degradation. Many factors influence the rate and degree of soil erosion including the initial organic content of the soil, the slope of the land, and cultivation practices. Of these, it is the slope of the land that has the greatest influence on soil erosion. The steeper the slope the greater is the potential rate of erosion. And that makes it a major concern for farmers in this province, particularly on the island.

Soils with high organic content act like sponges, holding water and slowing runoff. Soils with low organic content tend to be sandy or stony and are unable to hold the water necessary for plant growth.

Steeply sloping lands are at greater risk for erosion than level areas because water runs faster and therefore has more energy to carry material farther down the slope. If you ever swim in a river you can see that the force of moving water carries away fine-grained soil particles and leaves the larger ones behind. Small particles are important for good soil. The loss of fine-grained particles, nutrients, and organic matter, limits soil's water-holding capacity, lowers its ability to provide plant nutrients, and reduces the area available for root development.

Cultivation practices can encourage or discourage erosion. Forage crops like hay tend to hold soil together, reducing erosion. This is because only the tops of the plants are harvested. Crops like potatoes and corn have high rates of soil loss because their root systems are pulled out of the ground during harvest, leaving the soil broken and exposed.

Timing of harvest also impacts erosion. For example, land harvested late in the season is often left bare through winter, increasing the chances of wind erosion – especially if there is little snow cover.

Figure 11.39: Remnants of the "dirty '30s."

The Dirty '30s

Farmers in Western Canada witnessed the worst of soil erosion during the drought and dust conditions of what has come to be known as "the dirty '30s."

The damage of poor agricultural practices prior to the 1930s, was made worse by long periods without rain, and powerful windstorms. The combined degradation of the land made crop production extremely difficult. The result was food shortages, and an economic disaster for the farming industry.

Impacts of soil erosion

Erosion reduces the capacity of soil to support agriculture. Without the moist, fertile layer of topsoil with its nutrient-rich humus and clay, plants can no longer get the nutrients necessary for health growth and are more susceptible to disease.

Runoff caused by water erosion can create environmental problems. When silt and sand are carried into aquatic environment they smother benthic (seafloor) ecosystems. Fertilizers and pesticides can also wash out of eroding soils and enter the water table and waterways negatively affecting water quality and upsetting the natural balance of life in those environments.

Reducing Erosion

Unchecked, soil erosion can quickly deplete land of its agricultural value and negatively impact the surrounding environment. However, there are a number of ways farmers can reduce soil erosion:

Unchecked, soil erosion can quickly deplete land of its agricultural value and negatively impact the surrounding environment.

- Planting of cover crops is especially helpful for preventing erosion in horticultural operations. Cover crops protect the surface and structure of soils from exposure to weathering processes. Cover crops that can be grown in Newfoundland include:

  - Oats: can be grown in slightly acid soil, and are a good source of animal feed.

  - Annual ryegrass: can also be grown in slightly acid soil (a pH no less than 6). Ryegrass grows well in cool climates, and is suited to Newfoundland and Labrador's climate.

  - Fall rye: suitable for a pH of 6, this excellent cover crop can eventually be ploughed under as a source of nutrients for the next crop to be grown. It also makes good mulch for strawberries.

- Contour ploughing reduces water erosion. Contour ploughing means ploughing across a slope rather than straight up and down.

- Shallow ploughing disturbs less soil than traditional ploughing, which turns over as much as twenty centimetres of soil. The no-till approach uses ploughs that stir-up no more than five centimetres of soil. No-till ploughing reduces erosion by keeping organic crop and plant residues on the surface longer where they help slow erosion.

- Leaving crop residue on the field after harvesting. For example, after a corn harvest, the stalks are left on the field all winter to reduce erosion.

- Strip cropping means different crops planted in alternating rows. For best results, this would involve a row of late-harvest vegetables alternated with a row of early harvest vegetables. If one of these alternating plants is a good cover crop, it can help maintain soil integrity for the benefit of the other crop.

- Physical barriers such us tree lines and berms (low hills made from building up soil) can protect from wind erosion.

Compaction

Soil compaction increases soil density. That reduces the porosity of the soil and makes it harder for air and water to penetrate beneath the surface. For these reasons, plants do not grow well in compacted soil. Compaction can occur naturally, but on a farm it is caused by heavy machinery and the erosion of organic matter. The weight of farm machinery compacts soil and forces the pores to collapse. This occurs much more quickly when the soil is wet.

Figure 11.40: Using heavy equipment to spread lime.

Soil compaction and the loss of organic matter are related. Organic matter is important in maintaining soil structure by acting like a sponge. Repeated cultivation increases the rate at which organic matter decomposes so that soil loses its sponginess and collapses. Compaction is the result of this process. Farmers can reduce soil compaction in the following ways:

- Avoid working on wet soil.
- Minimize the number of trips with heavy equipment across a field.
- Always driving in the same lanes and routes.
- Use four-wheel drive vehicles, and limit weight to less than five tonnes per axle.
- Rotate crops to help prevent compaction. Deep-rooted crops can break up compacted soils at deeper levels.

Acidification

Soils become more acidic when acid-forming compounds such as sulphur and nitrogen exceed the ability of the soil to neutralize them. The result is a change in the soil's chemical and physical properties. These changes can have a negative impact on organisms in the soil. The main cause of acid rain is the burning of fossil fuels in cars, power plants, and factories. This combustion release sulphur and nitrogen into the atmosphere where they combine with the moisture to form sulphuric and nitric acids. As you will learn in Unit 5, these compounds can be transported great distances through wind patterns. They enter the soil in the form of acid precipitation (rain, snow, fog). This type of precipitation has the greatest impact on soils that are low in limestone or other neutralizing chemicals.

Depending on the species, most cultivated plants grow in soils with a slightly acid to neutral pH. In this environment, many of the nutrients required by plants for healthy growth—such as the minerals calcium, magnesium, and potassium—interact with clay and humus particles in the soil. The attractive forces between these minerals and the soil particles are strong enough to hold the nutrients in place and available to plant roots, even as water percolates through the soil.

However, acid rain can leach the calcium, magnesium, and potassium out of the soil, making it more acidic and carrying important mineral nutrients to deeper layers of the soil where plant roots cannot reach them. Ploughing or tilling the soil helps make these minerals available once more for plant growth.

When acid, from acid precipitation, builds up in the soil, the soil becomes acidic and some metals that are toxic to plants are released into the soil. Strong acids formed from the oxidation of ammonium and sulphur fertilizers can also cause this toxic release of metals. For example, aluminium becomes toxic when acid releases it into the soil (see side panel next page "Toxic aluminum in the soil!").

Acidification can even occur when organic matter decomposes and releases carbon dioxide to combine with the soil to form a weak acid. Soil acidity can be treated with limestone worked down through the upper layer of the soil.

Loss of Organic Matter

What is organic matter?

As you learned in the section on soil composition, organic matter, composed of dead and decaying plant material, makes up just five per cent of a soil. Yet its presence is essential to the growth of any plant life. As bacteria break down the organic matter it slowly releases nutrients into the soil to sustain living plants.

Loss of organic matter results from excessive tillage, soil erosion, and poor crop rotation. It can also occur during harvesting. For instance, removing potatoes from the ground damages soil by removing organic matter and breaking up the soil, exposing it to weathering processes.

Loss of organic matter can be prevented in the following ways:

- Rotate crops to add organic residues to the soil.
- Underseed (plant a crop that grows low to the ground and between the primary crop) cereal crops (such as barley, oats, or wheat) with alfalfa or clover to eliminate bare ground and tillage operations between crops.
- Reduce tillage. When tilling is necessary, ensure that it is shallow.
- Add organic material like peat, compost, or manure to the soil.

Toxic Aluminum in the soil!

Figure 11.41: The barley shown above have been affected by high aluminum levels in the soil. *Photo courtesy www.luminet.net/~ wenonah/min-def/plate017.jpg*

Increasing acidity can release aluminum ions into the soil. Aluminum ions are normally present in soil as an insoluble non-toxic form of aluminum hydroxide. When the soil pH reaches 5 or lower, aluminum ions are released. These ions dissolve in water and become toxic to plants, stunting root growth and preventing roots from absorbing calcium. Aluminum ions can also reduce helpful soil bacteria, which break down dead and decaying leaves and other debris. When present their activity releases nutrients like calcium, magnesium, phosphate, and nitrates into the soil. Aluminum slows this process and therefore damages the soils ability to sustain plant life.

Drainage

Agricultural Runoff

The water that falls on agricultural lands from rain, snow, and irrigation eventually ends up in ground water, rivers, lakes, and oceans. Aquatic ecosystems are always at risk of pollution from surrounding land-based activities including agriculture. Agricultural runoff includes soil sediment, nutrients, bacteria, and agricultural chemicals. This runoff has been linked to both silting and pollution of aquatic ecosystems. Since Newfoundland and Labrador is not as extensively farmed as other provinces like Prince Edward Island, the present level of agricultural impact on freshwater ecosystems is comparatively small. Every effort should be made, however to reduce drainage and its impact on the environment.

- Silting: Silting results from eroded soil making its way into streams, ponds and lakes. Agricultural causes of silting include tilling in late fall, ploughing with the slope, cultivating close to water with no buffers, and allowing cattle direct access to streams. Soil sediment has a variety of impacts on aquatic ecosystems. These are similar to the effects of forest harvesting and road construction covered in the Forestry section of this unit. What is unique to agricultural silt is the residue from fertilizer and manure, which cause bacterial and chemical contamination of surface and ground waters.

- Bacteria: Agriculture is a source of bacterial contamination of surface waters. Bacteria in animal manure enter aquatic ecosystems in runoff from grazing pastures, fields fertilized with manure, and manure storage areas. High levels of bacteria from agricultural sources may be responsible for causing water quality hazards in fish plants and shellfish harvesting in estuaries, as well as in household wells and other water supply systems.

- Fertilizers: Not all fertilizer that is spread on a field is absorbed by the plants. Much of it can be washed away, especially if there is heavy rain after fertilization. The resulting runoff carries nutrients like nitrogen and phosphorus into rivers and ponds. The result is accelerated **eutrophication** (nutrient enrichment) of aquatic habitats—especially ponds.

- Pesticides: Pesticides applied to crops can enter water systems through runoff or from the over spray. Overspray refers to pesticides that are carried by winds into areas where they were not meant to go, including lakes and streams.

CHECK your Understanding

1. Identify the different types of agricultural runoff.
2. How do buffers prevent silt laden runoff from reaching a stream or pond?
3. Bacteria from animals, fertilizers, and pesticides are carried by natural processes into ponds and streams. What are the potential effects of each of these on the aquatic ecosystem?
4. Manure may be made up of three components. What are they?
5. What are some alternative uses of manure?
6. Define tillage. How does it differ today compared to traditional methods used in this province?
7. List the advantages and disadvantages of tilling soils.
8. Explain the statement, "soil is the master recycler"
9. Describe three factors that influence soil erosion.
10. What are two agricultural practices that reduce soil erosion?
11. What are the causes and results of soil compaction? How do you think compaction can be reduced on agricultural land?
12. Why are the soils in Newfoundland and Labrador acidic? What must be done with the soils before agricultural use?
13. How are metal ions harmful to plants? Use aluminum as an example.
14. What is the role of fertilizer in agriculture?
15. Distinguish between organic and inorganic fertilizers.

For Further Discussion and/or Research

16. Build a simple biogas generator using manure or moose droppings. Plans for simple generators can be found on the Internet.
17. Find out how composting is used to manage farm waste.

AGRICULTURAL PEST CONTROL

In agriculture a pest is an organism, plant or animal, that reduces yield, impedes production, or negatively affects the health of crops or livestock. Animal pests include insects, rodents, and moose. Weeds are any nuisance plant. Pest management has a variety of approaches to prevent, suppress, or eradicate pests. These approaches involve the use of pesticides (chemicals that deter or kill pests) and natural pest control. Most farmers now use an approach called **Integrated Pest Management (IMP)**, which reduces pesticides and combines its use with a wide variety of natural controls. These approaches are described in detail below. But before we get to a discussion of how to control the pests we will turn our attention to the most common agricultural pests in Newfoundland and Labrador.

Common Agricultural Pests in Newfoundland and Labrador

Insects: Not all insects are pests. In fact, most insects are either helpful to agriculture or neutral—in that their presence causes no harm to crops or livestock. Insects pollinate plants. They help to break down and recycle organic matter. And some species of insects prey on pest insects and weeds.

Nevertheless, there are insects that are major agricultural pests. For example, flies may be parasites and disease vectors (carriers of disease) of livestock. Many moths and butterflies feed on crops, reducing yields or damaging produce so it cannot be sold. Other insects attack flowers, roots, or growing points, preventing the development of the crop. Some common insect pests in Newfoundland and Labrador are the cabbage maggot *(Delia radicum)* in rutabaga (*Brassica napobrassica)* and cole crops, European corn borer (*Ostrinia nubilalis)* in corn, and Black Vine weevil (*Otiorhynchus sulcatus)* in strawberries. There are a number of tools that help manage insect pests, including crop rotation, row covers, predators, parasites, and insecticides.

Figure 11.42: Lamb's quarters *(Chenopodium album)* is a common weed in Newfoundland and Labrador vegetable gardens.

Weeds: Any plant growing in an area where it is not wanted is a weed. In agriculture, we usually consider a plant a weed because it competes with the crop for light, moisture, space, and nutrients, and can reduce yield or impede crop germination and growth. Generally plants other than a crop that grow in the same area as a crop are considered weeds. Certain weed species can harbour plant diseases and insect pests. Some weeds found in the grazing pastures of livestock and in their feed may be noxious if eaten. It is important to manage weeds so they do not out-compete crops or interfere with animal or human health. Weed management uses tillage, hoeing, herbicide treatment, biological control and suppression through use of cover crops. Some common weeds in Newfoundland and Labrador gardens are lamb's quarters *(Chenopodium album)* and corn spurry *(Spergula arvensis)*.

Disease: A disease is a harmful alteration of the normal physiological and biochemical development of a plant or animal, and is usually noticed because of symptoms exhibited by the plant or animal. Organisms or events that cause diseases are called causal agents. Disease usually occurs because of a combination of three factors: the presence of a causal agent, a favourable environment, and a susceptible host. Environmental conditions, nutrient deficiency, and pathogens are potential causal agents. Human diseases like scurvy or osteoporosis are caused by nutrient and physiological deficiencies. Pathogens are usually fungal, bacterial, or viral.

Plant and livestock pathogens can be extremely costly for producers. One recent example in agriculture was the 2001 outbreak of hoof-and-mouth disease in Great Britain. This is a viral disease of cattle, pigs, deer *(Cervus elaphus)* , sheep, and other animals. It is highly contagious. Approximately seven million animals were slaughtered in an effort to halt the spread of the disease. The virus *Aphtae*

epizooticae is the causal agent of this disease. The fungal disease commonly known as potato wart or potato canker has resulted in a quarantine of all plant and soil products from the Island of Newfoundland that has remained in effect since the early 1900's. This disease is caused by a fungus, *Synchytrium endobioticum*, which can stay dormant in the soil for decades and yet remain viable and infectious.

Potato Canker

Many diseases affect crop production and yield. One example in Newfoundland and Labrador is known as potato wart or potato canker. It is caused by a microscopic soil fungus affecting many sites of potato cultivation around the world. The disease became established in Newfoundland in the early twentieth century and has led to an ongoing quarantine of all soil and plant products from the island.

Because of good agricultural practices on most commercial farms in the province, this disease does not usually affect potato production. However, the soils in more than ninety per cent of Newfoundland and Labrador are infected with the fungus. The fungus has an economic impact due to the quarantine, along with export restrictions placed on agricultural produce. The major symptom of wart disease is a gall at the base of the potato stem. Severe infestations destroy the potato crop by preventing tuber production (the tuber is the part of the potato plant that we eat). Potato wart spreads when the fungus is transported to new soil by contaminated soil, tools, footwear, hooves, wind, and manure from animals that have eaten infected potatoes. Control of the disease is difficult and involves quarantine, biological and chemical controls, and the development of resistant potato strains. It is not affected by most fungicides because of the protective chitinous wall of the resting spore. This wall allows the spore to remain viable within the soil for decades.

Figure 11.43: Potato canker reduces the yield of potato plants. *Photo courtesy Department of Natural Resources*

- Quarantine methods: Since the disease is already established in Newfoundland, there are a variety of quarantine measures preventing its spread to mainland Canada. Anyone who has travelled by ferry to the mainland from the island of Newfoundland will recall the inspection and car wash stations at the ferry terminal in Port aux Basques and in Argentia. Officials at these terminals are empowered to confiscate any materials that may harbour the fungus. Vehicles are visually inspected and, if necessary, their undercarriage is washed with high-pressure water to remove any soil which might contain spores.

- **Biological control**: What is the relationship between crabs and potatoes? Scientists at the St. John's Research Station know the answer. Their studies show that the potato wart can be reduced when crushed crab shells are added to the soil at a ratio of one part shell to twenty parts soil. Greenhouse experiments have shown that the number of resting spores in soil is reduced over several months after treating soil with crab shell meal. If farmers begin to adopt this method, they may reduce the amount of potato wart spores in infested soil, and will potentially raise the soil's pH. It would also put waste from the crab fishery to good use.

- **Chemical controls**: Chemicals are used to control many plant diseases. Toxic chemicals like copper sulphate and formaldehyde are effective in destroying potato wart spores. However, they are not used because they destroy the crop-producing capacity of soil and pollute well water and usable land.

- **Resistant strains**: Breeding potatoes for resistance is one way to battle this disease. At the Agriculture and Agri-Food Canada Research Station in St. John's, several resistant potatoes have been produced. Resistant varieties like Pink Pearl, Mirton Pearl, and many others, are grown at the provincial seed potato farm in Glenwood before being distributed to multiplier farms throughout the province.

Source: Michael C. Hampson, Agriculture and Agri-Food Canada, Atlantic Cool Climate Crop Research Centre

Pesticides

Pesticides are chemicals used to control pest populations. There are three types of pesticides that are important for agriculture in Newfoundland and Labrador:

- Herbicides are used to control unwanted plants. Farmers and gardeners use them to stop weeds from taking over their crops or gardens.

- Fungicides are used to kill different types of fungi that cause disease in plants and animals.

- Insecticides are used to kill insects that feed on crops and garden plants. They are used by farmers and gardeners. Some insecticides are applied on a large scale in uncultivated areas. This is done to control mosquitoes, which are capable of spreading diseases like West Nile virus *(Flavivirus)* among humans.

Pesticides are carefully regulated in Canada through a program of pre-market scientific assessment, enforcement, and education. This program is shared among federal, provincial, territorial, and municipal governments, and is regulated by various acts, regulations, guidelines, directives, and bylaws. Although it is a complex process, regulators at all levels work together in an attempt to protect Canadians from the risks posed by pesticides, and to try and ensure that pest control products do what they claim. Health Canada's Pest Management Regulatory Agency (PMRA) is responsible for the regulation of pest control products in Canada. Before a pesticide is considered for national registration, it must undergo extensive testing to determine potential risks to human health and the environment. The pesticide must also be assessed for how efficiently it works.

In addition to the three types of pesticides described above, pesticides can also be chemical or biological.

- Chemical Control: Chemical pesticides use either contact or systemic action:
  - Contact pesticides control the pest through direct contact. If the pesticide covers the insect or plant leaf, for example, the organism will die. This is effective if the pest is openly visible and application can be made to most individuals at treatment time.
  - Systemic pesticides are applied to the host and translocated throughout that host. That means, for example, a systemic insecticide applied to a plant is carried through the plant, making it toxic to the insect pest that feeds on it.

Pesticides are also classified according to their chemical family. This is a group of chemicals that have similar structures and properties. Most of the hundreds of different pesticides can be categorized into ten chemical classes or families. The table to the left shows five chemical classes and pesticides that belong to them.

Chemical Class	Pesticide
chlorinated hydrocarbons	DDT
organophosphates	malathion
carbamates	carbofuran
triazines	atrazine
phenoxys	2,4-D

Figure 11.44: Chemical class and pesticides.

- Biological Control and Biological Insecticides: Sooner or later all organisms are consumed by other organisms. When an ecosystem is in balance, it is because one organism is controlling the population of the other. Many insects are attacked by bacteria, fungi, viruses, and other insects. Biological control works on the principle that one species can control the population of another. Sometimes we use predators to attack the pest. One example is the use of ladybug beetles *(Insecta: Coleoptera: Coccinellidae)* to feed

on aphid pests in greenhouses. In taking this approach, farmers need to be cautious about which species of lady beetle they are getting through a vendor. This is because imported species have been out-competing native species.

Some biological control agents can be used to create biological insecticides. One example is the soil bacterium, *Bacillus thuringiensis*, or Bt that you learned about in the forestry section of this unit. It produces a protein that is toxic to insect larvae, including those of the spruce budworm. Bt is a bacterial pathogen of insects that is considered harmless to humans, wildlife, and aquatic organisms. There are several formulations of the Bt pathogen, and each formulation affects only one type of insect (for example, Btk affects caterpillars and cutworms, larvae of butterflies and moths). Because it must be ingested by the insect as it feeds on a host plant, other insects are not usually affected. In other words, this insecticide does not indiscriminately kill other insects, many of which are beneficial. This technology has even been used to produce insect-resistant plants. These plants have been genetically modified to contain the Bt gene. Pests eating the plant ingest the toxin and die.

Pesticide Licensing Requirements

Figure 11.45: Using commercial or restricted pesticides requires care and protective clothing.

Anybody can purchase and apply the domestic pesticides found in hardware stores. However, a **pesticide applicator licence** is required to apply a commercial or restricted-class pesticide to crops, orchards, greenhouses, and fields. A **pesticide operator licence** is also required to purchase these pesticides.

A commercial or restricted pesticide must be applied correctly, they can be very dangerous to the person who applies it and to the environment. A pesticide applicator licence ensures that the people who apply it and the environment are protected. Before anyone can qualify for a pesticide applicator licence, he or she requires training and must then pass relevant exams. There are ten types of pesticide applicator licences:

Types of Applicator Licences

1. Agricultural: for the use of pesticides by ground application for agricultural production including fruits and vegetables, Christmas tree plantations, sod farming, and control of pests related to production of livestock and poultry.

2. Aquatic: for the use of herbicides by ground application for the control of weeds in waterways.

3. Forestry: for the use of pesticides by ground application in forest management including outdoor nurseries and plantations.

4. Greenhouse: for the use of pesticides in greenhouses and areas immediately surrounding greenhouses, in mushroom houses, and for use on forest tree seedlings.

5. Industrial Vegetation: for the use of herbicides by ground application for controlling weeds on industrial areas including roadsides, power lines, pipelines, rights-of-way, railways, well sites, equipment yards, dams, dikes, and non-crop land.

6. Landscape: for the use of pesticides by ground application for the maintenance of ornamental trees, shrubs, flowers, and turf on outdoor residential, commercial, and public land including golf courses and cemeteries.

7. Mosquito and Biting Fly: for the use of insecticides by ground application for the control of mosquito or biting-fly larvae or adults.

8. Fumigation: for the use of fumigants.

9. Structural: for the use of pesticides other than herbicides or fumigants inside a structure.

10. Aerial: for the use of pesticides applied by aircraft.

Source: Newfoundland and Labrador Department of Environment and Conservation and Department of Natural Resources

Environmental Impacts of Pesticides

Pesticide use is controversial for many reasons. Its use has been linked to pollution and human illnesses. Government regulations are in place to help ensure that pesticides are tested and used properly in an attempt to minimize the risk to public health.

Nevertheless, there are consistent problems with pesticide use:

- Mortality of non-target species: Pesticides are poisons. When pesticides are sprayed, the wind carries them to non-target plants that are also susceptible to the poison. Insecticides kill non-target insect species that occupy important niches in the ecosystem. For example, honeybees pollinate flowers, but can be killed by insecticides meant to protect those flowers. When birds and other animal species feed on insects poisoned by insecticides, their health can be negatively affected. They may even die.

Figure 11.46: Farm animals can ingest pesticides when they have unrestricted access to natural waterways.

- Aquatic ecosystems: Rainwater can carry pesticides into streams and rivers, and from there to lakes or the ocean. When a poisonous chemical enters the food chain of an aquatic ecosystem, small organisms may ingest miniscule amounts. As larger organisms feed on these smaller poisoned organisms, they accumulate larger amounts of the toxic chemical. This continues up the food chain to the top feeders that tend to accumulate the largest concentration of these dangerous chemicals in their body tissue. And since humans are at the very top of the food chain, this process threatens the health of humans.

- Groundwater: Water from rain and snow accumulates beneath the surface of the Earth. It is an important source of clean water around the world. Pesticides washed down through the soil can enter the groundwater that is being used as a source of what is supposed to be clean drinking water.

Integrated Pest Management

As long as there have been farmers there have been crop-damaging pests. Historically, people used tilling practices to reduce weed and insect pressure on crops. Careful seed selection for the most resistant plant varieties can also help improve crop tolerance of pests. These practices were precursors to integrated pest management, or IPM, which is a prevention-based way to effectively manage pests. This approach reduces the need for chemical pesticides and saves on the cost of purchase, application, and storage of these chemicals. IPM programs give long-term pest solutions that protect the environment, human health, and

beneficial organisms. The six elements of an IPM program are:

1. Prevention: Organisms are kept from becoming pests by planning and properly managing farmland. This element of an IPM program considers pest problems before they arise and takes preventative measures to reduce or eliminate potential damage. Preventative approaches include:
    - Timing and temperature monitoring
    - Crop rotation
    - Sanitation of tools and refuse
    - Optimizing site and soil conditions to favour the crops and not the pests
    - Using exclusion techniques such as row covers, fences, and mulches

2. Identification: Correct identification of pest species is essential to a strong IPM program. It cannot be assumed, for example, that all flies are pests. Some are pollinators, some are beneficial parasitoids of other insects, and many are harmless. Likewise, brown spots on leaves do not automatically mean a pathogen is present. Those spots could be related to pollution or nutrient deficiency. Correct identification is essential to determine what treatment will be appropriate and effective.

3. Monitoring: This means systematic checking of a crop, barn, greenhouse, and other facilities and resources of the farm for pests or for evidence of pest damage. Some pests have predictable life cycles and tend to appear in a crop when temperatures are ideal for that insect or pathogen. Environmental monitoring helps farmers predict when such pests will appear. Temperature records and other warning information are used for this purpose. Farmers are warned of other pests through ongoing monitoring during the growing season.

    Tools used for pest monitoring include regular sweeps through a crop with a net, placing sticky traps in fields and greenhouses, and systematically using visual inspection of plants and animals to spot problem signs early. Some farmers in Newfoundland and Labrador conduct regular monitoring of their own crops. However, in much of Canada and the world, farmers hire monitoring services to provide regular information on pests. This task is commonly known as crop scouting. There are courses available to teach farmers and crop scouts appropriate techniques for effective pest monitoring.

4. Injury and Action Threshold: Injury and action thresholds are used to decide when to treat pest problems. When a pest is discovered, farmers must decide if they will take any action to control or eradicate the pest. They make this decision according to predetermined guidelines known as *action thresholds*.

   An action threshold is a numerical value relative to the specific pest and to the sampling or monitoring technique. Findings below the threshold value usually do not trigger any reaction by the farmer because low numbers may indicate that damage will be minimal, relative to the risk and expense of treatment. Values below the action threshold may also indicate that a dangerous pest is present but the major outbreak has not yet occurred, in which case, especially with the use of contact pesticides, the treatment would be not prevent the damage if applied too soon.

5. Treatments: One or more treatments are used to control the pest. These may be cultural, biological, physical, mechanical/physical, behavioural, or chemical. Treatments are chosen to have the smallest environmental impact and cost while providing adequate control. Treatments also vary with the type of pest and the severity of the problem.

6. Evaluation: The effectiveness of the IPM program is regularly evaluated. It is essential that farmers keep records of the timing and nature of all monitoring, decisions, and actions. These records can demonstrate whether or not decisions and subsequent actions were appropriate. They also help farmers anticipate future problems and show which actions were most effective in the past.

Strong integrated pest management increases a farmer's knowledge of his or her crop and the complex pest relationships associated with it. IPM promotes sustainable farming practices and a healthier food supply for all.

Figure 11.47: It takes a lot of work and knowledge to ensure we have a healthy food supply.

ECO SPOTLIGHT:

The hairy chinch bug: Integrated pest management in your own backyard

Figure 11.48: Chinch bug.
Photo courtesy Stephen Luk

The hairy chinch bug is a common lawn pest that feeds on the crowns and stems of turf grass. Adult chinch bugs are black with small, shiny white wing covers and are about 3 – 3.5 millimetres long. The damage, which is evident in hot, dry weather in July and August, is mostly caused by the nymphs (young ones). Lawns damaged by chinch bugs become more susceptible to weeds and other insects.

Figure 11.49: Lawn damaged by chinch bug.

Chinch bug damage appears as round, brownish-yellow dead patches. When chinch bugs are uncontrolled, large sections of lawn may die—particularly on sunny, dry areas near slopes and lawn edges. Population size depends on the weather. While wet conditions produce small populations, hot and dry weather early in the season can produce large populations.

Life Cycle: The chinch bug life cycle includes egg, nymph, and adult stages. Adults overwinter in sheltered locations in and around turf grass. When the temperature warms up in spring, adult chinch bugs come out of hibernation, start to feed, mate, and begin laying eggs. The microscopic eggs hatch into reddish nymphs (smaller than a pinhead) that pass through five growth stages before becoming adults. As they feed, they grow and shed their skin four times. In the last stage, nymphs are almost as big as adults, which are black and can be identified by a white band across the back.

Control

Monitoring: It is easy to confuse improper lawn care with chinch bug damage. It is important to determine if lawn damage is caused by chinch bugs, lack of moisture, over-fertilizing, or some other factor.

Begin monitoring for chinch bugs in June before populations reach high numbers. There are several effective monitoring methods:
Take a large can, cut both ends off and push it down into the top layer of the lawn. Pick an area of the lawn where brown-yellow or dead patches of grass meet green healthy grass, as this is where chinch bugs can be found. Fill the can with water and watch for adult chinch bugs to float to the top. You may have to cut a circle in the thatch with a knife if the thatch is really thick, so that the can fits snugly without any leaks.

Drench the damaged area with soapy water. Place a white towel over the area and within fifteen to twenty minutes chinch bugs will attach themselves to the towel to escape the soap.

When large numbers of chinch bugs are present, they can be seen on the surface where damaged and healthy grass meet.

Physical: A well- fertilized and nutrient-rich area can withstand a chinch bug attack. Good lawn care is the best prevention against chinch bug damage. Keep the lawn well fertilized and take caution not to add too much or too little nitrogen. Mow grass 6 – 7 centimetres high, remove thatch, maintain proper moisture levels, avoid water build up, aerate the lawn if it is compacted, and use a resistant variety of grass. If you are establishing a new lawn or re-seeding an old one, ensure there are at least fourteen centimetres of topsoil. Using a resistant variety of grass will offer protection against chinch bugs. Ask an expert at your neighbourhood garden centre.

Chemical: Landscape NL promotes integrated pest management in dealing with pests and diseases. Chemicals are used only as a last resort after other control methods have failed. If the methods outlined above are ineffective, choose a pesticide with minimal impact on you and the environment. Try an insecticidal soap spray on areas where damage has occurred. Products containing pyrethrin (a natural insecticide derived from chrysanthemum flowers) can also be used.

Alternative Approaches to Pest Management

Alternative methods of pest management include cultural, mechanical, physical, and reproductive control. It is important to learn how each of these treatments work.

Cultural Control: These are some of the oldest agricultural methods in use. These controls involve modifying normal cropping practices and landscape management to hinder pest establishment, dispersal, and survival.

Some examples of cultural control include:

- Trap crops
- Intercropping
- Rotation of crops
- Tillage of soil at critical times to expose pests to frost or predators
- Careful selection of resistant crop varieties/cultivars
- In some cases, planting can be delayed until after a pest insect lays its eggs for that generation

As with all other aspects of IPM, it is essential to identify the target pest and to be aware of its habit, life cycle, and weaknesses in order to control it.

Mechanical/Physical Control: Mechanical or physical control is any physical intervention preventing pest attacks or eliminating pests.

- Steam sterilization of soil in a greenhouse prevents growth of disease organisms, insect pests, or weed seeds.
- Mechanical traps are used to trap flies in barns.
- Bug vacuums are used to suction insects off of the soil or crop.
- Exclusion fences prevent invasions by pests such as moose from nearby habitats.
- On a larger scale, quarantine is used to restrict the spread of a particular pest (see sidebar on potato wart).
- Even mowing weeds can provide effective control, as long as plants have not set their seed.

Pheromones are chemicals that are produced by animals (especially insects) that influences the behaviour of other members of that species and often functions as a sex attractant to members of the opposite sex. **Pheromone traps** are containers that contain these chemicals and have openings to allow the insect to enter. Once inside the insect is caught in a sticky substance which prevents their escape.

Behavioural Control: Knowledge of pest behaviours can help control that pest. An example of a behavioural control is the use of pheromone traps to attract insects to a sticky lure. This reduces pests in three ways:

- Pest numbers may be reduced as a direct result of the traps.
- The attraction of males to the trap interferes with normal mating patterns and thereby reduces the size of future generations of pests.
- Light traps also use insect behaviour to attract insects, although they draw different species indiscriminately. These exploit the light guidance systems of insects that normally rely on moonlight.

CHECK your Understanding

1. Define integrated pest management.
2. List and briefly outline the six components of integrated pest management.
3. What three types of pesticides are used in Newfoundland and Labrador?
4. Why is DDT banned as a pesticide in much of the world?
5. List a common pesticides used in Newfoundland and Labrador's forests and identify its target organism.
6. Distinguish between chemical and biological control.

For Further Discussion and/or Research

7. What is organic gardening?
8. Discuss the statement "there was more organic gardening going on in Newfoundland and Labrador in my great grandparents' day than there is now."
9. Select one pesticide from figure 11.44 on page 391 and, through research on the web, prepare a display that gives information on the following:
    - What it is used for?
    - How it is made and from what ingredients?
    - Non-target organisms
    - Half-life
    - Possible side effects to humans and animals
    - An alternate method of controlling the pest
10. Why do you think it is important for handlers of pesticides to be properly trained?
11. In a table format identify all the herbicides, insecticides, and fungicides in your home. Next to each indicate the active chemical ingredient.

CAREERS IN AGRICULTURE

CAREER SPOTLIGHT:

Tara Neal

"When I was in high school, I didn't really think of a job in environmental management... I wanted to be a vet. I was very interested in sciences. When I went to the NSAC, I quickly realized that I didn't want to be a vet, and started looking at other careers. I really liked the school, and at that time, their environmental studies program was going through some changes, and really interested me. I remained at that school, to complete my degree," says Tara Neal.

Figure 11.50: Tara Neal. *Photo courtesy Tara Neal*

She now works as an environmental farm planner with the Newfoundland and Labrador Department of Natural Resources, Land Resource Stewardship Division. Other graduates from her program work as environmental educators, laboratory technicians, and consultants for a variety of industries.

Tara graduated from St. Stephens High in Stephenville in 1998. She went on to complete a Bachelor of Science in agriculture with a major in environmental sciences at Dalhousie University's Nova Scotia Agricultural College. Her study included courses in soil science, microbiology, ecosystems and conservation,

waste reduction and site remediation, biochemistry and environmental chemistry, environmental ethics, and environmental sampling and analysis.

Tara worked summers for the Government of Newfoundland and Labrador, at first doing a wide range of jobs for various people. But later she began to work exclusively with the Animal Health Division. There she completed her honours project on the possibility of West Nile Virus entering the Newfoundland ecosystem.

"Agriculture is an industry where standards have to be tailored to the needs of individual farms"

-Tara Neal

Now she works for the provincial government delivering and promoting the Environmental Farm Planning Program to producers and to the public. According to Tara, an environmental farm plan (EFP) helps producers to take an environmental perspective on their farms. It helps them see environmental risks and any steps they may already have taken to limit those risks. She says completion of an EFP gives producers peace of mind knowing that they are taking an active role in stewardship, while also assuring their customers that they are promoting and ensuring sustainable agriculture in our province.

"Agriculture is an industry where standards have to be tailored to the needs of individual farms" says Tara. "It's a challenge for producers to find solutions to environmental risks that meet government regulations and are cost-efficient." Producers have much to gain by investing in more efficient machinery. By comparison, "environmental projects often don't have the same monetary return, and so developing inexpensive and environmentally sound agricultural methods is an important and exciting challenge." As a result of these challenges, agriculture is business that must struggle with ongoing problems. Fortunately for her, Tara enjoys problem solving.

CAREER SPOTLIGHT:

Darryl Martin

When he was in high school Darryl got his first taste of agriculture at the former Sprung Greenhouse in Mount Pearl, an experimental hydroponic cucumber growing operation funded by the Newfoundland and Labrador government in the 1980s. Today, Darryl Martin is a plant molecular biology technician with Agriculture and Agri-Food Canada (AAFC). Following his graduation from Mount Pearl Senior High School in 1989, he completed a Bachelor of Science degree in biology at Memorial University of Newfoundland in St. John's.

Figure 11.51: Darryl Martin. *Photo courtesy Darryl Martin*

"Coming out of high school, I was looking at becoming a veterinarian. A federal summer job came up here [at AAFC] for a student, and I got the job. That was very lucky for me because I ended up working here four summers as a student because I just loved the job. After graduating, my training and experience, plus my education qualified me for several jobs within AAFC."

During his summer employment with Agriculture and Agri-Food Canada, Darryl worked with field crops like hay and corn, and in the soils lab. He has also worked for the Mariner Regional Economic Development Board (MRON) as an Agriculture Development Officer, and as a researcher with the Newfoundland and Labrador Federation of Agriculture.

Darryl is investigating the impact of molecular biology techniques on plant breeding in support of research by Dr. Samir Debnath, a research scientist at AAFC. Darryl's work involves DNA fingerprinting of plants, primarily berries. DNA fingerprinting is the processes of creating a genetic profile of a living thing, in this case a plant. The process begins with collecting plant tissue, which is then frozen in liquid nitrogen. "The next step is to crush it into a powder, then isolate the DNA." Small pieces of the DNA, called primers, are matched up along the chain, wherever possible, and copied from that point onward. The sample is then placed in a gel that an electric current is run through to separate the various lengths of DNA that were copied. The gel is then chemically stained and the DNA lengths appear as different bands on the gel. The DNA bands are compared to determine the relationship between two variations of a plant species. "For example, we can compare two varieties of raspberries," he says.

The goal of the research is to develop new and improved commercially available cultivars of berries and small fruits. The process involves combining two variations of plants to get positive aspects of both in one plant. This process can add to the levels of nutrients, such as antioxidants, in a food.

One of the most rewarding parts of his work is that it may contribute to making natural foods more delicious and nutritious! The next time you are at a supermarket picking out produce, consider that a molecular biologist like Darryl may have helped to develop that new variety of berry with the appealing look and the sweet, juicy taste.

Chapter 12: Mining in Newfoundland and Labrador

INTRODUCTION TO MINING

Figure 12.1: Mining equipment, Labrador City. *Photo courtesy of Iron Ore Company of Canada*

Mining is the systematic extraction of valuable minerals or other geological materials from Earth, usually (but not always) from an ore body, vein, or seam. Any material for human needs that cannot be grown from agricultural processes, or created artificially in a laboratory or factory, is usually mined. Mining in its broadest sense can also include extraction of petroleum, natural gas, and even water.

Examples of Minerals
Minerals include iron oxide minerals such as hematite (Fe_2O_3), nickel sulphides such as pentlandite ($Fe_5Ni_4S_8$), and even table salt (halite), which is composed of sodium and chlorine (NaCl).

Most mined materials are **minerals**. They can be composed of a single atomic element such as gold or, as is more often the case, they can be composed of two or more elements usually arranged in crystal structures.

Geologists have identified more than 2,000 different minerals. Most of these have little or no economic value—either they cannot be used commercially or the costs to extract the commercial elements are greater than the price for which they can be sold. For example, iron is contained within many different mineral deposits, but extracting it from most of the crystal structures in which it is found would require much more energy and money than could be gained from selling the smelted iron. However, the iron oxides hematite and magnetite are among the few minerals that contain iron in simple crystal structures that can profitably be broken down by heat. Geological deposits of minerals with a sufficient quantity of an element to be mined economically, such as iron or gold, are called ores.

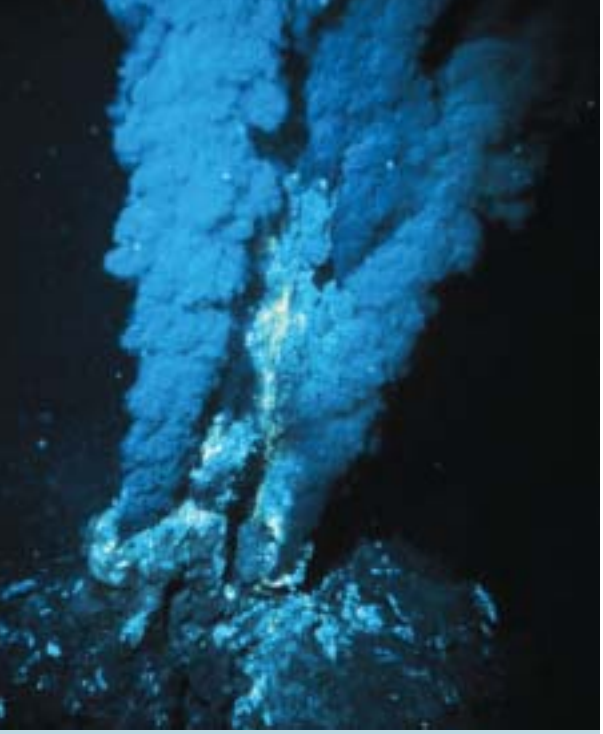


Figure 12.2: A black smoker in the Atlantic Ocean.

Black Smokers

In the early eighties, researchers investigating deep ocean trenches stumbled upon an alien world of strange tube worms, blind crabs, and bacteria huddled around the bases of geothermal vents. This unique ecosystem relied on bacteria that used sulphides for their energy source! Scientists named these vents "black smokers" after the thick black material that billowed from openings in the ocean floor. Surrounding the smokers were sulphide deposits rich in iron, copper, zinc, nickel and other metals. Chalcopyrite ($CuFeS_2$) is an example of a sulphide mineral made up of copper, iron, and sulphur. The sulphide deposits are a result of super heated water loaded with dissolved minerals, cooling and depositing the minerals around the vent.

The discovery of black smokers helped unravel the mystery of how land deposits of sulphide minerals might have been formed millions of years ago.

Minerals are rarely found in pure deposits. They are usually found together with other minerals. Those deposits, where the same minerals are found together, were formed under similar geological conditions. A mixture of minerals in a deposit may actually make it more economical to mine than a pure deposit because the mining company can adjust to a drop in prices for one mineral, or an increase in price for another mineral, by mining different minerals at different times. For example, at Sudbury, in northern Ontario, the mines originally produced silver. But they switched to nickel when the value of that mineral increased. Similarly, the Hope Brook gold mine was originally mined for copper. Improvements in analytical and mining techniques led to the development of a gold mine.

Some minerals occur in concentrations that are too small to be mined profitably by themselves, but can be mined when produced as a by-product of another refining operation. This is the case with titanium, tantalum, and cadmium production in Canada.

Minerals and rock products from mining (excluding coal and other fossil fuels, metallic ores, and gemstones) are referred to as "industrial minerals". This large category includes, for example, granite or marble for building stone, limestone taken to grind and process into cement, quartz sand used to make glass, and crushed stone, gravel, and sand used for roads.

Figure 12.3: Chalcopyrite ($CuFeS_2$). An ore of copper.
Photos courtesy Department of Natural Resources

Did You Know?

Salt is formed from the evaporation of water from ancient shallow seas. Limestone is formed from the compressed shells of marine organisms.

Pyrite or "fools gold" is formed by microorganisms breaking down hydrogen sulfide gas and releasing sulphur. The reaction occurs in environments where there is little or no oxygen.

Diamond is formed deep within volcanoes where carbon is exposed to high temperature and pressure.

Mining and Public Perception

Minerals are an essential part of our modern life. Although recycling and other practices can reduce demand for mined metals, the mining industry is still essential for sustaining many other industries. It provides direct and indirect economic benefits. One of the challenges facing the mining industry is how best to use environmental science to reduce the harm and maximize the benefits of mining for the environment.

The less it costs to mine an ore, the more profitable the operation can be for the owners. Unfortunately, the least expensive, and most profitable mining methods, often severely damage landscapes and cause pollution. In the developed world, this was especially true in the past when mine operators avoided costs by abandoning toxic materials at mining sites. There is a legacy of persistent environmental problems. For that reason, many people today regard mining with suspicion.

In Newfoundland and Labrador, we have developed a system of checks and balances to minimize the impact of mining on the environment and to reclaim the land once the mine closes. This system involves complex legislated interactions among the stakeholders including mine owners, workers, and the public. Because of this process, the modern mining industry operates in a much more environmentally sensitive manner. Environmental science plays an integral part of this process. It informs the development and monitoring of appropriate mining practices.

The Socio-economic Factors of Mining in Newfoundland and Labrador

Figure 12.4: An aerial view of a mine site (background) and town site (foreground). *Photo courtesy Department of Natural Resources*

The mineral industry in Newfoundland and Labrador produces many mineral commodities that contribute significantly to our economy. Between 2000 and 2008, the total value of Newfoundland and Labrador's mineral shipments averaged $1.75 billion, reaching a peak in 2007/08 with $3.75 billion in mineral shipments.

Shipments of minerals including non-metals such as pyrophyllite (talc), dimension stone, aggregate (crushed stone), limestone, and gypsum, averaged $40 million over the same period. In particular, sales of pyrophyllite, dimension stone, and aggregate are responsible for the increase in value of the industrial minerals sector.

Over the period 2000 – 2008, between 2,400 and 4,200 people were directly employed in mining. The largest increase in employment occurred on the Voisey's Bay project. Future employment in mining is expected to increase as new mines are developed.

Figure 12.5: An abandoned piece of mining equipment at the Buchan's mine site. *Photo courtesy Department of Natural Resources*

In the older style of mining development, a town was created as close to the mine site as possible. In this province, that included Wabana on Bell Island in the early 1900s and Buchans in Central Newfoundland during the 1950s. The mining company constructed the infrastructure required for the town including roads, schools, medical clinics, community buildings, houses, and recreational facilities. After the mines closed, the community remained, however, the direct employment from mining was gone. Those who remained in the small population inherited the environmental clean-up issues and an infrastructure that required more investment than the community was capable of generating without a major employer. By the 1970s and 1980s, temporary buildings (such as trailers) for town buildings was a more common practice because they moved when the mine closed. Examples include Hope Brook in western Newfoundland and Gagnon in Québec. And while pollution or toxic waste may still have been left behind, no single community was left to face the clean-up issues. But these temporary towns came with their own problems. Miners at these operations were not part of the local community. That could help to explain some of the social problems at these encampments. And after the mines closed, some of the so-called temporary buildings were not as portable as people assumed.

Today, mines use a commuter workforce (fly-in / fly-out (FIFO)) rather than develop a town around the site. This lessens the impact on the environment and spreads the economic benefits over a wider area, into the various communities where the miners live and spend their salaries. At Voisey's Bay, for example, the miners work onsite for a set period and then return to their home communities for their off-days.

Mining companies finance FIFO operations when they are more economical than alternatives. Building new towns in the remote locations of many new mines would not be financially feasible. At other times, new town construction is forbidden for environmental reasons or workers prefer to work under the FIFO system. There is

some benefit in this system to the mining companies. Miners go to work for intensive shifts, but they are responsible for their own family homes. In the older company towns, construction was a company expense.

Figure 12.6: Modern mining companies, such as the Voisey's Bay Nickel Corporation, develop mine sites that use a commuter workforce.
Photo courtesy of Department of Natural Resources

The distance that miners can live from the mine site is only limited by the company's willingness to subsidize transportation costs. Petroleum companies in Canada fly workers back and forth from Atlantic Canada to facilities in Alberta for three-week shifts. All metal mining operations established in northern Canada over the past twenty years—including Voisey's Bay and all of the diamond-mining operations in north-western Canada—use a FIFO workforce.

Compared to the older style of town development, FIFO operations provide fewer economic benefits to the existing communities closest to the mine. Money, which would otherwise be spent in local communities by miners, goes instead to the communities where the commuter workers live. For the local townspeople and businesses that anticipated an economic boom, this can lead to disappointment and a feeling that they are being bypassed. This lack of local economic benefits makes them much less likely to tolerate any negative environmental impacts from the mine.

CHECK your Understanding

1. What is the difference between a mineral and an ore?
2. What are "industrial minerals" and how are they used?
3. (a) Most new mine developments are fly-in/fly-out operations and not town-based for good economic reasons. Make a list of costs associated with the following two scenarios and indicate who pays the expenses in each case.
   i. Building the infrastructure for a town near a mine.
   ii. Using a FIFO operation.

   (b) What are the benefits and/or drawbacks of fly-in/fly-out mining operations for the employees of a mining company?

For Further Discussion and/or Research:

4. Which would have a reduced effect on the physical environment near the mine site: town-based or fly-in/fly-out mine operations? Explain.
5. If there is a mine close to your community, investigate and describe the history of the mineral discovery. Does the company have an environmental health and safety policy? What would be the purpose of such a policy?

Society's Dependence on Mining

People have depended on mined products throughout human history. Newfoundland and Labrador is no exception. Examples include:

- Bloody Bay Cove, Bonavista Bay: Here, 5,000 years ago, people quarried rhyolite, which is a dense red volcanic rock. Using rhyolite stone tools, they chipped it from the sides of the quarry to make arrow points, fishhooks, and knives. They also used it to make choppers and scrapers for cutting and cleaning caribou hides.

- Ramah Bay, Labrador: From the area north of Nain, as far back as 7,500 years ago, people began to mine Ramah chert (a form of silica) for making tools.

- Fleur-de-Lys, Baie Verte Peninsula: 1,600 years ago the Dorset people used this large soapstone quarry to remove soapstone for cooking pots, oil lamps, and ornaments.

- L'Anse-aux-Meadows, Great Northern Peninsula: Norse settlers smelted bog iron on this site in 1,000 AD to make iron nails and tools.

- Beothuks, who inhabited the coast and interior of Newfoundland, used red ochre (hematite) as a pigment.

Figure 12.7: An iron artifact found at L'Anse aux Meadows, Great Northern Peninsula.

Figure 12.8: Ground Red Ochre (hematite).

The extent of our dependence on mining and the number of different mineral products used in common items is not always immediately obvious. A car, for example, contains steel produced from iron and nickel, with additional chromium included for toughness and molybdenum for flexibility. Refer to Table 1 to learn about additional minerals and mineral products used.

Canada has one of the world's most active and diverse mining industries. Mining revenues are a substantial component of all provincial and territorial revenues. Although a few metals must be imported, such as chromium, Canada is self-sufficient in most minerals and is a significant exporter of many.

Figure 12.9: Limestone and/or dolomite being loaded onto a ship at the mine in Lower Cove on the Port au Port Peninsula, NL. *Photo courtesy Department of Natural Resources*

Products made from minerals are everywhere!

In a typical classroom, home, or office, you will likely encounter many products produced from minerals and other mined materials:

- Ceramic coffee cups
  - Made from clay
- Glasses and windows
  - Made from silica sand
- Paint
  - May contain mica, which enables it to flow readily
- Eye glasses
  - Frames are made of either graphite or titanium
- Computers
  - Made from 28 different minerals
- Toothpaste
  - Made of fluoride
- Sunscreen
  - Contains zinc
- Talcum powder
  - Contains talc
- Soap
  - Contains small amounts of volcanic pumice

Material	Amount	Use
Aluminum	110 kg	Light metal used in body
Antimony*	< 50 g	Fire retardant in upholstery
Asbestos*	500 g	Brake pads***
Barium*	< 50 g	Coating electrical conductors in ignition
Cadmium**	< 50 g	Coating on steel to inhibit rust
Graphite	21 kg	Additive to steel & radial tires
Cobalt**	< 50 g	In high-temperature metal engine parts
Copper*	20 kg	Wiring
Fluorspar*	< 50 g	Used to manufacture aluminum & steel
Gallium	< 50 g	Mirrors, transistors, LEDs
Garnet*	< 50 g	Polishing metals during manufacture
Gold*	< 50 g	Electronics systems
Iron*	2,250 kg	Steel
Lead*	11 kg	Battery
Magnesium**	2 kg	Strengthens aluminum and zinc
Manganese**	8 kg	Steel for axles and pistons; battery
Molybdenum	400 g	Steel and lubricants
Mica**	< 50 g	Shock absorbers and paints
Nickel*	4 kg	Plating for stainless steel
Palladium	< 50 g	Used as an alloy in electrical contacts
Petroleum	450 kg	Plastics, tires, upholstery, paint
Quartz sand*	75 kg	Glass
Silicon metal*	20 kg	Ceramics, computer components
Strontium	< 50 g	Night-glow dials
Sulphur**	1 kg	Battery
Tin	< 50 g	Copper alloys, solder
Titanium**	< 50 g	Paint, lacquers, plastics, engine parts
Tungsten	< 50 g	Light bulb filaments, ignition system
Vanadium	400 g	Axles, crank shafts, gears
Zinc*	8 kg	Screws, rust proofing, tires
Zirconium	< 50 g	Used to cut glare in glass of mirrors, light bulbs

* Currently mined or has been mined in Newfoundland and Labrador.
** Deposits are present in Newfoundland and Labrador, but no mines developed or proposed.
*** Although there are glass fibre substitutes for asbestos brake pads and linings, most linings are still made from asbestos.

Figure 12.10: Minerals required to produce a mid-size family car.

Mining in Newfoundland & Labrador

Company	Location	Main Commodity	Use
IOC	Labrador City	Iron, dolomite	Steel production
Wabush Mines	Wabush	Iron	Steel production
Atlantic Minerals	Lower Cove, Port au Port Peninsula	Limestone	Cement manufacture
Cabot Granite	Borney Lake	Granite	Dimension stone
Galen Gypsum	Coal Brook, St. George's Bay	Gypsum	Wallboard
Hi Point Industries	Bishop's Falls	Peat	Agriculture and gardening
Hurley Slate	Nut Cove, Trinity Bay	Slate, flagstone	Dimension stone
Vale Inco	Voisey's Bay	Nickel	Steel production
Labrador Inuit Development Corp.	Ten Mile Bay, near Nain	Labradorite	Dimension stone
Trinity Resources and Energy	Manuels	Pyrophyllite	Ceramic tiles, insecticides, talc
Shabogamo	Labrador City	Quartzite	Silicon metal, used in electronics
Anaconda Gold Corp.	Pine Cove, Baie Verte	Gold	Jewellery, electronics
Atlantic Barite Ltd	Buchans	Barite	Drilling mud
Aur Resources	Duck Pond, Central NL	Copper, zinc, silver, gold	Wiring, metal production
Beaver Brook Antimony Mines	Beaver Brook, near Glenwood	Antimony	Flame retardant in clothing, plastics
Crew Gold Canada Ltd	Nugget Pond, Baie Verte	Gold	Jewellery, electronics
Peat Resources Ltd	Stephenville	Peat	Agriculture and gardening

Figure 12.11: Some active mining operations in Newfoundland and Labrador (2008).

CHECK your Understanding

1. Give examples of historic mining activity in Newfoundland and Labrador.
2. In your classroom, identify as many items as you can that are derived from mining. Be imaginative. Compare your list to that of a classmate.

For Further Discussion and/or Research

3. Research and determine the twenty eight different materials that are needed to construct a computer. What role does recycling play in providing these materials?
4. Make a list of all of the costs of producing aluminum from ore and all of the costs of recycling aluminum cans. Also, list the people or group that pays each cost. Are any of the costs paid in a way that hides the true cost of the process? Based on your analysis, should we stop recycling aluminum cans? Explain.
5. About one third of the materials that we currently use are recycled. If we did not mine any new materials and nothing changed, only one third of what you are using now would be available to you. Make a list of materials you commonly use that are made from/with mined products. On your list of mined products, indicate which products you would like to keep using (one third of the ones on your list). Indicate which of those on your "stop using" list could reasonably be replaced by increased recycling. The other two thirds represent items you would have to stop using if mining activity ceased. Could you do without these materials?

The Mining Process

All mines begin the same way: with the discovery of a mineral body. The life of a mine can be as brief as a few months or longer than fifty years. The mining process consists of four main stages:

1. exploration;
2. ore extraction;
3. processing; and
4. closure/rehabilitation/reclamation

Exploration

The exploration phase is carried out mainly by prospectors. There has been a tremendous evolution in modern prospecting techniques over the past one hundred years. Most prospectors today are well trained and not just lucky. Among the ranks of the prospectors in the field are environmental scientists and technicians.

Figure 12.12: Geologist at work.

The initial step in searching for ore is to study geological maps to determine if rock types are present that might contain valuable minerals. Because high concentrations of elements such as copper, nickel, and lead can be detected in surface water, geological surveys include collection and chemical analyses

Geophysical surveys

Geophysical surveys measure the physical properties of Earth's surface. Geophysical properties measured include magnetic field strength, conductivity of the rock, specific gravity (density), and radioactivity. Any changes in the Earth's magnetic field, conductivity of the rock and its density, and radioactivity is called a geophysical anomaly. Geophysical anomalies are places where physical properties of Earth's surface differ from the surrounding. These anomalies may indicate the presence of mineralization.

of water and sediment from lakes, rivers, and surface sediments (till). Other elements may be useful because their presence in high concentrations may indicate the presence of other materials. For example, high levels of arsenic in water and sediment may indicate the presence of gold. Poor vegetation, which may be visible on satellite images, could indicate the presence of nickel deposits.

Did You Know?

When prospectors Al Chislett and Chris Verbiski spotted rusty outcrops in Northern Labrador in late 1993, they made one of the most substantial mineral discoveries in Canada in the last 40 years.

Subsequent exploration revealed extensive deposits of nickel, copper, and cobalt lying just below Earth's surface. Both open pit and underground mining will be undertaken at Voisey's Bay.

Courtesy: Voisey's Bay Nickel Company Limited

Assays

An assay is a chemical analysis that determines the proportion of metallic (Cu, Pb Zn, Au, Ag, etc.) or non- metallic (Fl, S, P, etc.) elements in a rock sample. A wide variety of materials can be chemically analyzed: these include water, vegetation, soil, sediment and rock. Assay labs can provide you with single and multi-element analyses by a variety of methods. Rock and soil samples are crushed, powdered, fused or digested in acid and then analysed using one of several analytical methods and instruments. Anybody can have a rock sample assayed, even you!

Source: Newfoundland and Labrador Department of Mines and Energy

Mining companies and individuals may claim or stake pieces of terrain, which gives them the right to explore for mineral deposits for a set period of time. Specialized techniques are used to search for particular minerals. For example, uranium ores can be located by measuring radioactivity using a Geiger counter or a scintillometer. Large bodies of iron ore can produce magnetic anomalies—areas where local changes in Earth's magnetic field cause compasses to fail. Gravitational anomalies produced by concentrations of dense minerals can also be detected by sensitive geophysical equipment.

Walking over thousands of square kilometres in the hope of tripping over an ore boulder is not a practical method of mineral exploration in sparsely settled areas of Canada. Modern prospectors analyze aerial photographs and images from satellites. Folds, faults, and other geological structures—potential host sites for ore deposits—can be detected in this way.

Another technique used in prospecting involves looking at how boulders are transported by glaciers. Finding an ore-rich boulder does not mean that the deposit is directly underneath. Boulders from the iron ore deposits in western Labrador can be found as far south as Long Island, NY. Using glacial landforms such as eskers and striations allows prospectors to determine the direction of ice movement. The investigator can then determine where the boulder may have come from and potentially find the source deposit.

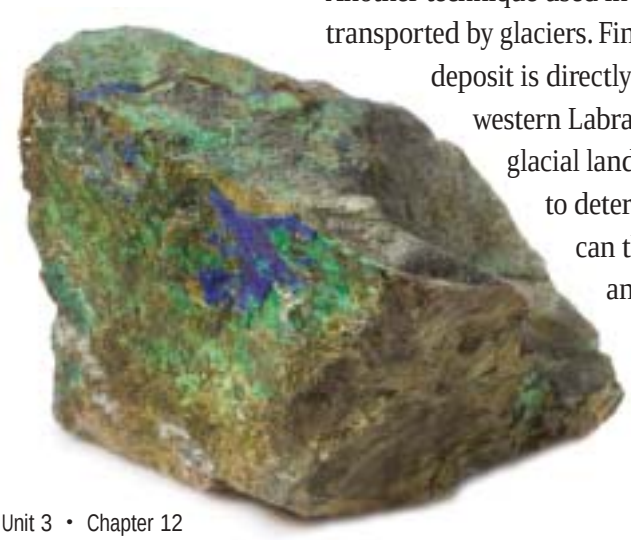


Figure 12.13: Surface weathering of ore minerals can produce minerals with distinctive colours. In this sample, the malachite (green) and azurite (blue) are copper minerals.

When prospecting identifies an area of interest, the overlying soil and sediment is removed from the bedrock in selected sites. Surface trenches are then blasted to remove the weathered and oxidized surface rock so that larger, fresh samples can be tested for mineral content. If results suggest that the deposit could be economically viable, then diamond drills are used to take core samples of the rock for further laboratory analysis and to determine the extent of the ore body.

Did You Know?

Computer software is used to model potential ore body size and concentration of ore. Data collected from drill cores is inputted into a desktop computer. The resulting three dimensional model assists mining engineers, mine planners, civil engineers, and environmental engineers in the decision making process.

Extraction

The mining or extraction of mineral ore from the ground is, by its very nature, a destructive practice. The choice of which mining technique to use is based on the way that the resource was formed, its geology, and the economic, social, and political factors involved. However, specific types of mineral deposits require specific mining techniques to extract them. Although mineral deposits come in many forms, we can recognize distinct styles notable for their impact upon the landscape and environment.

Figure 12.14: Extraction of a mineral commodity called pyrophyllite from a mine near Manuels, CBS.
Photo courtesy of Department of Natural Resources

Placer Mining

Placer deposits accumulate in river gravels and beach sands. These materials are concentrated in the sediments due to differences in density or hardness. As a result, they form distinct layers in gravels and sands. Typical materials found as placers include gold, platinum, tin, titanium, chromium-bearing minerals, diamonds, and resistant minerals such as garnets and corundum.

Figure 12.15: Panning for gold along a river.

Most of us are familiar with the technique of panning for gold. This technique is used for mining a placer deposit. Pure gold is nineteen times denser than water. Therefore, a river has to exert more energy to move a gold nugget than it does for the less dense granite and sandstone pebbles. Sand-sized grains of gold tend to concentrate in distinctive layers. When these layers are panned—swirling the water around in the pan and gently pouring off the excess water and lighter sand—the heavier gold flakes concentrate in the bottom of the pan.

Commercial placer mines in Yukon, Alaska, and elsewhere no longer use panning to extract gold. Gravel and sand are dredged or excavated, filtered, and sorted to remove the gold. The same technique is used to extract diamonds from beach

Bog Iron

Bog iron occurs in glaciated regions throughout the world, and so would have been very familiar to the Norse explorers at L'anse au Meadows when they arrived at the northern tip of the island of Newfoundland over 1000 years ago.

Bog iron consists mainly of limonite (iron oxide and water). Limonite is a low grade iron ore that may contain between 40 to 60 per cent iron. It forms when streams carry dissolved iron and manganese from nearby hills into a bog. In the bog, the iron is concentrated by two processes, chemical action and bacterial action. The bogs are acidic and have a low concentration of dissolved oxygen. In the acidic environment, a chemical reaction forms insoluble iron compounds which precipitate out as solids. The second process is carried out by anaerobic bacteria growing under the surface of the bog. These bacteria can survive in environments with little oxygen and concentrate the iron as part of their life processes! Their presence can be detected on the surface by the iridescent oily film they leave on the water. This oily film is often mistaken by outdoor enthusiasts as an "oil spill". A quick test is to poke the film with a stick oil will not break up, this film, consisting of an iron and manganese will!

Source: Where Continents Collide, Western School District

and river placer deposits in Namibia and Australia, and to remove tin- and titanium-bearing minerals from beach sands in Indonesia and Malaysia.

With placer mining, the excess sediment is discarded in piles of disturbed material. These can potentially contaminate the surrounding environment. In many placer mined areas, the materials discarded during earlier periods of mining have been mined again as increasing metal prices and better technology make it economically possible to process the waste materials. Around Dawson City, Yukon, many piles of placer mined materials have been mined several times.

In some cases, filtering and sorting is not necessary, as the minerals of interest are already concentrated in distinctive bands. This is the case with many beach placer deposits, notably those with garnets and corundum.

Relatively few types of minerals are concentrated in placer deposits; even most commercial gold and diamond mines are not placer operations. **Hard-rock** mining is much more common. Hard-rock mining is the extraction of minerals that are embedded in rock.

Underground Mining

Underground mining, in tunnels and cavities, is the least visible form of mining, although its tailings are toxic and can still have considerable negative impact on the environment. Underground mining can also be the most dangerous and unhealthy form of mining for the miners.

Figure 12.16: Example of an underground mine.

Figure 12.17: Although Hope Brook gold mine was primarily an underground mining operation, a large surface facility was required.
Photo courtesy Department of Natural Resources

Underground mining is only practical under certain circumstances. The deposit must be in the form of relatively pure, discrete, concentrated layers, veins or shafts that can be excavated in tunnels without removing the surrounding material. In an underground coal mine, coal is present in distinctive beds, or seams, which are tunnelled out of the earth, leaving the surrounding sandstone and shale as supports for the tunnel. In the former Bell Island iron mines, as well as in lead-zinc mines (for example Buchans and Hawkes Bay) and nickel mines, the metals are also concentrated in distinctive areas. The layers and veins rich in the minerals of interest can be removed, leaving the other surrounding rock—also known as the **host** or **country** rock—to form and support the excavated tunnels or cavities. Most gold mines (for example Hope Brook) and diamond mines are a combination of underground and **open pit** operations.

Did You Know?

Fluorspar, which was mined in Newfoundland for many years, was mainly used as a flux in steel making. It is also used in the chemical industry to make fluorine to add to drinking water and toothpaste. Fluorspar was also used to make chloro-fluorocarbons, which in turn were used as aerosol propellants and as a coolant in refrigerators, but are now recognized as chemicals that contributed to the destruction of Earth's protective ozone layer.

Underground mining is the preferred method of mining where large quantities of other rock would have to be removed in order to expose the mineral deposits. This was the case in the former fluorspar mine at St. Lawrence, but it imposed considerable health risks on the miners. Underground mining, regardless of the minerals being extracted, poses considerable safety and health risks for the workers. Safety in these operations demands a highly-trained and professional workforce. Today, underground miners in Canada are professionals, usually unionized, who demand fair compensation for the risks they take every day on the job.

Open Pit Mining

Open-pit mines, or **quarries**, are used when underground mining is either impractical or too expensive. Quarrying is the only way to mine dimension stone to produce polished marble and granite used for building construction. In Newfoundland and Labrador, dimension stone quarries include the labradorite (anorthosite) quarry at Nain, the marble quarry at Goose Arm, the granite quarry at Lumsden and Cat Arm, and the slate quarry on Random Island.

Open pits are the most economical way to extract gravel and crushed stone for road-building and concrete manufacture, sand and limestone for cement, gypsum for wallboard—as at Flat Bay on Newfoundland's west coast—and clay for pottery and ceramics.

Figure 12.18: Equipment at work in the Brown's Arm open pit mine, which is mined for aggregates.
Photo courtesy of Natural Resources

Open-pit mining of some metals is also common. Elements may be dispersed throughout the rock as individual mineral crystals or even atoms, as is the case with many copper deposits in igneous rocks. Extraction of copper from an igneous rock requires that the rock be completely removed, resulting in the levelling of landscapes and their gradual replacement by large open pits. Open pit mines characterize the copper producing areas of British Columbia, Yukon, and the western United States. Open pit mining is also used to extract iron ore from some types of deposits such as, for example, in the open pits near Labrador City-Wabush. It is also used for other geological materials including molybdenum, phosphate at Long Harbour, Placentia Bay, asbestos from Baie Verte, barite near Colliers Point, and talc or pyrophyllite from the talc mines of Conception Bay South on the Avalon Peninsula.

Figure 12.19: Example of an open pit mine.
Photo courtesy Department of Natural Resources

In some cases, the choice between open-pit and underground mining depends on the individual characteristics of the site. Coal deposits in eastern North America (Nova Scotia and Pennsylvania) were generally developed as underground mines. The coal was relatively hard (anthracite), the surrounding rock was strong, the seams were thick (allowing tunnelling), and the overlying non-productive rock was locally very thick.

In Alberta, British Columbia, and Wyoming, the coal is relatively soft (lignite), the surrounding rocks are weak, many seams are thin, and the coal is locally exposed on the surface. Under these circumstances, open-pit mining is the most cost-effective option.

Changing economic circumstances, including miners' salaries and improved safety requirements, can also tip the balance in favour of open-pit mining over underground mining. This is evident in both the coal and iron-mining industries. Open pits are the only economic form of coal mining in the developed world, with highly-paid, unionized labour forces, and safety standards that are considered reasonable by the stakeholders.

For any mining operation, once the deposit is identified and its concentration and extent is confirmed as economically viable, and all environmental requirements have been met, then mining can begin. This usually involves blasting, digging, washing, or whichever technique is most appropriate as described above. This must be done carefully in order to avoid creating excessive dust and noise. It also must be done in as safe a manner as possible.

Blasting and digging operations in open pit mines have the most potential to release dust into the air. This dust can damage nearby plants by blocking stomata, the small pores that allow air into the leaves, and by reducing the amount of sunlight entering the leaf tissue. Airborne dust can be transported by wind to nearby areas. Modern mining sites are planned so that living areas are located upwind from open pits where possible to minimize the effects on miners and support workers.

EXPERIMENT:

Concentrator in a test tube

This activity will help you understand some of the concepts associated with concentrating ore. Place one spoonful of iron filings and two spoonfuls of sand into a large test tube, shake it up, and dump the mixture on a piece of paper. Pass a magnet through the mixture. Explain your observations.

Place the mixture back into the test tube and fill the test tube with water. Shake well and let the contents settle. Explain your observations.

The dust produced will also contain high levels of the minerals and elements mined at the site. In underground mines, dust concentrations are often higher than above ground. Some dust, such as coal dust, is harmful. Many miners who worked in older coal mines developed 'black lung', a general term for a number of respiratory diseases and cancers. The extraction of some minerals results in the release of gases which can be hazardous to miners. Methane, which is produced during coal mining, is both flammable and toxic. Here in Newfoundland and Labrador, the mining of fluorspar at St. Lawrence produced radon gas that was linked to cancer in the former miners.

Dust from open-pit mines can also pose health problems. Asbestos was mined in open pits in Newfoundland on the Baie Verte Peninsula and in Québec. Miners who breathed the asbestos fibres for many years had an increased risk of developing silicosis and lung cancer. Today, asbestos is no longer extensively used and is being removed from many buildings. (The regulations to protect the health of the workers removing this asbestos specify the need to wear protective equipment.)

Blasting is a noisy process. If an open-pit mine, quarry, or gravel pit is close to houses, the blasting noise may cause inconvenience or problems that may lead to disagreements between quarry and pit operators, and nearby residents. These issues have to be resolved with attention not only to economic viability, but also to the quality of life, safety, and the convenience of local residents.

Figure 12.20: Miners wearing safety clothing and equipment in the Hammerdown Gold Mine, which is located near King's Point in the central region of the province. *Photo courtesy Department of Natural Resources*

Government regulated inspections are conducted on all mining operations to ensure that safety regulations are followed. Both unions and industry strive to reduce accidents.

Processing

Different types of materials require different types of processing techniques. High-grade coal may need no further processing. Gravel may only require washing. And granite may only need to be cut and polished. However, many ores require extensive processing. Nickel ore mined at Voisey's Bay contains less than three per cent nickel. Copper ores commonly contain less than one per cent copper. Gold concentrations in ores that can be mined economically are commonly

Mineral Separation Techniques - Definitions

Gravity Separation

This technique involves the process of separating materials by relying on the force of gravity. The milled ore is mixed with water and the heavier (more dense) materials settle to the bottom first. Gravity methods include jigging, in which the ground ore is fed into a pulsating body of water so that the heavier mineral fractions settle out, leaving lighter wastes at the top, or washing the ore down inclined planes, spirals, or shaking tables so that mineral and waste fractions settle in different areas.

Magnetic Separation

This process works with minerals such as iron ore that are naturally magnetic. In this process, the ore, which may be less than thirty per cent iron, is mixed with water and then finely ground. The pulp is then passed over a revolving magnetic drum, to which the magnetic iron minerals attach. These minerals are then scraped off and retained, while the non-metallic particles are discarded with the water.

expressed in grams (or ounces) of gold per tonne of rock. Extensive processing requires more energy, time, and facilities, and has a greater impact upon the environment.

Processing of metal ores commonly involves initial preparation of raw ore to an ore concentrate, which is then further refined to produce metal. Ore concentrate contains a higher percentage of metal than raw ore taken from the mine and is more economical to ship to the smelter for final processing.

Raw ore is first passed through a series of crushers to break it up into smaller pieces. The resulting mixture is then milled by crushing and grinding through rod and ball mills. In the presence of a liquid, the process is called **wet milling**. Without a liquid the process is called **dry milling**. The milled ore is separated into high-grade material, rich in metal, for further concentration or for smelting, and low-grade material or **tailings**, which will be disposed of as waste.

The milled ore may be shipped directly to a smelter for final processing. Alternatively, especially if the smelter is far away from the mine site, the milled ore may be further concentrated to reduce the volume and weight of material that needs to be transported.

Leaching usually uses toxic liquids to dissolve soluble metals from the milled ores (chemical leaching). Liquids containing cyanide are used to extract gold or silver. To leach gold from ore, more than 3000 litres of cyanide must be added to each cubic metre of ore. The cyanide liquid slowly leaches the gold as it percolates through the ore. The liquid containing the concentration of gold is collected. The gold is recovered from the cyanide solution and then processed. Sulphuric acid leaching is used to extract copper or uranium from ore.

Figure 12.21: A tailings pond at the Duck Pond site in central Newfoundland and Labrador. *Photo courtesy Department of Natural Resources*

It is important to use caution when leaching with cyanide. Exposure to cyanide can be fatal. Lower level exposure over time can also cause problems with breathing, disrupt the central nervous system, and interfere with the functioning of the digestive tract. Modern mining operations conduct the leaching process in closed tanks, which do not permit the liquid to escape into the environment. The liquid is recycled where possible.

Mineral Separation Techniques - Definitions

Heap Leaching
In this process, the crushed ore is layered on an impermeable material. The ore is then irrigated with a liquid (which will vary depending on the mineral). The liquid percolates through the layer of ore and dissolves out the valuable materials. The leach solution is then collected and treated with chemicals to cause the dissolved materials to precipitate out of the solution.

Flotation
This is the process of separating minerals from the surrounding ore by agitating the crushed ore with water, oil, and chemicals. The ground ore is suspended in water and, after chemical treatment, subjected to bubbles of air. The minerals attach to the air bubbles, rise through the suspension, and are removed with the froth that forms on top of the pulp.

Bioleaching
Imagine bacteria taking over the role of miners! Bioleaching is a new technique use by the mining industry to extract gold and copper from ore. The process uses bacteria to break down the ore and release the valuable metal in the form of ions. The metal ions are collected and converted back to metal using electrolyses. A class of bacteria, called chemolithotrophs, get their energy to live, grow, and reproduce from breaking down (eating!) inorganic materials like sulphide ores. The process removes over 90 per cent of the desired metal. Aside from being simpler and cheaper than traditional mining processes, bioleaching is also more environmentally friendly.

Many older mining operations, as well as some in less developed countries, involved leaching in heaps of ore exposed on the ground surface or in artificial ponds. We now know that liquids exposed on the surface pose hazards to wildlife and birds. Cyanide and acid could also leach into the rock beneath the piles of ore or the ponds, potentially contaminating the groundwater. In some cases, the banks of the holding ponds have collapsed, releasing cyanide or acid into near by waterways, contaminating the water, and killing fish far downstream.

An alternative form of leaching uses bacteria to break down the ore and release the metal ions (**bioleaching**). The metal ions are collected and converted back to metal using electrolysis. This process is used primarily for sulphide ores such as sphalerite (zinc sulphide) and chalcopyrite (copper sulphide). In addition to being simpler and cheaper, bioleaching is also more environmentally friendly. It eliminates emissions from smelting and reduces the impact on the landscape. However, it is a considerably slower process than smelting and may not be economical for some processing operations.

The final stage of mineral processing in mining is **smelting or refining**. One method, called pyromet, uses heat to separate the metal from the ore concentrate. Heating the ore allows the desired metal to be extracted. The process produces two forms of waste: the residual solid material, termed slag; and the gases given

off during smelting. Both of these waste products are potentially harmful to the environment if disposed of in uncontrolled ways.

Did You Know?

The Hope Brook gold mine operated from 1987 to 1997. In 1999, Royal Oak Mines Inc., the owner of the site, entered into receivership. Ownership of the site was subsequently transferred to the Government of Newfoundland and Labrador by the Ontario Superior Court on December 13, 1999.
The main environmental concerns at the mine site are acid mine drainage, the tailings impoundment areas, waste rock dumps, heap leach materials, hazardous waste, and garbage disposal. Millions of dollars have since been spent on reclamation at this site.

Many ores contain sulphides, therefore smelting results in the production of sulphur gas compounds, particularly sulphur dioxide. Sulphur dioxide combines with water in the atmosphere to produce weak sulphuric acid. This is the cause of acid rain, a dangerous phenomenon that can lead to widespread environmental damage. When smelting of copper and nickel began at Sudbury in the 1890s, the effects of acid rain and airborne nickel aerosols were not well understood so there were no environmental regulations in place. Initially, this smelting released the sulphur dioxide through smaller smelter stacks. When this killed much of the vegetation within a ten kilometre radius around the smelters, regulations were imposed requiring the construction of taller smelter stacks. These dispersed the sulphur dioxide away from the smelters, reducing the local effect on the vegetation, but they spread acid rain for hundreds of kilometres downwind.

Modern technology has reduced sulphur emissions through the installation of chemical **scrubbers** on the stacks. These scrubbers contain chemicals that react with the sulphurous gases. Between 1980 and 1997, INCO and Falconbridge, the two major producers of smelter emissions in the Sudbury area, installed scrubbers and reduced their sulphur dioxide (SO_2) emissions by seventy five per cent and fifty six per cent respectively. Emissions of nickel, copper, and other metals through the stacks have been reduced by more than eighty per cent since 1988.

NOTE: *You will learn more about the problems with SO_2 and other emissions in Unit 5.*

Figure 12.22: A facility carrying out the hydromet process in Voisey's Bay. *Photo courtesy of Voisey's Bay Nickel Corporation*

An alternative to smelting nickel is the hydromet process, currently under development by INCO. The hydromet process is a chemical leaching method, but unlike cyanide or acid liquid leaching, the hydromet process is designed to use pure oxygen and water. Oxygen is added to the nickel sulphide ores to oxidize the sulphur. This breaks down the ore and produces solid sulphur, iron oxide waste, residual sulphuric acid (which also helps in further dissolving the ore), and nickel sulphate solution. The nickel ions in the nickel sulphate solution can then be directly converted to nickel.

Closure

Mine site reclamation and rehabilitation is an accepted requirement in Canada today. As part of the Environmental Assessment process, companies such as Voisey's Bay Nickel Company are required to allocate funding for clean-up prior to receiving permission to mine. This requirement avoids the previous situation where a bankrupt mining company had no financial resources to accomplish clean-up. Governments have also undertaken clean-up operations at abandoned mines, both for environmental health and human safety.

Figure 12.23: Buchart Gardens, Victoria, British Columbia, was originally a limestone quarry before reclamation.

The type of reclamation required depends upon the type of mining that took place on the site. For a gravel pit, reclamation may involve simply grading the slopes so that they do not pose a collapse hazard, removing any machinery, and cleaning up oil residue. The pit is then reclaimed naturally by the surrounding vegetation or may be used for recreational activity. A dimension stone quarry, especially one filled with water, may be fenced after decommissioning to prevent public access. More involved reclamation efforts must be undertaken where hazardous materials, such as liquid wastes or sulphur-bearing tailings, are involved.

Environmental scientists and technicians have conducted tests to determine which types of vegetation grow best on tailings of various chemical compositions. A successful re-vegetation project on the sulphur and nickel-rich tailings surrounding Sudbury has proven that reclamation is possible. Tailings piles can be graded to reduce the slopes. This limits the possibilities of collapse and the potential for rainwater runoff and contamination of nearby water supplies. Tailings pond dams must have proper maintenance and monitoring. Liquid wastes must be chemically neutralized, for example, by adding lime to acidic wastewaters to increase the pH.

Problems with reclamation can be significant. This is especially true in cases where a mine has been inactive for a considerable period of time. Records concerning the extraction and refining processes used, the locations of the waste disposal areas, and the volumes of waste involved may be lacking. Under these circumstances, reclamation by governments is generally the most effective approach. Environmental scientists and technicians are frequently called in to participate in these efforts.

CHECK your Understanding

1. Briefly describe the four stages of the mining process.
2. What are some health problems associated with dust from mining operations?
3. What is the difference between raw ore and concentrate?
4. Why is the chemical leaching process of refining ore potentially dangerous for the environment?
5. What is smelting? Why is the emission of SO_2 during smelting operations a major environmental concern?
6. What are the key differences between extraction techniques of placer mining, underground mining, and open pit mining?

For Further Research/Discussion

7. What factors in underground mining make it the most dangerous and unhealthy form of mining for miners?
8. What are some reasons why INCO is testing hydrometallurgy technology in Argentia, Placentia Bay, instead of constructing a traditional pyrometallurgy smelter?
9. What is the purpose of scrubbers in smelter stacks?
10. What factors determine whether or not a mineral deposit will be mined?
11. Why is the INCO "super stack" in Sudbury, Ontario, so well known?
12. Use Google Earth to view the following mines:
    - Iron Ore Company, Labrador City, Newfoundland and Labrador
    - GECO mines (closed), Manitouwadge, Ontario
    - Escondida, Antofagasta, Chile (south east of Antofagasta)
    - Hope Brook Gold (closed), south west Newfoundland and Labrador

    (a) Can you find more mines on planet Earth?
    (b) Based on your observations, what mining method has the most visible impact on the planet?
    (c) How does it compare to other human activities such as agriculture, forestry, and urbanization?

MITIGATION AND MONITORING OF WASTE PRODUCTS

Figure 12.24: A mine site showing evidence of environmental damage.

There are three forms of waste produced by the mining industry:

1. Gases and aerosols from smelter stacks.
2. Solid materials including tailings and slag.
3. Liquid materials including cyanide and acid leachate.

This section examines the last two: solid and liquid mining waste. They can pose significant environmental problems.

Most mines produce enormous quantities of unwanted solid waste. For a gold mine, the process of extracting a few grams of gold from tonnes of rock leaves tonnes of waste tailings which, depending upon the chemical composition, can vary in the environmental risk that they pose. Most difficulties occur when the tailings are acidic. This is an all too common problem with the by-products of mining sulphide minerals such as lead, zinc, copper, and nickel. All are sources of acidic tailings. Slag also poses a disposal problem, although it is less subject to water leaching than are tailings.

Acid mine drainage

Acid mine drainage is the most serious problem associated with operating and closed mines. When waste rock or tailings react with oxygen, they oxidize and change colour to rusty brown. If waste rock or tailings contains sulfide minerals such as pyrite (FeS_2), then acid rock drainage is produced. Exposure to oxygen and water results in the sulphur reacting with oxygen and with the help of bacteria (Thiobacillus ferroxidans), forming sulfuric acid. The sulphuric acid causes acidic waters. Acidic waters moving over or through the ground dissolve metals which in certain quantities are harmful to aquatic life and humans.

The *Metal Mining Effluent Regulations* of the Government of Canada require all metal mines to contain their tailings behind a dam or other structure. This structure can only discharge effluent into the environment that complies with regulations. Proper disposal of the tailings and slag requires that they be isolated as much as possible from humans and animals and that they be kept isolated from surface water and groundwater. It is not sufficient to pile the tailings in large heaps and put wire fences around them—although this was common practice in the past. Rain and snow falling on the tailings piles can cause water to leach through the tailings where it is acidified. When this water reaches nearby streams or ponds, it raises the pH of these water bodies to levels that are toxic to aquatic life and makes the water unfit for drinking. If this acidic water enters a groundwater system, it will contaminate that water.

The preferred method of disposal for solid mine waste is to isolate the tailings from water as much as possible. This may involve disposal in a man-made impoundment (basin) lined with clay or an artificial liner that does not allow water to escape. Disposal in an excavated basin also eliminates the problem of collapse of the tailings pile, a former difficulty when the tailings were piled in steeply-sloping heaps.

Liquid waste, particularly cyanide and acid, must be contained and isolated from surface water and groundwater. If the leaching takes place on the surface in artificial ponds, care must be taken to ensure that there is no seepage from the ponds through the dams and that the lining for the ponds limits leakage. The waste acidic liquid can be neutralized by adding lime to reduce the acidity.

It is inevitable that some waste products from mining will escape into the environment. Companies are responsible to ensure that any waste products (liquid, solid, gas) are handled properly and that they comply with all government regulations. Environmental scientists and technicians are employed to monitor the waste, to assess the degree of chemical activity, and to aid in the design of waste containment and management systems.

Figure 12.25: The company that is responsible for polluting the water is also responsible for having it treated/cleaned.

Containing tailings or liquid waste in a basin is common practice in the mining industry. But in order to avoid environmental damage, the dams of the basin must be secure over the long term. Worldwide, failure of tailings pond dams is a significant environmental problem. As of 2006, the United Nations Environment Programme (UNEP) had recorded more than 220 failures of tailings pond dams that released toxic material to river systems, or had other serious environmental consequences. In January 2000,

a poorly designed tailings dam at a Romanian gold mine failed. Cyanide waste was released into the Danube River where it killed most aquatic life downstream and affected drinking water for more than two million people in Romania, Hungary, and Bulgaria. A similar failure in Guyana in 1995 resulted in eighty kilometres of river habitat being affected by cyanide waste. This problem, and other similar problems, could have been prevented with proper regulation, engineering design, and long-term environmental maintenance and monitoring.

Did You Know?

The Iron Ore Company of Canada (IOC) is Canada's largest iron ore producer and a leading global supplier of iron ore pellets and concentrates.

The facility began operation in 1962 and has produced more than one billion tonnes of crude ore with an average iron content of thirty nine per cent.

The site has known reserves of 1.4 billion tonnes, enough to support operations for the next fifty years.

After processing at the Labrador City operations, the pellets and concentrate are transported south 418 kilometres on railway to the company's shipping terminal in Sept-Îles, Quebec. The trains consist of 265 cars stretching four kilometres from the engine to the caboose!

Courtesy IOC

On insular Newfoundland, two former mines on the Baie Verte Peninsula illustrate the change in approach in tailings disposal over the last thirty years. The underground Rambler Mine was active in the 1970s and early 1980s, producing copper and gold. The acid generating tailings, which contain sulphur, were placed in a large tailings pond and impounded by an earthen dam. Efforts were made to isolate them to preserve stream water quality. After the mine closed, wind dispersed dust from the exposed tailings. Environmental monitoring found high copper values in black spruce twigs as far as three kilometres away from the tailings site. When the neglected main dam failed, water from the tailings pond acidified local river systems and raised the concentrations of copper, lead, and zinc to the point where the water is toxic for most aquatic life. Since then, efforts have been made to restore the original diversion structures and to rehabilitate the streams. But this is a little like closing the barn door after the horse has fled.

A more modern and environmentally informed approach was adopted at the Nugget Pond gold mill by the operator Richmont Mines. In fact, the company won national awards for environmental awareness in the development of this deposit. The cyanide waste tailings from the mill were impounded in an area that was developed by modifying an existing lake basin. The use of a pre-existing basin meant that dam failure was less likely than in a man-made basin. To compensate for the infilling of the lake, Richmont Mines developed additional habitat for fish, including construction of a fish ladder, as required under provisions of the federal Fisheries Act. Regular monitoring of water quality was carried out by a company throughout the lifetime of the mill.

The success of the Nugget Pond mill, combined with its minimal environmental impact, has meant that its life has exceeded that of the Nugget Pond deposit. After the gold at Nugget Pond was extracted the mine closed in 2004, but the mill continued to be used to process gold ore from the Hammerdown Mine on the southern Baie Verte Peninsula. The mill may process ore from additional mine sites in the future.

"Red water" is the local name for the reddish discolouration of Wabush Lake. It is caused by the tailings from the iron ore mine. Since mining operations began in 1962, the Iron Ore Company of Canada (IOC) has dumped its tailings into a

designated portion of the lake in compliance with provincial regulations. The suspended particles have increased the turbidity of the downstream waters, affected the ecology, and reduced the social and recreational value of the lake. In 1999, IOC began assessing options for tailings management in order to comply with the new *Metal Mining Effluent Regulations* (MMER). At the same time, IOC made a commitment to restore the ecological and recreational values of Wabush Lake and eliminate the red water.

Flocculation is a process in which solids suspended in water, such as tailings, clump together to form flakes or flocs that, in the case of iron ore tailings, settle to the bottom. When this takes place in a large body of water, such as Wabush Lake, it can reduce turbidity and make the water clearer and more natural in appearance.

The project involves rehabilitation of tailings accumulated over forty years and disposal of tailings expected over the next fifty years of mine operation. The resulting pile of tailings would cover thirty square kilometres.

The preferred solution, agreed to by all stakeholders during the public and third party consultations, was to consolidate tailings effluent to a single point discharge within a fifteen kilometre-long rock filled dike. This structure would isolate the tailings from the rest of the lake and serve as a kind of filter to allow the tailings to settle within the dike instead of in the lake.

In 2002, in an effort to further reduce the environmental impact of the tailings, IOC proposed next to modify the in-lake tailings by using three short dike sections in the north end of the lake to confine the tailings there. Further refinements and negotiations led to an alternative proposal that involves the flocculation of tailings that would see them confined in a naturally-occurring deep trench within Wabush Lake. According to the company, a four month full-scale flocculation trial in 2004 demonstrated "significant improvements to lake water quality, removing the suspended colloidal material that produced the red hue".

Figure 12.26: Canada Geese *(Branta Canadensis)* taking advantage of tailings reclamation at IOC. This new habitat will benefit American black ducks *(Anas rubripes)*, common terns *(Sterna hirundo hirundo)*, shorebirds, fish, and many other wildlife and plant species. *Photo courtesy Iron Ore Company of Canada*

As of 2007, the company was negotiating with the federal government, but still did not have approval for this revised tailings management program as the preferred way to ensure the long-term sustainability of the Wabush Lake ecosystem.

As part of their program, IOC maintains that its goal is to restore the ecological and recreational aspects of Wabush Lake. Their biodiversity stewardship program involves partners from the Eastern Habitat Joint Venture and the North American Waterfowl Management Plan. The program will see the introduction of a range of wildlife habitats to the beach. The plan is to create a series of wetlands between the tailings beach and the edge of the lake, as well as to landscape the uplands, shorelines, and wetlands with native plants. The biodiversity program should result in a self-sustaining ecosystem that will attract native birds and animals to the rehabilitated site.

Development of any mine in Newfoundland and Labrador requires a comprehensive plan for long-term containment of tailings and site rehabilitation. Iron ore mining in western Labrador produces huge volumes of tailings. Extensive efforts are being made to stabilise the surface of the tailings by re-vegetation. Testing at Wabush Lake has produced encouraging results. Within two years, grasses and shrubs on the tailings began to thrive. This attracted birds and animals. In the first wetland, aquatic vegetation has taken root and is starting to colonize.

Real-time water quality monitoring, where continuous measurements of some water characteristics are taken, is a new, innovative approach to monitoring mining sites. In 2007, IOC began real time monitoring of Wabush Lake. The real-time monitoring at Voisey's Bay is a first in Canada.

MINING: OCCUPATIONAL HEALTH AND SAFETY

All heavy industrial operations pose risk to workers' health. Mining is no exception. Strict health and safety codes, that are rigorously enforced, can help reduce the number of miners injured or killed in the course of mining operations. The improved mining safety record in Canada indicates that this approach protects workers.

Underground coal mines, because of the dust and gas hazards, the nature of the sedimentary rocks surrounding the coal, and the tendency to construct relatively small tunnels following the coal seams, are more susceptible to collapse than are underground metal mines. Galleries and tunnels in underground mines can fail as a result of earthquakes, blasting operations, explosions caused by coal dust build-up, or the collapse of roofs. These mining disasters receive substantial publicity in the news media. Miners and companies alike are aware of the risks and attempt to reduce the possibilities of accidents. Safety procedures and governmental regulations have steadily improved throughout the past fifty years, partially in response to each collapse or tragedy.


Coal dust, methane lethal duo

Tragedy in Nova Scotia

At 5:18 A.M. on May 9, 1992, there was a powerful explosion in the Westray coal mine, in Plymouth, Nova Scotia. All twenty six miners in the tunnels that morning were killed. The explosion was so strong it blew the top off the mine entrance, more than 1.6 km above, and blew away steel roof supports throughout the mine. In the nearby towns, windows shattered and houses shook.

It has been known for centuries that highly flammable methane-rich gases are trapped in most coal seams. The coal seam mined at Westray was known to have particularly high concentrations of this gas. Any digging or drilling activity that disturbs the coal seam releases quantities of methane. In an open-pit mine with lots of fresh air, that release is not a problem. But in a confined underground shaft, like the Westray mine, methane mixed with air can be extremely dangerous.

Westray mine never re-opened.

In Newfoundland and Labrador, the health of miners at the underground fluorspar mine in St. Lawrence was once a major concern. The initial problems appeared in the 1930s when the large amount of dust produced by drilling caused silicosis in the miners. Silica dust progressively scarred miners' lungs, making breathing difficult. The silica was produced from drilling the granite rock that held the fluorspar deposits and not from mining the fluorspar itself. Improvements in drilling methods and a greater awareness of the importance of reducing dust in the mine led to considerable improvements in working conditions by the 1960s until the mine closed in 1999.

Figure 12.27: St. Lawrence miners in 1961. *Photo courtesy Town of St. Lawrence*

The mine also contained radioactive radon gas from decaying radioactive minerals in the granite host rock. In addition to its presence in the air, radon gas also entered the mine in groundwater. So people working in the mine breathed concentrated amounts of radon gas and were exposed to high levels of radiation. The result was high rates of lung cancer. When this was recognized, improved ventilation and air monitoring was introduced, but the damage was done and many miners had already been afflicted. It is hard to estimate the direct effects of silicosis and radon gas on the mine workers because of the common incidence of other diseases, especially tuberculosis. It is estimated that more that 250 miners died as a result of their employment in the mine.

Open-pit mines do not pose the problems of tunnel collapse or explosions of confined dust concentrations. Collapse of quarry or gravel pit walls can be prevented by following proper procedures during excavation such as limiting the height of the wall by creating steps or terraces and by ensuring that walls are not cut at excessively steep angles. The Government of Newfoundland and Labrador regularly conducts inspections of gravel pits and quarries to ensure that proper procedures are followed. Blasting operations are also regulated in attempts to prevent accidents.

Figure 12.28: An example of open-pit mining following proper procedures for mine operation.

MINING AND THE NEW ATTITUDE OF ENVIRONMENTAL STEWARDSHIP

Attitudes toward the environment have changed over time. Practices that were acceptable in the past, and which have left environmental damage on the landscape, are not acceptable today in industries such as mining.

Figure 12.29: Torngait Ujaganniavingit Corporation quarry. *Photo courtesy Department of Natural Resources*

The mining industry in Canada has undergone many changes since the 1960s in response to environmental concerns. These changes include advances in health and safety, **environmental assessments** prior to the start of operations, more focused efforts to minimize environmental damage during operation, monitoring of changes during the life of the mine, and clean-up (decommissioning) after the mine ceases to produce.

In a sustainable society, all development to meet the needs of the present must be carried out in such a way that Earth's ability to meet the needs of the future is not compromised. Environmental assessments are a planning tool used by federal and provincial governments to anticipate adverse environmental effects caused by a project or development and to provide plans to eliminate or minimize those effects. This allows governments to help sustain the environment while promoting development.

The Newfoundland and Labrador *Environmental Protection Act* states that the purpose of environmental assessment is to "protect the environment and quality of life of the people of the province and facilitate the wise management of the natural resources of the province". The environmental assessment process is meant to *ensure* that projects proceed in a manner that is informed by sensitivity to the environmental impact of the project and a desire to minimize that impact.

Under the legislation governing environmental assessments, environment is defined in the broadest possible way to include not only wildlife and vegetation, but also landscape, sediment, and soil. Historical and cultural resources, such as archaeological sites and places important to the local residents and communities, must also be discussed within the environmental assessment. Furthermore, the people of the region where the proposed activity is located are also considered as part of the environment. The social and economic impacts on their communities, on their culture and recreation, and on their present way of life must be considered in the environmental assessment.

An environmental assessment document gives a description of the proposed project, a description of the existing environment, including baseline environmental conditions and sensitive or valued ecosystem components, and the anticipated effects of the project on the environment. The environmental assessment document states whether or not the project will have any significant negative impacts on the environment and, if so, identifies mitigation measures or alternatives.

Environmental Assessment Legislation:

In Newfoundland and Labrador, the provincial Environmental Protection Act and federal Canadian Environmental Assessment Act outline which types of projects will undergo an environmental assessment. More detail on the provincial process can be found on the Department of Environment and Conservation's website.

An environmental assessment must be conducted regardless of where a proposed mine is located or how large or small it is intended to be. All of the costs involved with the environmental assessment are paid by the mining company. When the initial draft of the environmental assessment is prepared, it is subject to review and commentary from government agencies, community representatives, environmental groups, stakeholders, and the general public. All citizens are entitled to express their opinions. Changes and additions to the draft environmental assessment are frequently requested and any matters which remain unclear must be addressed by the proponent before the environmental assessment is accepted.

Many of these changes have been imposed by government regulation to prevent governments and companies from acting out of short-term interest. There is increasing recognition within the industry that mining companies must be responsible environmental citizens. It is also recognized that laws and regulations are needed to ensure appropriate actions are taken. Some proposed mine developments in Canada have been blocked by public concern and political action. Mining companies and governments need to gain and retain the confidence of the public by operating in a manner that is sensitive to local and environmental concerns.

CORE LABORATORY ACTIVITY

Simulating a Surface Mining Operation

Background

Today's economy depends on the exploitation of mineral resources despite the environmental damages this activity can cause. Mining involves the resource discovery, removal, and processing. In more modern times, it also means site cleanup and restoration.

Mining is an expensive undertaking and costs must be controlled—sometimes to the detriment of the environment. To prevent this damage to the environment, government regulation is required.

In this simulation, you and your partners will operate a simulated mine, and make day-to-day decisions on how to operate it, control costs, make a profit, and protect the environment. You will be given starting capital and some basic mining equipment. From there you must purchase additional equipment as needed.

Remember: this is not a contest. Your objective is to acquire wealth as represented by the ore you mine, not to defeat any other team. Good luck, good mining, and take good care of our Earth.

Materials

- Background sheet, data table, one mining site, probes, forceps (crane), one tray, peanuts, walnuts, beans, brushes (for cleaning), small cups (trucks).

Minerals

- You will be provided with a list of items which will represent various minerals.

Additional Charges

- As with any mining endeavor, there are various items you can purchase to improve the job you do. There are also various costs that any mine operator might have to pay. Your teacher will provide you with a list of these.

Procedure

- You will be divided into groups of four.
- Your teacher will provide you with a description of the procedure to be followed and a list of roles for group members to play.
- Your "mining day" will only last a few minutes so you will have to ensure everyone is on task.
- At the end of the time period, calculate your profits and losses. Return equipment as directed.

Analyze and Conclude

1. A summary of your work is required. It should describe in detail how much ore was found, costs to recover the ore, costs of remediation of the site, and any profit made. Include a sketch of your original site and list your company name.
2. Discuss the problems that your company encountered from the start.
3. In what way was this activity a realistic model of mining? Give examples. In what way was this activity not a realistic model of mining? Give examples.
4. As high-grade ore (ore with lots of minerals in it) is used up, what are some of the options that mining companies have?
5. Give at least one environmental impact with each of the following mining stages and suggest how these problems can be reduced:
    a. Exploration.
    b. Removal and storage of overburden.
    c. Removal of ore and processing of ore.
    d. Using the mineral to make a product.

6. On a scale of 1 to 10 (10 = extremely difficult), how difficult was this mine site to operate? Explain your answer. What were some of the problems encountered on your particular site? How did you get around them? Should this mine site have been worked?
7. Did you make a profit? How much?
8. What were some of the decisions that your company had to make?
9. What guidelines would you give to new "miners" prior to this laboratory simulation so that they would do less environmental harm?
10. If this was a wilderness site, what anthropogenic changes (changes caused by the influence of human beings on the environment) would be required before mining could commence?
11. What are some of the environmental concerns that the mining company needs to address in either the preparation of the site or its reclamation?
12. Based on your data sheet, graph your production (dollars recovered on the y axis and the individual round on the X axis.) Indicate highlights of the mining operation along the graph.
13. At what point was the mine most profitable? Was there ever a point where you would have just given up? Explain. Based on your graph, what were some good decisions? What were some mistakes?
14. Compare your simulation with those of others. How did your results compare to those of other groups? Why were there differences?

Mining Simulation Lab: Data Sheet

		Minerals Recovered				Costs		Profits
		With Shells		Shells Removed				
Day	Beans	Peanuts	Other	Peanuts	Other	Waste Dumped	Purchases	$$$$
1								
2								
Totals								

Adapted from *Surface Mining Simulation Lab*, The Environmental Literacy Council, 2002

CASE STUDY

Voisey's Bay Environmental Assessment

The Voisey's Bay Nickel Company (VBNC) mines nickel, together with copper and cobalt, in Northern Labrador, thirty five kilometres south of Nain and seventy nine kilometres north of Davis Inlet. The company plans to mine thirty two million tonnes of ore from the open pit and carry out more exploration in the area.

While stringent environmental assessment (EA) procedures apply to all industrial developments, the EA process surrounding the Voisey's Bay nickel development is not representative of a typical environmental review for a mining project—or any other industrial development for that matter. This project was a unique and in-depth case, with the EA largely driven by aboriginal interests and the value of the resource/socio-economic benefit to all Canadians.

The proponent, VBNC, hired numerous environmental scientists and technicians, along with biologists, archaeologists, geographers, geologists, anthropologists, sociologists, medical professionals, and residents of the surrounding communities to aid in preparing the EA. The consultation process involved working with communities throughout Labrador and Newfoundland communities as well because the anticipated FIFO (fly in, fly out) operation would have impacts far beyond the mine site.

Figure 12.30: Labrador's pristine environment.
Photo courtesy Department of Education

The investigations lasted for almost three years. This was then followed by a panel review process that involved public input and consultations and led to a panel report published in March 1999 (Griffiths, L., S. Metcalfe, L. Michael, C. Pelley and P. Usher. *Report on the Proposed Voisey's Bay Mine and Mill Project: Joint Environmental Assessment Panel Review.* Report submitted to Government of Canada, Government of Newfoundland and Labrador, Innu Nation, Labrador Inuit Association, Ottawa, 1999. [*www.ceaa.gc.ca/010/0001/0001/0011/0002/ contents_e.htm*]). This report was released more than six years before the first ore was mined and included the findings of all the EA investigations, as well as a summary of the environmental management plan developed by VBNC in response to the researchers' findings and community concerns.

The Government of Canada responded to the panel report in August of 1999. Then minister of Fisheries and Oceans, David Anderson, in a press release, stated, "The Government of Canada has concluded that the environmental effects of the mine-mill project will be acceptable, as long as appropriate mitigative measures are put in place. Appropriate monitoring and other follow-up programs will also have to be undertaken to ensure that these measures are being successfully implemented".

The EA process included consideration of the project in the context of sustainable development, resource stewardship, Innu and Inuit rights, and impact and benefit agreements for communities.

An Environmental Management Agreement was reached between the Governments of Canada and Newfoundland and Labrador, the Innu Nation and the Labrador Inuit Association in July, 2002 (*www.nr.gov.nl.ca/voiseys/pdf/envmanagement.pdf*). The EA process included consideration of the project in the context of sustainable development, resource stewardship, Innu and Inuit rights, and impact and benefit agreements for communities. It involved assessment of:

- air quality, including dust management and emission reduction;
- tailings and site water management;
- potential effects of contaminants in the environment;
- impacts on freshwater fish;
- impacts on marine fish and mammals (including polar bears);
- impacts of shipping, including ice-breaking (and including ring seals);
- impacts on terrestrial wildlife and birds;
- impacts on Innu and Inuit traditional land use and communities;
- economic impacts; and
- impacts on family and community life and public services.

The summary report also outlined the environmental management plan to be instituted by VBNC. This included issues of environmental co-management, decommissioning, reclamation, and rehabilitation plans upon cessation of mining, monitoring efforts, and procedures for incorporating traditional community knowledge in environmental assessments. The management plan includes policies, management decisions, technical designs, equipment selection, and detailed work procedures.

Analysis

1. Why is the Voisey's Bay environmental assessment unique?
2. How many years did it take to complete the environmental assessment?
3. The environmental assessment included consideration of four elements. What were they?

CAREERS IN THE MINING INDUSTRY

Environmental Scientists and Technicians in the Mining Industry

Environmental scientists and technicians are involved with all stages of mining. Environmental assessment investigations, which form the key first step, involve numerous branches of environmental study. Environmental indicators, such as types of vegetation, may indicate where resources can be found. Interpreting the indicators requires knowledge of environmental science. Issues surrounding health and safety, storage and disposal of waste products, and monitoring the impacts of emissions on the surrounding area, all require trained, environmentally-aware professionals. Decommissioning and reclamation of the hundreds of abandoned mines throughout Canada, and planning for the eventual decommissioning of the new mines operating today, also requires environmental professionals.

Figure 12.31:
Environmental Technician.
Photo courtesy Iron Ore Company of Canada

In less economically developed countries, environmental awareness is growing. Environmental professionals are seeing increasing opportunities for work outside Canada, assisting with the development of environmental standards and techniques, and working with people to help improve the environment associated with mining in their countries.

The mining industry has evolved in response to environmental concerns and it continues to change. You too can be involved with these developments in the role of Mining and the Environment.

CHECK your Understanding

1. What are mine tailings? What are some environmental problems associated with tailings disposal?
2. What is the preferred method of dealing with tailings disposal?
3. Contrast the tailings disposal techniques of the Rambler Mine and the Nugget Pond Gold Mill.
4. What is the purpose of the Occupational Health and Safety Guidelines for the mining sector?
5. Why is the consultation process of an Environmental Assessment so important?
6. What were some of the environmental parameters examined in the Voisey's Bay Environmental Assessment?

For Further Discussion and/or Research

7. Through research on the web, find out about one piece of exploration technology that has been specifically developed to reduce environmental impacts during mining exploration.
8. Decommissioned underground mines are sometimes used to store hazardous chemicals. Through research, find out how these mines are modified for this purpose and some of the technologies employed to ensure safe storage.

Role-playing Exercise

A mineral exploration company has been working near your community and has identified an economic mineral deposit that they wish to exploit. *

The questions that arise are:

- What will be the impact of this development?
- Can the economic and social benefits be balanced against the environmental concerns?
- Will the mine be profitable if all of the real costs and benefits are included?

The class will be divided into groups:

- mining company representatives;
- environmental professionals;
- members of the community; and
- municipal politicians.

As a representative of the mining company

- How will you convince the community to support mining development?
- What regulations will you have to comply with?
- How will your choice of mining methods be influenced by environmental considerations?

As a member of the community:

- What questions should you ask the mining company to assure yourself that the mine will proceed in an environmentally sensitive manner?
- How does the type of mine, and type of commodity being mined, affect your decision?
- Is it better to obtain essential metals from your community, with strict environmental standards, rather than from elsewhere in the world?

As an environmental professional:

- What questions should you ask the mining company to assure yourself that the mine will develop in an environmentally sensitive manner?
- How could you contribute to the environmental assessment process?
- How can you use your knowledge to help the other community members make a good decision?

As a politician or policy maker (who has authority over whether or not the development will proceed):

- Will your decision on development be influenced by the economic status of the community? Would you be willing to accept more environmental

impact in an area of high unemployment?

- How do you evaluate the quality of an environmental impact statement prepared by the company?
- How can you make sure that the mine will not only be left in a safe state on closure, but that the scars left on the environment will be reasonably removed?

At the end of the discussion, the class will vote on whether the mining project should proceed or not.

* *Your local community should be used, including any local issues (protected or significant areas, traditional land use, economic situation, local wildlife) that apply to your particular community.*

Because development of each type of deposit poses different environmental issues, we will specify a particular mineral deposit from the following list. Students should independently conduct some Internet research to find out a little about the particular material chosen for the exercise.

Platinum, underground mine, producing tailings and liquid waste.
Niobium, open-pit mine, producing tailings and liquid waste.
Lithium, open-pit mine, producing tailings.
Chromium, underground mine, producing tailings and liquid waste.
Vanadium, open-pit mine, producing tailings.

Summary

Without the wealth of the resources extracted from Earth through mining, our societies would have not reached the present levels of technological development. Mining is essential to future development and advancement. Much of the negativity towards the mining industry is a result of past practices and the legacies that they have left behind. Today we possess the technology and science to deal with the many environmental challenges faced in the mining sector. Mining companies now see that environmental concerns during the development, operation, and closure of a mine are included in the overall costs and not separate from them. With this is mind, and strengthened by legislation at all levels of government, the mining sector in this province will have a future if it works in harmony with the environment.

Unit 3: For Further Reading

Lundrigan, C.G. (1993). Applicability of silvicultural systems to forests of the Bonavista Peninsula. 27 pp.

Meades, W.J. (1986). Ph.D. Thesis. University of Connecticut.

Cornish, J. (n.d.). *Boreal forest fact sheet.* Retrieved March 18, 2009, from *http://www.cdli.ca/CITE/artsmarts/boreal_factsheets.PDF.*

Natural Resources Canada & Canadian Forest Service (n.d.). F*orest regions of Canada.* Retrieved March 18, 2009, from *http://ecosys.cfl.scf.rncan.gc.ca /images/classif/forest-reg2_e.pdf.*

Canadian Forestry Association (n.d.). *Forest regions.* Retrieved March 18, 2009, from *http://www.canadianforestry.com/html/forest/forest_regions_e.html.*

Department of Natural Resources, Forestry Services Branch, Government of Newfoundland and Labrador (2006). *2006 island wood supply analysis: public review.* Retrieved March 18, 2009, from *http://www.nr.gov.nl.ca /forestry/publications/2006islandwood.pdf.*

Department of Natural Resources, Forestry Services Branch, Government of Newfoundland and Labrador (n.d.). *Forest management history.* Retrieved March 18, 2009, from *http://www.nr.gov.nl.ca/forestry/ourforest/history.stm.*

Department of Natural Resources, Forestry Services Branch, Government of Newfoundland and Labrador (n.d.). *Forest types.* Retrieved March 18, 2009, from *http://www.nr.gov.nl.ca/forestry/ourforest/forest_types.stm.*

Department of Natural Resources, Geological Survey, Government of Newfoundland and Labrador (n.d.). *Geological maps.* Retrieved March 18, 2009, from *http://www.nr.gov.nl.ca/mines&en/geosurvey/maps/.*

Department of Environment and Conservation (2008). *Strategic plan 2008-2011*. Retrieved April 9, 2009, from *www.assembly.nl.ca/business/tabled/envirocon _strategic08-11.pdf*.