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2014

20th Anniversary

Sustainable Agriculture

2014

This Study Guide is to be used to help Envirothon teams prepare for the Ontario Envirothon Program.

FORESTS ONTARIO

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1.0 Sustainable Agriculture

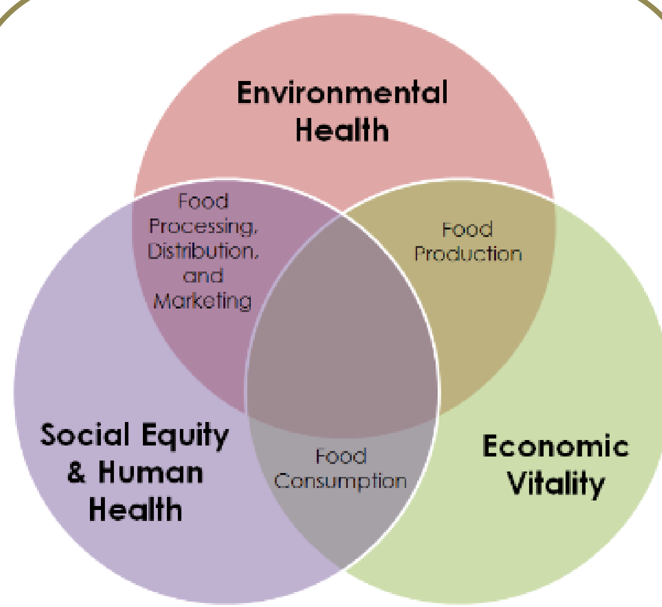
1.1 Introduction to Sustainable Agriculture

Agriculture- the practice of cultivating the soil, producing crops, and raising livestock- is vital for feeding the world's population. Conventional agricultural practices have been essential in meeting the needs of a growing world population by increasing the efficiencies and productivity of farmland.

However it is important to be aware of environmental costs that have arisen as a result of intensive agricultural practices. Negative environmental impacts include decreased water quality, soil quality, biodiversity and overall health of agricultural lands and surrounding environments. These impacts can be attributed to agricultural runoff, synthetic pesticide use, greenhouse gas emissions, biodiversity loss, and poor resource management, which can result from unsustainable agricultural practices. Degraded soils can reduce crop yields, and in some cases, lead to infertile agricultural land. This may pose a serious threat to global food security.

In a world where the population continues to rise, and where natural resources and **arable** soils are limited, there is a critical need for the agricultural industry to continue to shift toward more sustainable agricultural practices.

Sustainable agriculture can be achieved by generating enough food to meet our current population's needs without compromising the ability of future generations to meet their



Environmental Health – ensures that food production and procurement do not compromise the land, air, or water now or for future generations.
Economic Vitality –ensures that the people who are producing our food are able to earn a decent living wage doing so. This ensures that producers can continue to produce our food.
Human Health & Social Equity – ensures that particular importance is placed on community development and the health of the community, making sure that healthy foods are available economically and physically to the community and that people are able to access these foods in a dignified manner.

Figure 1. Pillars of sustainable agriculture as described by Food Security Network of Newfoundland and Labrador. (**Source:** FSN Newfoundland and Labrador, 2012)

needs. Therefore, sustainable farming practices must be implemented to minimize the negative impacts that agriculture can have on the environment. A variety of methods can be employed to reduce energy and chemical inputs, water usage, pest infestations, pollution, and soil degradation. Sustainable farming practices are those that produce large quantities of food without overexploiting resources and have minimal negative impacts on the environment. However, farming systems must also be socially and economically viable to be sustainable(Figure 1). Therefore, it is necessary to consider whether select environmentally sustainable farming practices can be afforded by farmers and allow them to maintain a good quality of life. Sustainable agriculture aims to maintain soil structure and fertility, protect water quality both on and off of the farm, maximize biodiversity and improve resource management. Transitioning certain farming practices to more sustainable ones can require huge upfront costs. For instance, different farming methods require different machinery, which will be expensive to acquire. This may be a deterrent for many individual farms and municipalities to transitioning to sustainable farming.

1.2 Agriculture in Canada

Agriculture is an extremely important industry in Canada. In 2011 there were over 205,000 farms operating in Canada, producing varieties of grains, vegetables, dairy products and meats (Figure 2). Total farm land in Canada at this time was 160.2 million acres (67.5 million ha). Approximately 60% of the farms in Canada are crop-based farms, with the remaining 40% being livestock-based farms. Cropland makes up 55% of farm land, followed by pastures, which make up for 31% of Canada's total farm land. In Ontario, top agri-food exports in 2008 were grains, vegetables and red meats. Top grain exports were corn, soybean and wheat. Given agriculture's important role in Canada's economy,

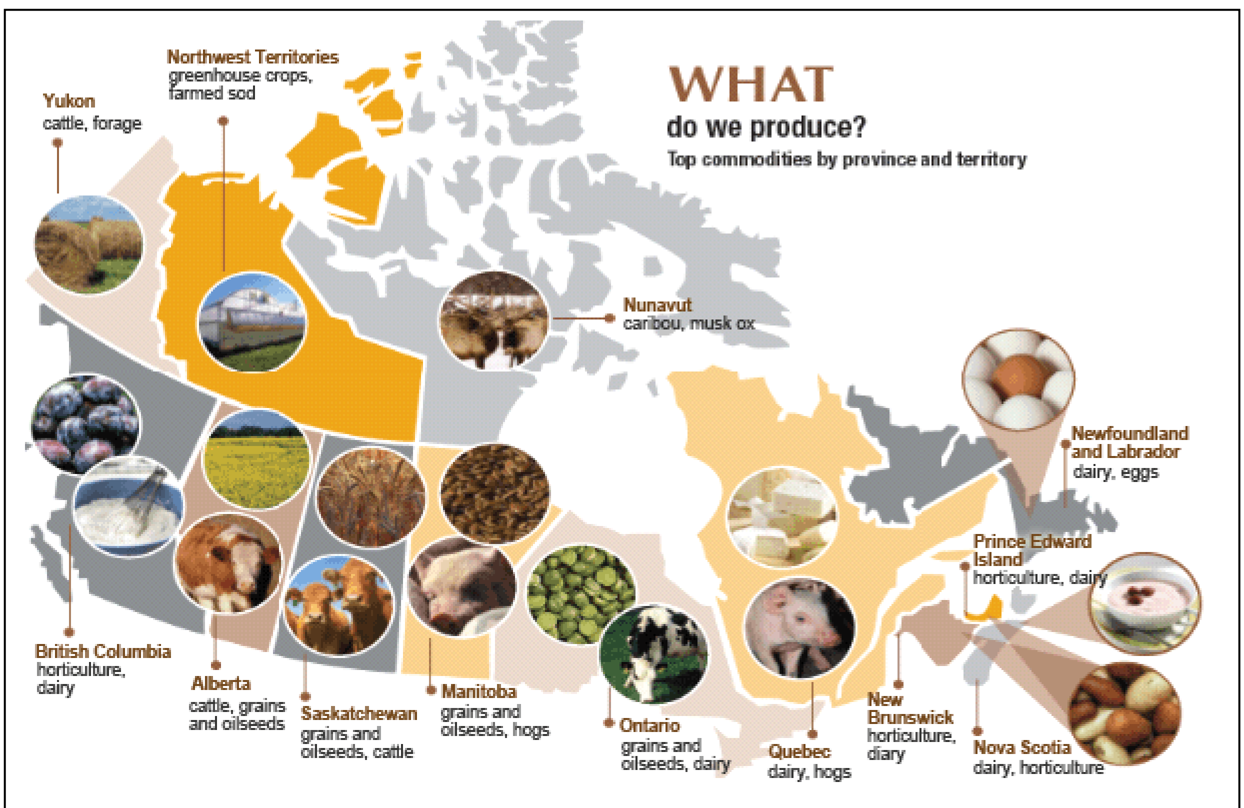


Figure 2. Top agricultural commodities in Canada by province and territory.
(**Source**: Agriculture and Agri-Food Canada, 2012)

sustainable farming practices need to be a driver to ensure future production.

1.2.1 Local Agriculture in Ontario

While there is no one official definition of local agriculture in terms of geographical distance, from farm to table the local food movement has gained signifigent traction in North America. Local food focuses on providing food sources that are grown in Ontario. Ontario is fortunate enough to have rich soils in many regions that are ideal for growing crops. The agricultural sector in Ontario alone produces more than 200 commodities, supports 740,000 jobs and generates 34 billion dollars.

In late 2013 the Legislative Assembly of Ontario passed Bill 36, also known as the Local Food Act. The Act is intended to increase access and use to local food as well as improve the public's knowledge of the benefits of local food.

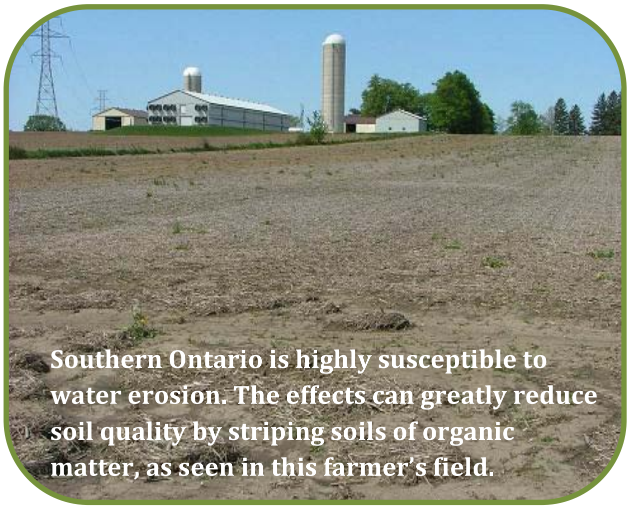
1.3 Conventional Agriculture

Conventional agriculture, also know as industrial agriculture, is a form of modern farming that refers to industrialized production of crops. It has increased productivity and efficiency, helping to meet the increased demand on food production worldwide. Conventional agriculture varies from farm to farm, however they share many of the following characteristics (http://www.nal.usda.gov/afsic/pubs/terms/srb9902.shtml):

- Technological innovation
- Large-scale farms
- Single crops grown continuously over many seasons
- Use of pesticides, fertilizers and high energy inputs

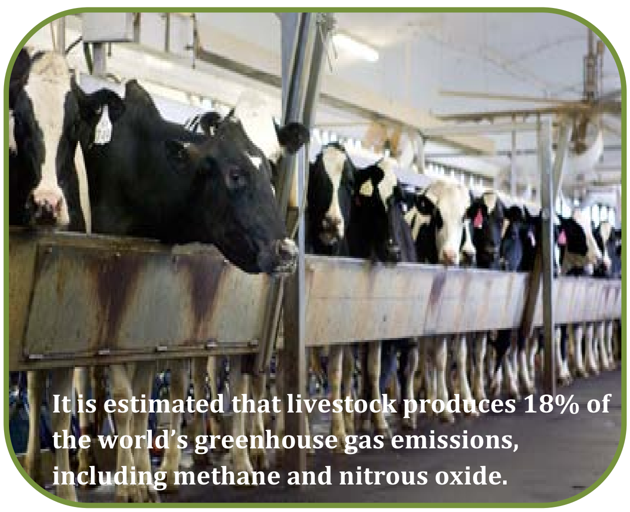
Conventional agriculture practices have been known to cause environmental issues and can be detrimental to a farm's productivity over time. Crop-based farms are typically **monoculture** fields, and rely on heavy machinery, fossil fuels and chemicals to produce satisfactory crop yields. Common problems associated with conventional farming techniques include:

- **Eutrophication** & water pollution by agricultural runoff (fertilizers, sediments and pesticides)
- **Soil erosion** by water, wind and overproduction
- High water and energy consumption
- Ethical issues surrounding **factory farming** (livestock disease, hormone use, animal cruelty)
- Wildlife and human exposure to toxic chemicals and pathogens– pesticides, synthetic chemicals and livestock waste



(**Photo:**Source: Agriculture and Agri-Food Canada, 2012)

(**Photo:**Source: Wikipedia, 2013)



(**Photo:**Source: Sun News Network, 2013)

(**Photo:**Source: flickr, 2013)

1.4 Sustainable Agriculture: Best Management Practices

The impacts on the environment from conventional farming have highlighted the need for a shift towards a more sustainable farming practices. Farming practices are adaptive and change as new methods and science become available. The following are some examples of best management practices that can improve the sustainability of agriculture.

These **best management practices** can help to maintain the health of a farmer's crop and produce high quality yields, maintaining healthy ecosystem functioning. These practices can also prevent agricultural lands from being overused and eventually degraded. Listed below are several best management practices that can increase sustainability of farms throughout Canada.

1.4.1 Conservation Tillage

Conservation tillage has become a popular method for maintaining soil quality. Conventional tillage buries the majority of crop residue into the soil, leaving the soil bare. Conversely, conservation tillage entails minimal or zero tillage which retains most of the crop residue on the soil's surface and reduces soil disturbance. Due to the environmental benefits of conservation tillage, its use in Canada has risen over time (Figure 3). These benefits include reduced soil erosion and agricultural runoff. However, conservation tillage is not suitable for all crops.

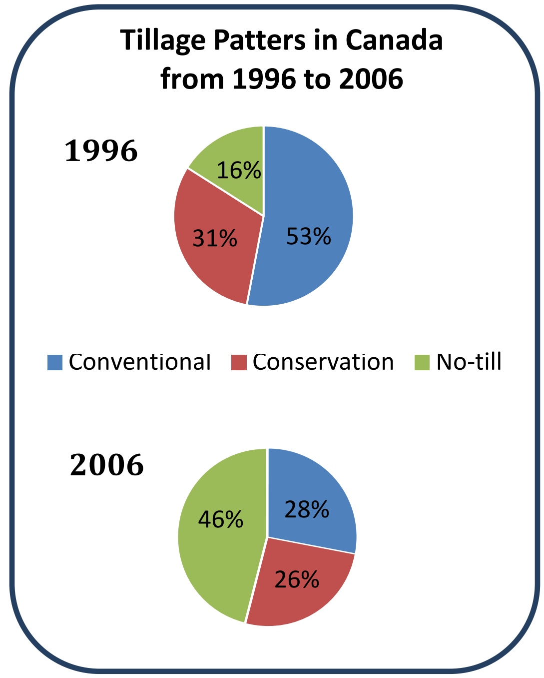


Figure 3. Changes in Tillage patterns in Canada from 1996-2006. (**Source**: Statistics Canada, Census of Agriculture, 1996-2006)

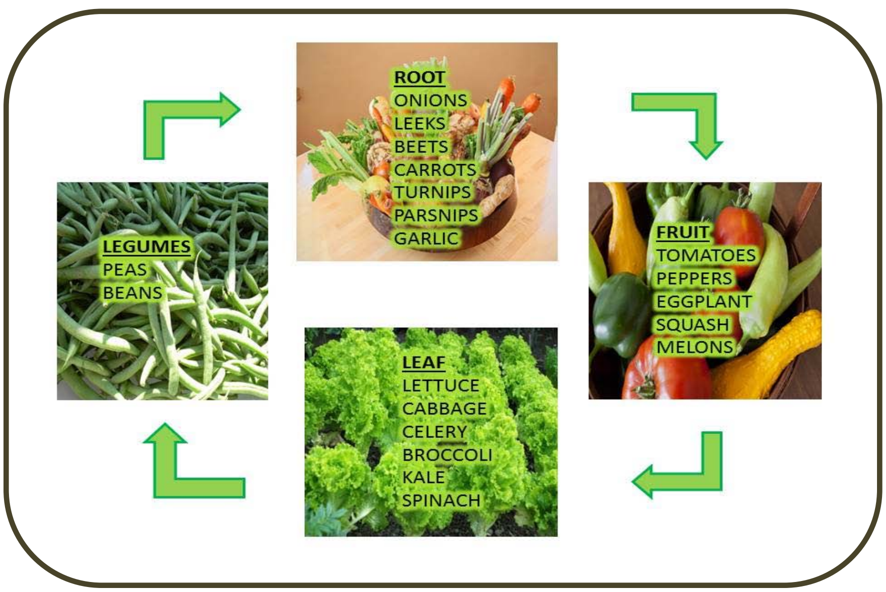


Figure 4. Successive plants in crop rotations should not come from the same plant family. Well planned crop rotations can help reduce weeds, diseases, and insects, and build soil fertility. (**Source:** Green Off the Grid, 2013)

1.4.2 Crop Rotation

Crop rotation is the practice of growing different crops in succession on the same piece of land. A well planned crop rotation can reduce soil degradation, improve soil structure, and conserve seasonal soil moisture, which can result in increased crop yields. Additional benefits include a decreased need for external inputs such as pesticides, and reduced greenhouse gas emissions. Crops in the same **family** should not be planted after one another in a crop rotation in order to prevent disease outbreaks. Crops from the same family should be separated by at least two years. For example, a crop rotation can consist of root vegetables, fruit, leafy vegetables, and legumes (Figure 4).

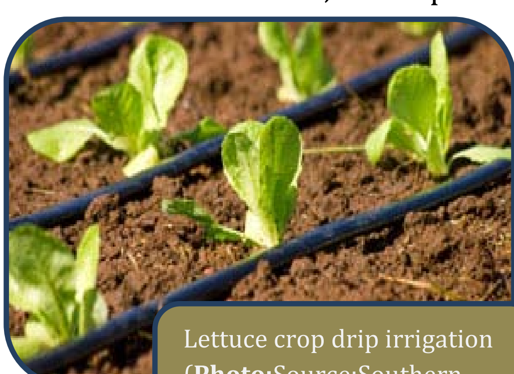
1.4.3 Cover Crops

It is believed that crop cover mixtures create “more natural cover”, such as this common cover crop mixture of rye, peas, and oilseed radish. (**Photo**: Source:Ministry of Agriculture and Food, 2012)

Cover crops are non-cash crops that are used in farming systems to protect soil quality and improve soil productivity. Cover crops can be planted in a pure stand, or mixed in with other crops, including the cash crop, for varying lengths of time. Cover crops provide a number of benefits that contribute towards healthier soils and increased crop productivity, including:

i. *Erosion control:* Soil erosion by wind and water can be reduced by cover crops.
ii. *Increased organic matter:* cover crops may be used as a ‘green manure’ and be incorporated into the soil and enhance soil biological activity or physical characteristics.
iii. *Nutrient retention:* nutrients that may be lost due to leaching can be conserved by cover crops
iv. *Pest suppression:* Proliferation of pests, disease, and weeds can be reduced with the presence of cover crops.
v. *Increased biodiversity:* Cover crops can provide habitats for a variety of wildlife, including pollinators.

Despite the benefits associated with cover crops, they can be detrimental to cash crops if they alter soil conditions and nutrient availability in such a way that cash crop productivity is inhibited. Thus, it is important to ensure that cover crops are selected appropriately for specific farm sites.



Lettuce crop drip irrigation (**Photo:**Source:Southern Drip Irrigation Ltd., 2012)

1.4.4 Drip Irrigation

Drip irrigation is a method of water application, where the water is applied directly to the root zone of theplant. There is an increasing interest in this method for the following benefits drip irrigation has over conventionalsprinkler systems:

i. *Improved water efficiency & conservation:*
Drip irrigation is only applied to the root, which eliminates evaporation from the leaves and stems. In addition, drip irrigation uses much less water, which reduces the amount of agricultural runoff.

ii. *Reduced pest & weed growth:* Applying water directly to root zones reduces weed germination. In addition, an absence of wet foliage makes it more difficult for pests to thrive.

iii.*Improved soil conditions*: Drip irrigation maintains desirable soil moisture conditions which increases plant growth and resilience.

Switching from conventional sprinklers to drip irrigation will reduce a farm's consumption of fresh water, making it more sustainable. The farm will also have reduced costs from the reduction in water use and increased crop productivity.

1.4.5 Agroforestry

Agroforestry is a farming method that incorporates trees and shrubs into agricultural landscapes. Agroforestry practices vary from region to region due to the vast differences in climate, soils, and socioeconomic factors found across North America, however they can contribute to protecting biodiversity, soil, water, and air quality in agricultural landscapes. In Canada and the United States, agriculture is dominated by monoculture crop systems which can be unsustainable for a variety of reasons. The inclusion of trees and shrubs in farming systems can mitigate the negative impacts of traditional monoculture crops including:

Incorporating trees and shrubs into agricultural landscapes is important for preserving environmental quality. (**Photo**:Source:Natural Resources Conservation Service, 2013)

i. *Agricultural runoff:* Trees and shrubs can act as sediment traps and riparian buffers, thereby reducing the infiltration of pesticides, nutrients, and fertilizers into water systems.

ii. *Soil degradation*: Studies have shown that microbial populations are more diverse when trees are incorporated into the landscape, which can help maintain soil quality.
iii. *Soil erosion*: Trees and shrubs are commonly used as windbreaks. Windbreaks protect soils from wind erosion and protect crops from wind damage.
iv. *Low biodiversity levels*: Trees and shrubs can provide food and shelter for wildlife species, including pollinators, thereby increasing biodiversity in the landscape. Diverse wildlife populations can help to reduce pests and the need for pesticides.

There are 800 species of bees native to Canada, most of which live in the ground. Ground-nesting bees improve soil texture, and mix soil nutrients. (**Photo:** Source:David Suzuki Foundation, 2013)

1.4.6 Pollinator Habitat Enhancements

The significant decline of insect pollinator populations, such as honey bees, bumble bees, and butterflies, poses a serious threat to general biodiversity, crop production and global food security. Causes of pollinator population declines include habitat loss, degradation and fragmentation, as well as parasites, disease and widespread use of pesticides. Habitat loss is the largest contributor to pollinator decline through human activity.

Suitable habitats can be incorporated into farm landscapes by way of field margins, such as non-crop buffer strips and hedgerows. Maintaining floral diversity and pollen abundance can sustain a variety of insect pollinators. Naturalizing habitats surrounding agricultural fields can also help increase pollinator populations and species diversity. Enhancing pollinator habitats provides additional benefits to sustaining healthy pollinator populations including:
(i) increased biodiversity
(ii) pest reductions
(iii) reduced pesticide use
(iv) improved crop productivity and quality
(v) alternative sources of income
(vi) improved environmental health and sustainability

There are thousands of pollinating insects in Canada including flies, bees, wasps and beetles. Hummingbirds also pollinate plants. (**Photo:**Source**:** Wikia,

1.5 Principles of Permaculture

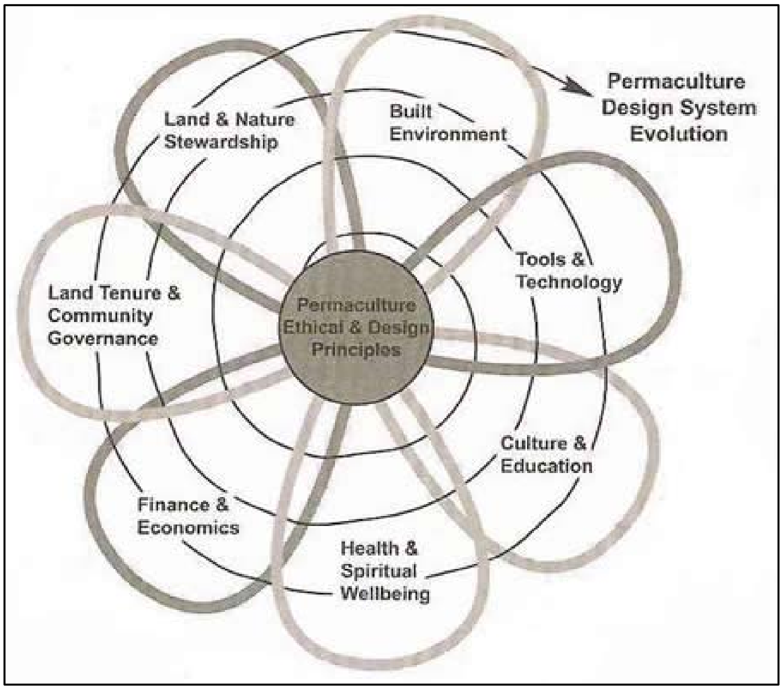


Figure 5. Elements of permaculture.
(**Source:** Permaculture Ottawa, 2013)

Permaculture is a community design system that outlines the necessary steps that communities can take to become more self-sufficient and sustainable. It is a collection of design principles, which are guided by ethics, that work together to achieve sustainability in all functions of the community (eg. agriculture practices, community infrastructure etc.). There are 12 core design principles in permaculture's design system. Each design principle is not mutually exclusive,rather, each work in conjunction with one another in the establishment of sustainable communities (Figure 5).

Permaculture principles outline how to design a community around the natural landscape rather than altering it, to better manage resources that are naturally present in the environment, and to reduce waste and consumption. However, sustainability can only be achieved if the entire community is willing to work towardsachieving it.

For a detailed description of each Permaculture Principle visit:
http://www.permacultureprinciples.com/

1.6 The Big Picture: Ecosystem Services Are Vital for Food Production

Agriculture is required to feed our growing population. Each farm requires a unique combination of best management practices to make the operation more sustainable. To meet the needs of future generations, farming operations should protect ecosystem services (Figure 6).

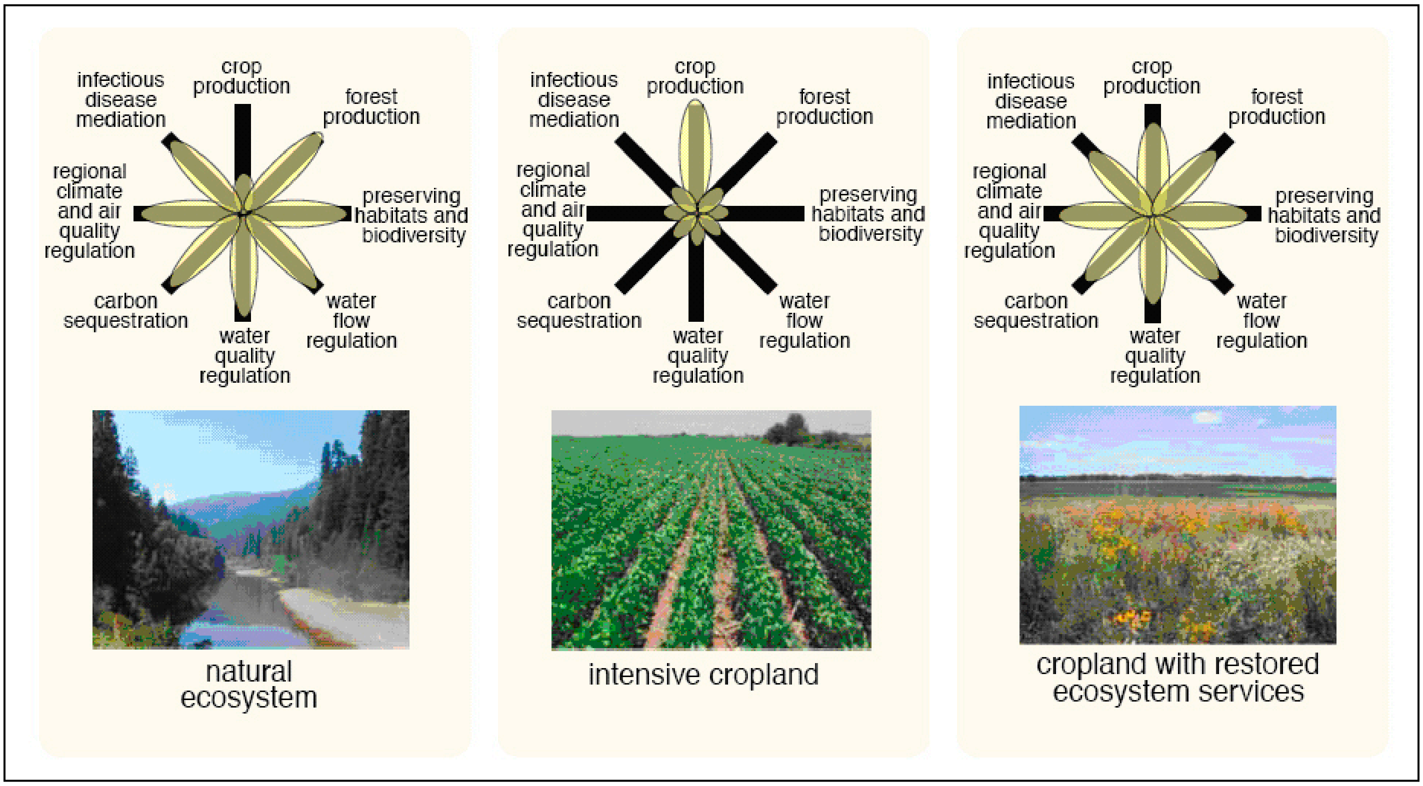


Figure 6. To maintain food security for future generations, ecosystem services must be maintained. (**Source:** Foley, J. A. et al., 2005).

1.7 Discussion Questions

1) What are some of the problems associated with conventional agriculture?
2) What is sustainable agriculture?
3) What are some key sustainable agriculture principles and practices?
4) Why aren't all farmers and/or municipalities making sustainable farming mandatory?

2.0 Aquatics

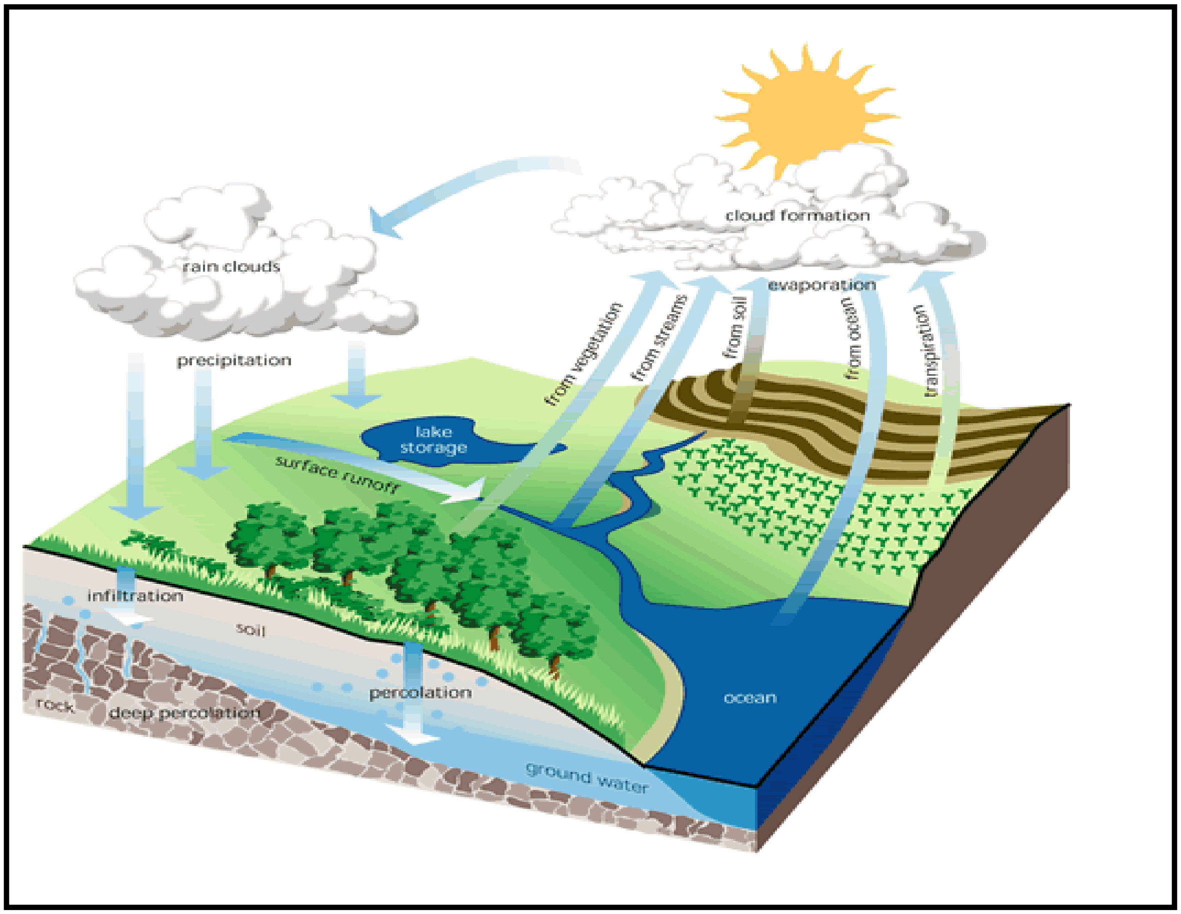
2.1 Introduction to Aquatics

Water is an essential part of our lives and is the basis for all life on our planet. It is important to understand that agricultural operations rely on water sources to operate and function. Water covers about 75% of our earth's surface and about 96% of this is found in the oceans. The remaining 4% is found in polar ice caps (2%), groundwater (1.8%), freshwater lakes and rivers (<0.020%) and in atmospheric vapour (<0.001%). It is important to note that of all the water on the earth, only 0.017% of this water is fresh and is available at the earth's surface for use or consumption by humans. Of all the available groundwater, only 0.62% is accessible within the top 200m of the surface of the earth. This availability of 0.62% is a global average as many desert areas may have 0% where other areas may have an exceptional amount with perhaps 3-5% of the global supply available to them. Approximately 25% of the earth's freshwater exist in the lakes and rivers of Canada. The Great Lakes alone contain 22,000 cubic kilometers of water and one of every three Canadians and one of every seven Americans rely on the Great Lakes for water. Of all the available freshwater utilized by humans, some of it has undesirable substances, is polluted or is considered unfit for human consumption. Since freshwater is a vital substance to all living organisms pressures are increasing on the human population to reduce contamination of water supplies and to find new sources.

(**Source**: Wikimedia, 2013)

2.2The Hydrological Cycle

The Ocean holds the largest pool of water on the planet which accounts for all but 4% of the total. Less than 1% of water is available for human use and as mentioned, some of this is tainted by human negligence. The most significant source of freshwater on our planet is in the form of precipitation and 87% of this is supplied from the Oceans as evaporation. Only about 7% of this precipitation reaches land transported as vapour in the form of clouds while the remaining 80% falls back into the oceans. The only other major source of freshwater is through the evaporation from lakes, rivers and land along with evapo-transpiration from plants which contribute about 13%. Water is constantly moving and changing forms and Figure 7 shows the movements and cycling of water and the major pathways and processes involved in the hydrological cycle. The hydrological cycle can be divided into gains and losses for a drainage basin (watershed) and for the body of water itself (lake basin).



(Figure 7. The hydrological cycle. **Source**: Iowa State University, 2013)

2.3The Importance of Wetlands

Wetlands are an extremely important feature of farm ecosystems acting as biological filters of water. These wetland systems are an essential component of a healthy agricultural ecosystem as they serve as essential resources for crop and animal production. Wetlands can be separated into four categories which are *marshes, swamps, bogs* and *fens.* Some characteristics of each wetland type are summarized below (Table 1).

Table 1. Characteristics of each wetland type.

Wetland Type	**Typical Emergent Plants**	**Floating/Submerged Macrophytes**	**pH**	**Water Source**	**Relative (Organic)**
Marsh	Cattails, rushes, reeds, sedges, grasses	Lilies, duck weed/pondweeds, milfoil, bladderwort	5.1-7.0	Stream(s), groundwater	High
Swamp	Trees (willows, cedars, cypress)	Water lilies, duckweed, water hyacinths, water lettuce	3.0-7.0	Stream(s), groundwater	Least
Bog	*Sphagnum*	*Sphagnum*	3.6-4.7	Precipitation	Highest
Fen	Mosses, sedges, grasses	Horsetails, cotton grass	5.1-7.6	Groundwater	High

Wetlands are biological filters acting as accumulators or sinks for silt and other suspended particles and soluble inorganic nutrients (e.g. nitrates and phosphates) and detoxify and filter many pesticides. Wetlands are also sources of dissolved and particulate organic matter and only wetlands that contain significant amounts of algae and periphyton can effectively remove nutrients. Wetlands have the ability to transform substances from inorganic nutrients to soluble and particulate organic compounds.

2.3.1 Marsh

Marshes are flooded areas which have an external source of water and contain emergent and submergent macrophytes. Emergent means plants which rise above the surface of the water and submergent are plants that live under the water. Most marshes are similar to lakes and small

(Source: EPA, 2012)

ponds, although in lakes macrophytes are replaced by phytoplankton algae as the primary producers of oxygen. Marshes also have algae (called *periphyton*) which contribute most of the food and oxygen for aquatic organisms. These algae can be found attached to stems and leaves of the macrophytes. As Autumn comes, most of the macrophytes die and fall to the bottom where they accumulate as organic matter and peat. Flooding may remove some of this organic matter but most will slowly decompose and accumulate. Because of this most marshes are considered to be characterized by anoxia (lack of oxygen) or very low levels of oxygen. Marshes are still able to support aquatic life but this is only possible with inputs of external sources of water such as overflows of streams and rivers or groundwater along with oxygen producing submergent macrophytes. Marshes are known to have relatively short hydraulic retention times which are usually 3-7 days during summer time.

2.3.2 Swamp


(Source: NHDFL, 2013)

Swamps may be defined as flooded areas which contain trees such as willows, maples, and cedars with the presence of macrophytes in open, sunlight areas. Swamps are similar to marshes in that they both have external sources of water although swamps do not accumulate significant amounts of peat and organic matter. Swamps are also characterized by anoxia and organisms are dependent on submergent macrophytes and flood waters in order to replenish oxygen supplies. Swamps are also characterized by having the presence of *ephemeral* and *vernal pools* which are areas of open water that are only present in the spring time. Many organisms which inhabit swamps have adapted to a brief aquatic stage. Hydraulic retention times of swamps are relatively short, from a few hours to 1-2 days during summer.

2.3.3 Bog


(**Source**: Wikimedia, 2013)

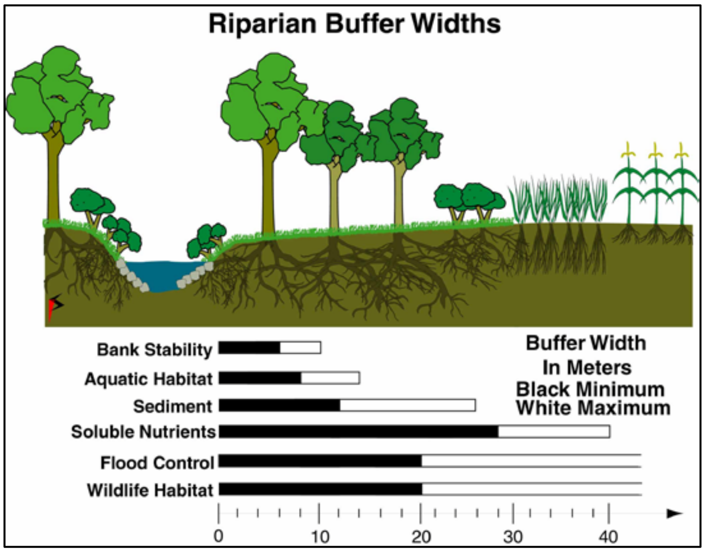
Bogs can be characterized by the dominance of *Sphagnum* moss and have an acidic pH (3.5-5) caused by *humic acids.* The majority of bogs consist entirely of living and dead mounds of *Sphagnum* with open water within the depressions. Considerable amounts of peat accumulate on the bottom which results in the characteristic rotten egg smell due to the production of hydrogen sulfide gas from sulphur bacteria. Bogs have thick organic ooze throughout the system. Bogs have much longer hydraulic resistance times than any other wetland type, generally ranging from two to four months.

2.3.4 Fen

Fens are known to have a higher pH (~5-8) than bogs and contain a diverse variety of aquatic vegetation. Some of the characteristics of bogs and marshes are shared such as having a mineral rich nutrient source although fens have a more neutral pH than bogs. Waters in fens are usually clear unlike the brown water of bogs. Common plant species encountered in fens are mosses, sedges and willows. Hydraulic residence times are similar to marshes (4-8 days)

(Source: NHDFL, 2013)

2.4 Riparian Zones



(Source: Iowa State University, 2013)

Riparian zones can usually be defined as areas of vegetation within 30m of the water's edge plus another 30m to allow for wind fallen trees and shrubs which totals 60m from the water's edge. These riparian zones act as buffer strips that absorb chemical and physical fluctuations to the environment. As an example they absorb excessive nutrients (phosphates and nitrates), pesticides and silty runoff before these substances have a chance to enter the water body. Some riparian zones are essential for regulating temperatures of streams as trees shade the water and prevent higher temperatures which would be lethal to biological components of the ecosystem. Plants are an important part of these zones as the roots also absorb nutrients and contaminants from runoff before entering the stream. As water flows through this vegetation, the speed at which it travels is slowed and suspended particles tend to settle. By doing this riparian zones also act as effective water clarifiers by removing suspended particles from water before it enters the lake or river.

2.5Case Study: Retiring Marginally Profitable Sections of Agricultural Fields in Ontario Economically Justified

Background

Maintaining agricultural land with the intention of producing consistent and stable yields can be challenging and has many variables. Some of these variables include differences in fertility, slope and water retention, sunlight distribution and soil texture. In most cases the unstable yields are found to be located on the perimeters of fields which are often adjacent to pooling water, marsh or forest of which all hold potential for environmental filters and wildlife habitat. This case study was conducted by Brethour et al of the George Morris Centre which is a national, independent, non-profit economic research institute focused exclusively on agriculture and food industry. The study took place in the year 2000 and involved data collected between 1995 and 2000. The study is intended to present an analysis of the variation of gross margins that occurs within typical agricultural fields in Ontario. Data was compiled by the Ontario Ministry of Agriculture and Food Rural Affairs (OMAFRA) for a source of yield data for respective producers.

Purpose

The purpose of the study was to assess the potential to retire marginally productive lands from agriculture in Ontario. The main objectives were to identify marginally productive land within a set of case studies, and to assess the opportunity cost for landowners and producers to set aside such land for the purpose of improving the environment and agricultural production. The land that was set aside could be used for wetland, filter strip, riparian zone or wildlife corridors depending on existing physical characteristics of the site.

(Source: USDA, 2011)

Methods

By reviewing previous research in Ontario, five sites were selected from thirteen possible producers which met requirements set forth by the study. Upon analysis of the data in the case study, land use of agriculture may be interpreted in the context of fixed costs of production. Geographic Information System (GIS) data was used to determine areas of agricultural land which may be marginally profitable. Yields of crop were determined at the end of the season and were then compared with all sections of crop land to gain an understanding of the productivity of the land in question.

Results

Determining the value of agricultural land is an aspect which is overlooked by many farmers in Ontario. This study demonstrates the potential for agricultural land to be retired from production if its gross margin is less than the fixed cost. Data analysis shows that three of the five farms in the study contained significant areas where gross margins were at or below fixed costs.

Benefits to farmers from having increased wildlife habitats in the form of buffer strips, wetlands, wildlife corridors or riparian zones have been recognized throughout the study and include:

- Elimination of the cost of growing on marginally productive land
- Aesthetic value of farmland and farm stewardship are increased
- Increase in biodiversity of insects, organisms and animals
- Larger water source for irrigation
- Improved nutrient cycling
- Increased stream bank stability (reduction of erosion)
- Increased nutrient uptake by plants
- Filtration of sediments
- Improved water quality
- Reduced flooding and drought
- Reduction of stream water temperature due to shading

2.6 Acid Rain Experiments: Making a Natural pH Indicator

In this experiment you will make your own pH indicator from red cabbage. Red cabbage contains a chemical that turns from its natural deep purple color to red in acids and blue in bases. Litmus paper, another natural pH indicator, also turns red in acids and blue in bases. The red cabbage pH indicator can be obtained by boiling the cabbage.

Materials

- sliced red cabbage
- stainless steel or enamel pan or microwave casserole dish
- 1 quart water
- stove, microwave, or hotplate
- white vinegar
- ammonia or baking soda
- clear, non-cola beverage (eg. 7up or Sprite)
- 3 glass cups (preferably clear)
- measuring spoons
- 3 clean teaspoons for stirring
- measuring cup (1/4 cup)
- notebook and pencil

Instructions

- Boil cabbage in a covered pan for 30 minutes or microwave for 10 minutes. (Do not let the water boil away.)
- Let cool before removing the cabbage.
- Pour about 1/4 cup of cabbage juice into each cup.
- Add 1/2 teaspoon ammonia or baking soda to one cup and stir with a clean spoon.
- Add 1/2 teaspoon vinegar to second cup, stir with a clean spoon.
- Add about 1 teaspoon clear non-cola to the last cup and stir with a clean spoon.
- After answering the first two questions for this experiment, pour the contents of the vinegar cup into the ammonia cup.

Discussion Questions

1. **What color change took place when you added vinegar to the cabbage juice? Why?** The vinegar and cabbage juice mixture should change from deep purple to

red, indicating that vinegar is an acid.

2. **Did the ammonia turn the cabbage juice pH indicator red or blue? Why?** The ammonia and cabbage juice mixture should change from deep purple to blue, because ammonia, like baking soda, is a base, which reacts chemically with the pH indicator, turning it blue.

3. **What happens to the color if you pour the contents of the vinegar cup into the ammonia cup?**
   You should find that the acid and base are neutralized, changing the color from blue or red to purple, which is the original, neutral color of the cabbage juice

4. **If you were to gradually add vinegar to the cup containing the baking soda (or ammonia) and cabbage juice, what do you think would happen to the color of the indicator? Try it, stirring constantly.**
   As you add more vinegar, the acid level increases and the color becomes red.

5. **Is the non-cola soft drink acidic or basic?**
   It is acidic and turns the cabbage juice pH indicator red.

Related Experiment: Neutralizing Acids or Bases Using a Garden Soil pH Tester Kit

Pour 1/4 teaspoon of the contents of the vinegar cup into the test container, and add 1/4 teaspoon of the test solution. Seal the top of the test container with your finger, shake once or twice, or stir if necessary, and compare with the color chart. Then pour about 1/4 teaspoon of the contents of the ammonia cup into the test container. Mix it and compare with the color chart. What happens to the pH? What would happen if you added more of the ammonia mixture? (For answers: see questions 3 and 4.)

3.0 Soils

3.1 Introduction to Soils

Depending on the context, the word soil may have many different meanings. A widely used definition of soil is: the material that plants grow in, and which provides them with physical support and nutrients.

3.2 Components of Soil

Soil is a mixture of weathered (ground up and chemically changed) rock and organic matter (living and dead plant material, manure, etc.). This mixture is not solid, but contains many holes or pores. These holes will contain air or water, depending upon the type of soil and the weather. In clay soils after rain many of the holes are full of water, but in sandy soils, the water drains away quickly leaving most holes full of air.

3.3 Soil Formation

Within your local area there are many different types of soil. These differences arise because of the variety of landforms and climatic conditions. Soil interacts with its environment. For example, soils often vary because of the way water flows over and through the soil. Water flowing over the soil surface removes soil material from the top of the slope, transports it downslope and deposits it at the bottom of the slope. Due to this movement soils at the bottom of the slope are usually deeper than soils at the top of the slope. Water flows downhill, so soils at the bottom of the slope may also be wetter than up slope soils. The differences between soils along a slope can be seen if you dig soil pits at the top, middle and bottom of a slope. The wetter soils will have grey or yellowish colours, whereas soils further upslope may have brown colours.

3.4 Soil Colour

Soil colour provides useful information about soils. The colour is partly derived from the rock particles which make up the soil, but it also reflects changes that have taken place in the soil since its formation. The dominant red/brown colour of soil is due to the presence of minerals containing iron. When these minerals are exposed to water and air the iron oxidizes and forms a reddish colour, just as iron objects go rusty if they are not protected from air and water. If there is too much water and too little air, the dominant colours will not be brown but greys and yellowish greys. Soils which are waterlogged for part of the year are called gleys. Dark brown/black colours in soil usually indicate the presence of organic matter which is material derived from plants or animals, e.g. dead leaves, stubble, manure, sewage, slurry, rotting vegetation. When organic matter is added to the soil it is decomposed by microorganisms until eventually its original form is lost, and all that remains is a soft, dark brown, crumbly material which is called humus. In some soils the rock material from which they are derived has a dominant influence on the soil colour. For example, shallow soils developed on chalky or limestone material are often greyish white in colour below the surface layers.

3.5 Soil Texture

Soils are made up of four components: minerals, air, water, and organic matter. In most soils minerals represent around 45% of the total volume, water and air about 25% each, and organic matter from 2% to 5%. The mineral portion consists of three distinct particle sizes classified as sand, silt or clay. Sand is the largest size particle that can be considered soil. Sand is largely the mineral quartz, though other minerals are also present. Since quartz contains no plant nutrients, sand is the lowest contributor to soil fertility of the three soil particle sizes. Furthermore, sand cannot hold nutrients–they leach out easily with rainfall. That is why sandy soils are not as productive as loams and need to be spoon-fed fertilizer. Silt particles are much smaller than sand but, like sand, silt is mostly quartz.

The smallest of all the soil particles is clay. Clays are quite different from sand or silt and contain appreciable amounts of plant nutrients. Clay has a large surface area resulting from the plate-like shape of the individual particles. The textural designation of a soil is derived from the relative portions of sand, silt, and clay. A sandy loam, for example, has much more sand and much less clay than does a clay loam. A loam soil is a mixture of sand, silt and clay. Most soils are some type of loam. They are more accurately described by the prefaces each loam, such as: sandy loam or clay loam. The texture designations are found in Table 2 below.

Table 2. Soil Textures

	Texture Designations
Coarse Textured	Sand
	Loamy sand
	Sandy loam
↓	Fine sandy loam
	Loam
	Silty loam
	Silt
	Silty clay loam
	Clay loam
Fine Textured	Clay

3.6 Soil Classification

Soil properties and horizon development vary with depth, and are dependent on climate, organisms, topographic position, parent material and time. Soil classification is a method of organizing information so that it can be recalled systematically and communicated. The Canadian System of Soil Classification defines taxa based on observable and measurable soil properties that reflect the process of soil genesis and environmental factors. In forest ecosystems, soil classification assists scientists and practitioners in assessing land productivity, suitability of a site for a particular tree species and the potential impact of management practices on soil physical and chemical properties. Soil classification information facilitates improved land management decisions that maintain soil productivity and therefore preserve forest sustainability and long-term ecosystem health.

A soil monolith is a vertical section of the soil profile that is extracted from the field and mounted for display and teaching purposes. The natural appearance of the soil, including its horizonation, colour and structure is preserved using this technique.

Below are soil monoliths, derived from Great Lakes Forestry Centre in Sault Ste. Marie, Ontario, Canada (Figures 10-19). The profiles sampled are located at experimental sites that are being studied as part of the research of the Soil and Water Sustainability Project and are representative of soil types found in north-eastern Ontario.

The action and interaction of soil-forming processes as influences by soil-forming factors gives rise to distinct soil horizons, these layers are assigned distinctive alphabetic symbols as a form of shorthand for their characteristics. The horizon description system begins by splitting soil horizons into two distinct groups: organic and mineral horizons. Organic horizons are those that contain 17% or more organic carbon; mineral horizons have less than 17% organic carbon.

The major symbols used in describing mineral soil layers in Canada are shown below (Table 3). The assignment of mineral soil layers to each horizon is done by comparing the properties of the horizons in the field to a list of distinctive characteristics, called diagnostic properties.

Table 3. Basic description of mineral soil horizons in the Canadian System of Soil Classification

Master Horizon	Suffixes	Basic Description
A		Mineral horizon formed at or near the soil surface
	Ah	Accumulation of soil organic matter (SOM)
	Ae	Removal of clay, SOM, iron, or aluminum
B		Horizon formed by accumulation of material removed from Ae horizon or by alteration of the parent material
	Bh	Accumulation of SOM
	Bf	Accumulation of iron and/or aluminum
	Bss	Presence of slickensides (smooth clay coating caused by stress in high clay soils)
	Bv	Vertic horizon caused by turbation (mixing) of material in high clay soils
	Bt	Accumulation of clay
	Bn	Strong soil structure and sodium accumulation
	Bg	Mottling and gleying due to water saturation
	Bm	Slight colour or structural changes from the parent material
C	C	Horizon with little evidence of pedogenic activity
	Cca	Accumulation of Ca and Mg carbonates
	Cs	Accumulation of soluble salts
	Ck	Presence of original Ca and Mg carbonates
	Css	Presence of slickensides
	Cg	Mottling and gleying due to water saturation
R		Consolidated bedrock
W		Water layer

Table 4. Basic description of organic soil horizons as classified in the Canadian System of Soil

Master Horizon	Suffixes	Basic Description
O		An organic horizon developed mainly from bog vegetation; it is more commonly called peat. These materials are usually water saturated.
	Of	Composed of fibrous materials of readily recognizable origin
	Om	Organic materials in an intermediate (or mesic) stage of decomposition; some have a recognizable form, but the remainder is highly decomposed
	Oh	Organic material which is highly decomposed (in a humic state); the origin of the material is unrecognizable
L, F, H		Organic materials that occur from the accumulation of leaves, twigs and woody materials and which overlies a mineral soil; commonly found in well to imperfectly drained forest environments.
	L	Leaf litter, readily recognizable
	F	Partially decomposed leaf and twig material (folic material)
	H	Humic material; decomposed organic materials with no original structures evident

Soil Types and Sustainable Agriculture

It is important to utilize the most correct soil types depending on how the land is being used. If the soil doesn't suit how the land is being used it will result in degradation. By properly complementing the soil with the proper management the land can be used without putting environmental sustainability into jeopardy.

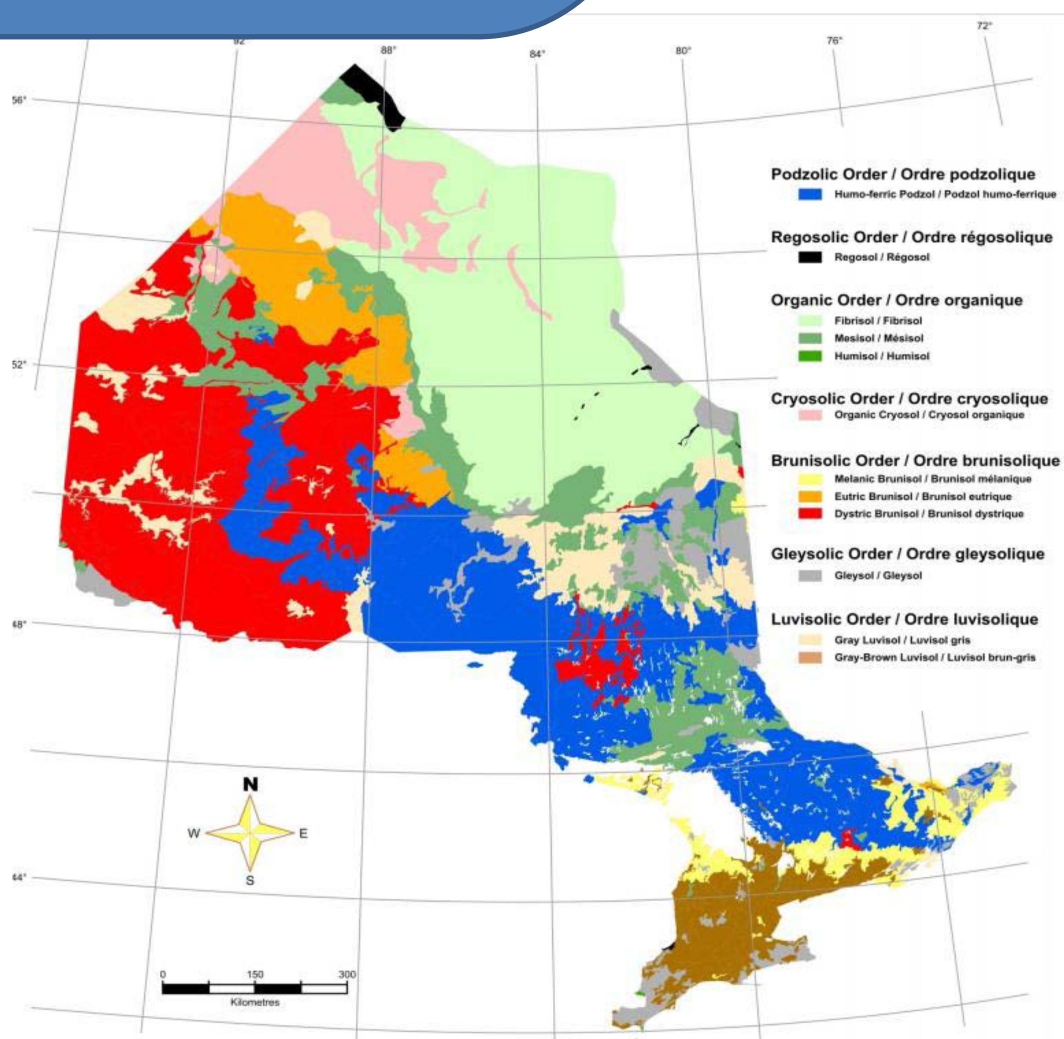


Figure 9. Soil Classification in Ontario (Source: NR Canada, 2013)

Soil by the Numbers: There are 70,000 different types of soil in the U.S.

Dystric brunisol

80-year-old fire-origin jack pine stand on silty loam material over glacio-fluvial sand and gravel near Chapleau. This soil has a strongly developed Ae horizon, however the low accumulation of iron (Fe) and aluminum (Al) in the B horizon excludes it from the Podzolic Order.

Diagnostic properties of Brunisolic Order - sufficient horizon development to exclude from Regosolic, but lacking in specific horizons associated with other soil orders.

(Source: NR Canada, 2013)

Figure 10. Dystric brunisol profile (Source: NR Canada, 2013)

Importance of Soil Organisms: Earthworm burrows enhance water infiltration and soil aeration. Earthworm tunneling can increase the rate of water entry into the ground 4 to 10 times higher than fields that lack worm tunnels.

Soil by the Numbers: 1 Tablespoon of soil has more organisms in it than there are people on earth

Humo-ferric podzol

6-year-old jack pine planted after a forest fire on a medium textured material over glacio-fluvial sand deposit near Foleyet. Organic layers are absent in this profile due to the forest fire. This well-drained profile has a strongly developed B horizon with bright colours.

Diagnostic properties of Podzolic Order - B horizons with accumulation of humified organic matter combined with aluminum (Al) and iron (Fe).

(Source: NR Canada, 2013)

Importance of Soil Organisms: Worms eat dead plant material left on top of the soil and redistribute the organic matter and nutrients throughout the topsoil layer. Nutrient-rich organic compounds line the tunnels that may remain in place for years if not disturbed

Soil by the Numbers: 500 - Minimum years it takes to form one inch of topsoil

Mesisol

Uneven-aged black spruce stand on peat over fine to medium textured glaciolacustrine deposits near Cochrane. This profile illustrates a gradient of decomposition from undecomposed sphagnum moss at the surface to strongly decomposed peat deeper in the profile.

Diagnostic properties of Organic Order – horizons composed largely of organic materials frequently saturated with water for prolonged periods.

Importance of Soil Organisms:Sowbugs, millipedes, centipedes, slugs, snails and springtail are primarydecomposers. Their role is to eat and shred the large particles of plant and animal residues.

Soil by the Numbers: 0.01% of the earth's water held in soil

Gray luvisol

Boreal mixed wood spruce/aspen stand on soil formed in lacustrine sediments near Cochrane. This profile has developed in clay parent material on an imperfectly drained site.

Diagnostic properties of Luvisolic Order - light coloured eluvial horizons and B horizons with accumulation of silicate clays.

(Source: NR Canada, 2013)

Importance of Soil Organisms: One of the major benefits bacteria provide for plants is in helping them take up nutrients. Some species release nitrogen, sulfur, phosphorus, and trace elements from organic matter. Others break down soil minerals and release potassium, phosphorus, magnesium, calcium and iron. Still other species make and release natural plant growth hormones, which stimulate root growth.

Figure 13. Gray luvisol forest (Source: NR Canada, 2013)

Soil by the Numbers: 1,400,000 Earthworms that can be found in an acre of cropland

Soil Organisms: Sowbugs, millipedes, centipedes, slugs, snails and springtail are primary decomposers. Their role is to eat and shred the large particles of plant and animal residues.

Humo-ferric podzol

70-year-old fire-origin jack pine stand on a sandy ridge overglacio-fluvial sand and gravel near Wharncliffe. This profile represents a weakly developed podzol, lacking aneluviated A horizon.

Diagnostic properties of Podzolic Order -B horizons with accumulation of humified organic matter combined with aluminum (Al) and iron (Fe).

(Source: NR Canada, 2013)

Importance of Soil Organisms: Most numerous among soil organisms are the bacteria; every gram of soil contains at least a million of these tiny one-celled organisms.

Figure 14. Humo-ferric profile (Source:NR Canada, 2013)

Soil by the Numbers: 75% of the earth's crust is composed of silica and oxygen.

Figure 15. Ferro-humic profile (Source: NR Canada, 2013)

Ferro-humic podzol

Uneven-aged mature sugar maple-yellow birch forest on a stony, silty-loam ablation till over compacted sandy basal till at the Turkey Lakes Watershed north of Sault Ste. Marie. The fine textures in the upper portion of this podzol have resulted in the accumulation of organic matter from decayed plants and animals. Various sized, angular rocks throughout the profile are characteristic of glacial till deposits.

Diagnostic properties of Podzolic Order -B horizons with accumulation of humified organic matter combined with aluminum (Al) and iron (Fe).

(Source: NR Canada, 2013)

Importance of Soil Organisms:Fungi aid plants by breaking down organic matter or by releasing nutrients from soil minerals. Fungi are generally early to colonize larger pieces of organic matter and begin the decomposition process

Soil by the Numbers: 20,000 Pounds of total living matter in the top six inches of an acre of soil

Regosol

50-year-old red pine plantation on a deep deltaic deposit of sand at the Kirkwood Forest,Thessalon. This profile has developed after reforestation of plowed agricultural fields that were abandoned in the early 1900s.

Diagnostic properties of Regosolic Order -weak horizon development due to youthfulness of parent material. Regosolicsoil horizons do not meet requirements of other soil orders diagnostic horizons.

(Source: NR Canada, 2013)

Figure 16. Regosol profile (Source: NR Canada, 2013)

Importance of Soil Organisms:Different species of algae also live in the upper half-inch of the soil. Algae improve soil structure by producing slimy substances that glue soil together into water-

Soil by the Numbers: 10 Percent of the world's carbon dioxide emissions stored in soil

Figure 17. Orthic humic gleysol profile (Source: NR Canada, 2013)

Orthic humic gleysol

15-year-old black spruce planted after clearcut harvest on soil formed in lacustrine sediments near Cochrane. This profile has a pronounced band of colour with low chroma (known as gleying) indicative of water table influence and reducing conditions.

Diagnostic properties of Gleysolic Order - redox features indicative of periodic of prolonged saturation with water and reducing conditions.

(Source: NR Canada, 2013)

Importance of Soil Organisms:Protozoa are free-living microorganisms that crawl or swim in the water between soil particles. By eating and digesting bacteria, protozoa speed up the cycling of nitrogen from the bacteria, making it more available to plants.

Soil by the Numbers: 11,000 gallons of water is required by soil to produce one bushel of wheat

Humo-ferric podzol

95-year-old fire-origin upland black spruce stand on a stone free glaciolacustrine deposit with 40 % clay content within the B horizon. This soil was sampled from the Esker Lakes Research Area, 100 km north of Cochrane. The forest floor at the site is dominated by feathermoss and slow decomposition rates have resulted in deep organic horizons up to 20 cm thick.

Diagnostic properties of Podzolic Order - B horizons with accumulation of humified organic matter combined with Al and Fe.

(Source: NR Canada, 2013)

Figure 18. Humo-ferric podzol profile (Source: NR Canada, 2013)

Important of Soil Organisms: Roots can also release various substances into the soil that stimulate soil microbes. These substances serve as food for select organisms. Some scientists and practitioners theorize that plants use this means to stimulate the specific population of microorganisms capable of releasing or otherwise

Soil by the Numbers: 4,000 Gallons of water soil needs to produce one bushel of corn

Sombric brunisol

Mixed hardwood stand with conifer species also present including white pine, white spruce and balsam fir near Basswood Lake north of Thessalon. This profile has developed in an acidic glacial till, has a thick Ah horizon and has developed mottles in the C horizon due to a seasonal high water table.

Diagnostic properties of Brunisolic Order - sufficient horizon development to exclude from Regosolic, but lacking in specific horizons associated with other soil orders.

Figure 19. Sombric brunisol profile (Source: NR Canada, 2013)

Importance of Soil Organisms:Beneath the surface litter layer, a rich complexity of soil organisms decompose plant residue and dead roots, then release their stored nutrients slowly over time. In fact, topsoil is the most biologically diverse part of the earth

3.7 Sustainable Soil Management

3.7.1 Sustainable Soil Management Principles:

- Soil livestock cycle nutrients and provide many other benefits.
- Organic matter is the food for the soil livestock herd.
- The soil shall be covered to protect it from erosion.
- Tillage speeds the decomposition of organic matter.
- Excess nitrogen speeds the decomposition of organic matter.
- Moldboard plowing speeds the decomposition of organic matter, destroys earthworm habitat, and increases erosion.
- To build soil organic matter, the production or addition of organic matter must exceed the decomposition of organic matter.
- Soil fertility levels need to be within acceptable ranges before starting a soil building program.

3.7.2 Techniques to Build Soil

3.7.2.1 Animal Manure

Manure is an excellent soil amendment, providing both organic matter and nutrients. Typical rates for dairy manure would be 10 to 30 tons per acre or 4,000 to 11,000 gallons of liquid for corn. At these rates the crop would get between 50 and 150 pounds of available nitrogen per acre. Additionally, lots of carbon would be added to the soil, resulting in no loss of soil organic matter. High crop residues grown from this manure application would also contribute organic matter.

3.7.2.2 Compost

Composting farm manure and other organic materials is an excellent way to stabilize their nutrient content. A significant portion of raw-manure nutrients are in unstable, soluble forms. Such unstable forms are more likely to run off if surface applied, or to leach if tilled into the soil. Therefore compost is not a good source of readily available plant nutrients like manures are. Compost releases its nutrients slowly, thereby minimizing losses. Quality compost contains more humus than its raw components because primary decomposition has occurred during the composting process. It also does not contribute the sticky gums and waxes that aggregate soil particles together as much as does raw manure because these substances are also released during the primary decomposition phase. Unlike manure, compost can be used at almost any rate without burning plants. In fact some greenhouse potting mixes contain 20 to 30% compost. Compost (like manure) should be analyzed by a laboratory to determine the nutrient value of a particular batch and insure its wise use.

3.7.2.3 Cover Crops and Green Manures

Many types of plants can be grown as cover crops. Some of the more common ones include: rye, buckwheat, hairy vetch, crimson clover, subterranean clover, red clover, sweet clover, cowpeas, millet, and forage sorghums. Each of these plants has advantages over the others and their area of adaptability. Cover crops can maintain or increase soil organic matter if they are allowed to grow long enough to produce high herbage. All too often, people get in a hurry and take out a good cover crop just a week or two before it has reached its full potential. Hairy vetch or crimson clover can yield up to 2.5 tons per acre if allowed to go to 25% bloom stage. A mixture of rye and hairy vetch can produce even more.

3.7.2.4 Reduce Tillage

While tillage has become common to many production systems, its effects on the soil can be counter-productive. Tillage smoothes the soil surface and reduces natural soil aggregation and earthworm channels. Porosity and water infiltration are decreased following most tillage operations. Plow pans may develop in many situations. Tilled soils have much higher erosion rates than soils left covered with crop residue.

Due to many problems associated with conventional tillage operations, acreage under reduced tillage systems is increasing on the North American landscape. Any tillage system that leaves in excess of 30% surface residue is considered a "conservation tillage" system by USDA (32). Conservation tillage includes no-till, zero till, ridge-till, zone till, and some variations of chisel plowing and disking. These conservation till strategies and techniques allow for establishing crops into the previous crop's residues, which are purposely left on the soil surface. The principal benefits of conservation tillage are the reduction of soil erosion and improved water retention in the soil, resulting in more drought resistance.

3.8 Case Studies

3.8.1 Columbia

When it comes to growing crops and protecting the environment, Pedro Herrera is on top of things – in more ways than one. The small-scale farmer lives in the upper reaches of southern Colombia's Andean hills, some 1,500m above sea level, in the province of Cauca. This is one of the country's poorest regions. He and his family are active participants in a bold, four year-old experiment to conserve natural resources in the local watershed and to help community members improve their standard of living.

The district where Herrera lives is aptly named 'Buenavista' (Good View). His earthen-floor home overlooks a vast gray-green landscape, which, though spectacular, bears many scars of deforestation and erosion. His fields lie at the head of a 7,000 hectare area drained by the Cabuyal River, which in turn feeds into the larger watershed of the Ovejas River. Water running down from Herrera's land eventually makes its way to the populous city of Cali, 100kms to the north.

With help from the Inter-Institutional Consortium for Sustainable Agriculture on Hillsides (CIPASLA), Herrera and other farmers have agreed to act as the first line of defense for the Cabuyal watershed. They fence off mountain springs, plant trees, and protect hillside soils from erosion. In return, CIPASLA provides research services, technical advice, training, and information about agricultural production, processing, marketing, land management, and community organization. They also arrange loans for small enterprises such as milk processing and marmalade making.

Pedro Herrera's farm is a showcase for the wide array of crops that can be grown on a small farm without causing a decline in its natural resources. He has set aside more than one-third of his land to protect five natural springs that feed the watershed. Yet his farm income has increased. The 10 hectares remaining in production provide enough both for his extended family of 15 and for the local market. Herrera's crops include beans, maize, coffee, sugarcane, cassava, sweet peas, and, his pride and joy, blackberries. His cows provide milk for his own table and for sale. He raises carp in a hillside pond.

3.8.2 The United States

For generations, American farmers have worked to protect and improve the land and the quality of rural life. Early farmers such as George Washington and Thomas Jefferson, seeing a need to change some standard agricultural practices, became leaders in adopting new farming methods. Washington was among the first of his generation to practice crop rotation, compost livestock waste and help pioneer the use of new planting methods. Jefferson remained a fervent advocate of testing new crops and varieties throughout his life, always seeking plants best suited to the land and people's needs. Washington and Jefferson's search for alternative methods that would improve agriculture, the land and the lives and health of the citizenry is emulated today by producers who farm with an eye toward sustainability. The approaches many of today's farmers and ranchers take as they grapple with these tough issues has come to be known as sustainable agriculture.

Each produce pick-up day, as the customers flood Carol Eichelberger and Jean Mills' community-supported agriculture (CSA) farm, the owners renew their commitment to this rapidly expanding form of cooperative farming. The enthusiasm of their customers partners of a sort who pay in advance for fresh produce harvested from spring through fall recharge the hard-working CSA partners.

"We love the whole CSA package," says Eichelberger, who opened the four-acre venture with Mills in 1989. While the women grow and harvest the produce, many of their customers volunteer to wash, weigh, bag and distribute, all the while learning more about how their food is produced and how buying locally helps create a sustainable food systemin their Alabama community. The involvement of the community in the farm gives them

more than vegetables and gives us energy we don't get just from growing.

The CSA concept premiered in the United States in the mid-1980s, uniting a non-farm public that craved great-tasting, locally grown fruit and vegetables with farmers who want a secure customer base. This new trend among small vegetable farms helps maintain profitability for growers, who sell fresh food often to specification directly to their neighbors in exchange for money up front and a local buyer's empathy for drought, floods or pest outbreaks. CSA's, most of which are organic, also are considered sustainable because they rejuvenate rural communities and can help bridge the widening gap between rural and urban America.

Located outside Tuscaloosa, Ala., Eichelberger and Mills' CSA draws a steady crowd of customers from the University of Alabama and the surrounding community. Eichelberger and Mills, who grow organically, provide a specialized market for customers who want organic produce as well as a greater variety than can be found in the average supermarket.

Eichelberger and Mills work hard to improve a soil that receives 57 inches of rain a year and bakes under the Alabama sun. "We tend to think locally when it comes to sustainability," Eichelberger says. "We have relatively poor soil, and we're trying to do what we can to build it up and preserve what we've got."

The first year, they left some walkways between the rows unplanted and bare. To avoid exposing the soil to the harsh southern conditions, the following year they planted white dutch clover as a living mulch between vegetable beds. The clover cover keeps the soil from compacting and washing away while providing habitat for beneficial insects. As part of a SARE producer grant, Eichelberger and Mills mow the clover and compost it with sawdust, straw, grass clippings and vegetable waste. They apply the compost, rich in nitrogen and organic matter, and hope to eliminate the need to buy fertilizer.

Discussion Questions

1)Describe (i) the types of agriculture being practiced in two of these case studies, and (ii) identify the principles that you think underlie these practices.
Many farmers around the world are working to protect and improve their land – just like the farmers in the case studies. While their cultures and socio-economic contexts may be different, they are united by a shared set of principles.

2) Review your summary of the case studies and make a list of principles that are shared by the farmers.

3)How useful might these principles be for farmers in your country? How would the principles need to be adapted to be more culturally appropriate?

4) How useful might these principles be for a family or community food garden in your neighbourhood? How would the principles need to be adapted to be more culturally appropriate?

3.9 Soil Activity

Educational Goals

- Demonstrate that less disturbed soils contain more “soil glue” and are held together better than more disturbed soils, when soils of the same type are compared.
- Demonstrate why it is important to protect soils from disturbance.
- Provide examples of situations where soils must be disturbed along with further investigation into actions that can be taken to protect soils when they are disturbed.

Background

Soil organisms increase in abundance and in the variety of species represented when soil is not disturbed. Fungi in particular make proteins, such as glomalin, that ooze into the soil and help glue soil particles together.When soil is heavily cultivated (tilled) or disturbed during construction, the surface layer (topsoil) is often drastically changed, buried, or removed. Change takes place when oxygen gets into the soil and provides energy for decomposers to convert dead organic matter to energy, carbon dioxide, and water. This reduces the amount of organic matter in the soil and the amount of glue that is available to hold soil together as aggregates. Soil habitat is destroyed and live soil creatures are reduced in number and/or variety, or they are eliminated. When the soil is not disturbed, more animals, plants, fungi, and microorganisms thrive in the soil. The amount of soil glue, such as glomalin, increases and the soil holds together better.

Explanation

(Source: USDA, 2012)

Soil from the surface layer of a lawn, an orchard, and a field that has not been disturbed or tilled for a couple of years, will hold together in a wire mesh basket when immersed in water. Often the soil clods will hold together so well that the water will evaporate before the soil falls apart. If any of the soil does fall through the wire mesh basket, it generally will be in the form of small soil aggregates, and the water will remain clear instead of becoming cloudy with loose soil particles.

Soil from a continuously tilled field, a construction site, or from several inches below the surface will generally fall apart (disperse) into individual soil particles when immersed in water. The loose soil will make the water cloudy, and when it settles it will form a layer of sediment in the bottom of the jar.

In addition to level of soil disturbance, two special cases exist that affect the results of this demonstration. If the soil is held together chemically it may not fall apart during this test. Sometimes soils with a high clay content are bound together chemically.

A second exception is exhibited by thick, dark soils. The mineral particles of these soils are held together by organic matter that was created decades or centuries ago. This recalcitrant organic matter is resistant to decomposition. If these soils are cultivated, the soil clods will fall apart very fast as sand-sized aggregates. The water will remain clear after the sand-sized aggregates settle to the bottom of the jar.

Examples of situations where soils must be disturbed include production of underground crops, such as potatoes and peanuts, and the construction of roads and houses. Planting cover crops and covering disturbed soils with mulch provides protection from raindrops and food for soil glue-producing organisms.

Materials & Preparation

√ 2 Wide-mouthed glass jars

√ 2 Pieces of ¼-inch wire mesh about 1½ x 6 inches

√ 2 Clods of soil, each about the size of an egg, from the top two inches of soil from two different areas.

Some examples of areas to sample are:

- lawns
- orchards
- pastures
- forests
- worn down paths
- construction sites
- farm fields that have been plowed (disturbed)
- farm fields that have not

Shape two wire mesh baskets to sit about 1½ inches below the rim of each jar

√ Fill each jar with water to within ½ inch of the top

√ Place soil clods from two different sources into the baskets and lower them gently into the jars

√ Observe the results

√ Compare samples from the same general area at the same depth to see how similarly they act.

√ Compare samples from the same area before and after disturbance (before and after tilling).

√ Compare moist samples to samples that have been dried. Does drying affect the results?

Further Investigations

√ Compare samples from the same soil at different depths.

(Source: USDA, 2012)

Discussion Questions

1. Did both soil samples react the same way? (Did the soil stay together or fall apart?)
2. Was the water clearer in one jar than the other?
3. Which soil is more apt to resist erosion during a rain storm?

4.0 Forests

4.1 Forests in Canada

Approximately 50% of Canada's landmass is covered by forests, which accounts for 10% of the world's forest cover. Ontario has approximately 71 million hectares of forest, which accounts for 17 % of Canada's forest, and 2% of the world's forest land.
Ontario is home to three of Canada's eight identified forest regions (Figure 20):

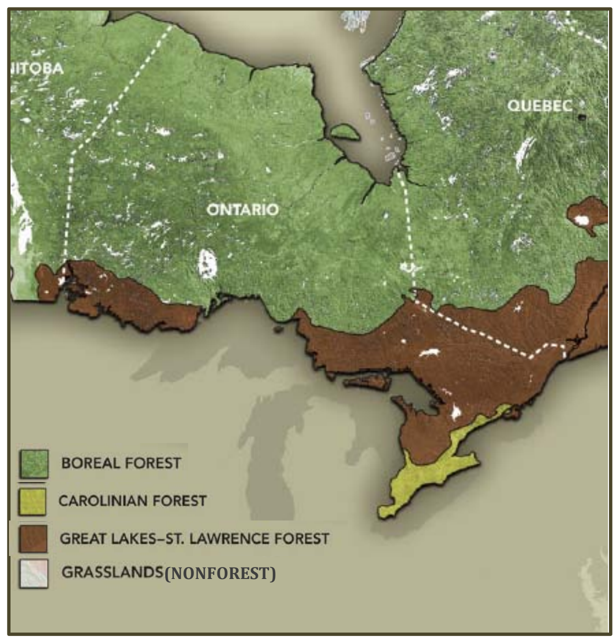


Figure 20. Map of Ontario's Forest Regions. (**Source**: Adapted from the Ministry of Natural Resources, 2013)

Boreal Forest

- The largest forested area in Canada, dominated by coniferous tree species, with a mix of deciduous species.
- Predominant tree species: white spruce, black spruce, balsam fir, jack pine, white birch, trembling aspen, tamarack, willow

Carolinian Forest

- Forest located in southwestern Ontario between Lakes Huron, Erie and Ontario. Dominated by deciduous tree species, with a few conifer species such as eastern red cedar and eastern white pine.
- Predominant tree species: beech, maple, black walnut, hickory, oak

Great Lakes/St. Lawrence Forest

- Forest extends inland from much of the Great Lakes and St, Lawrence River to southeastern Manitoba. This forest region is composed of a mix of coniferous and deciduous tree species
- Predominant tree species: red pine, eastern white pine, eastern hemlock, yellow birch, maple, oak

4.2 Forest ecosystems

A forest is a complex **ecosystem**, whereby trees are the dominant vegetation form. Interactions between all living things and the physical environment within the forest result in the large number of ecosystem services that people and wildlife have come to depend on, such as water filtration, air purification and nutrient cycling (Figure 21).

4.3 Important Forest Functions

In Canada, forests are an important for our natural heritage and our economy, given that they provide a multitude of **ecological goods and services** (Figure 22). They provide us with recreational opportunities such as hunting, hiking, camping, and wildlife observation. More importantly, forests perform ecological functions that support many wildlife species and enable Canadians to sustain healthy lives. It is important to note that these functions are extremely important to agriculture, as these ecological functions improve air, soil and water quality. Some of these functions have been listed in Table 5 below.

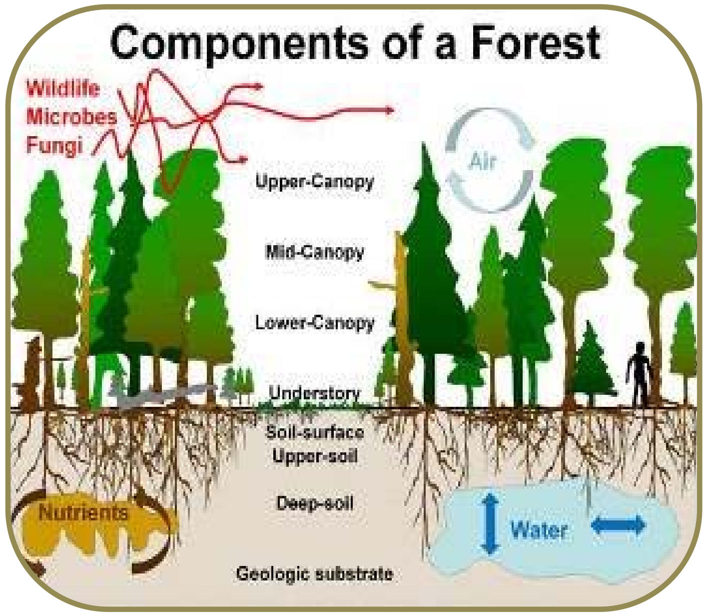


Figure 21. Forest ecosystems are dominated by trees, but are also made up of various microbes, plants and animals that interact with each other and their physical environment. These interactions result in ecosystem services such as nutrient cycling. (**Source:** Extension.org, 2013; **Diagram Credit:** Peter Kolb, University of Montana)

Table 5. Important ecological functions of forest ecosystems.

Function	Description
Soil Erosion Prevention	Through overhead crown cover and underground root structures, forests prevent soil erosion. Forests help maintain terrestrial stability.
Nutrient Cycling	Forests extract nutrients from soils for their use, and convert nutrients for use by other species.
Hydrological Cycling	Forests affect water quality and quantity. They reduce the amount of storm water that enters water systems; remove toxins, nutrients and sediments from runoff waters; regulate water temperature; provide suitable habitat for fish species; recharge groundwater systems; provide wetland habitats; provide food sources for aquatic and terrestrial species.

Function	Description
Flood and Erosion Control	Forests reduce flooding and erosion caused from increased runoff from paved surfaces.
Clean Air & Carbon Storage	Forests provide oxygen for use by other species and by humans. They reduce air pollution and greenhouse emissions by trapping atmospheric air pollutants and absorbing carbon from the atmosphere.
Wildlife Habitat	Forests are important components of watershed systems and contribute to ecosystem integrity, as many flora and fauna species are dependent on forests for habitat and food sources.

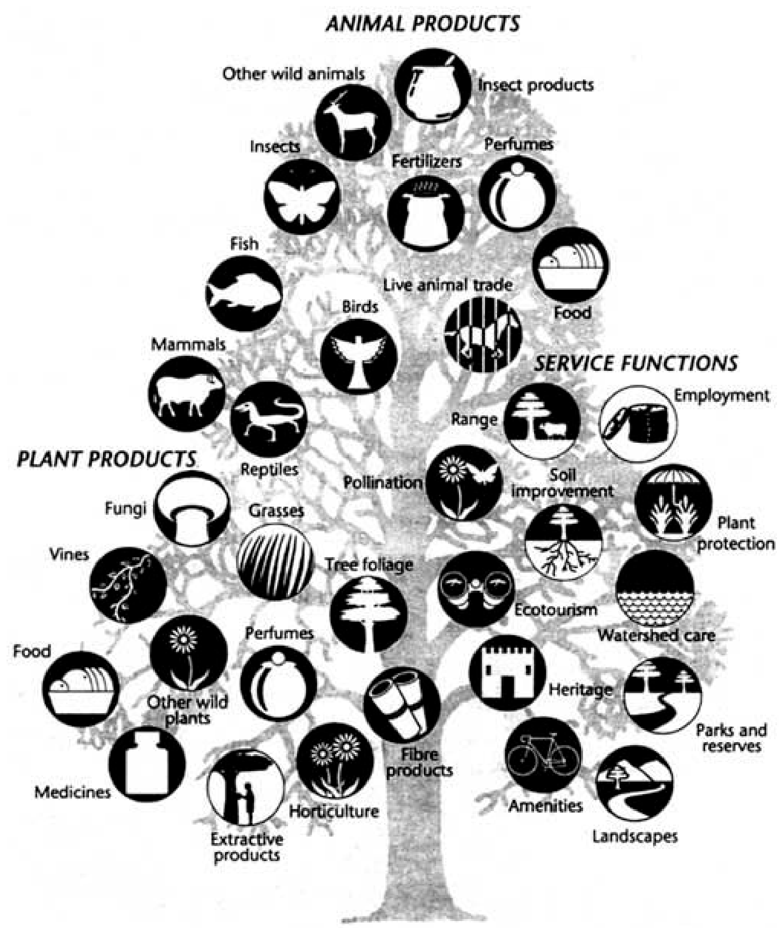


Figure 22. Forest ecosystems provide people with a multitude of ecological goods and services including food products, timber and water purification. Not only do these goods and services help sustain the human populations, they are extremely important to Canada's economy.
(**Source**: Food and Agriculture Organization of the United Nations, 2013)

4.4 Impacts of Agriculture on Forests

Agriculture is one of the principal drivers of deforestation. (**Photo:**Source: glogster.com, 2013)

Deforestation is the permanent removal of forest cover from an area, and using the land for other purposes. The principal drivers of deforestation are agriculture, industrial development, resource extraction and urban expansion. Worldwide, most deforestation occurs to accommodate for expanding agriculture, either to make room for livestock or to grow field crops. In Canada, the conversion from forest to agriculture is less frequent. In 2010, approximately 45,000 hectares were deforested in Canada, 43% of which was converted for agricultural purposes. However Canada's overall deforestation rate has been decreasing for the past 20 years.

With the conversion of forest cover to any other type of land use, ecosystem services that were once provided by forests are lost and environmental health is decreased. Several negative impacts of deforestation include:

4.4.1 Habitat Loss & Fragmentation

When forested land is converted into agricultural fields, the landscape becomes fragmented, as seen above. The fragmented forest patches are unable to support as many wildlife species and individuals as a larger continuous area of forest would be capable of doing. (**Photo:**Source: Google Maps, 2013)

Habitat loss is the leading cause of species extinction in Canada and across the globe. When habitat is lost, wildlife species are unable to find shelter and sources of food to survive. Habitat fragmentation reduces habitat patch size and can impact species living within the forest. Fewer species and individual animals can live in these smaller patches of forest, which disrupts the population dynamics and **food web** within the ecosystem (Figure 23). Any disruption of the forest ecosystem can have profound impacts on the overall health and functioning of the forest (eg. there will be fewer trees to provide clean air or there may be fewer predatory species to prevent herbivore populations from getting too large).

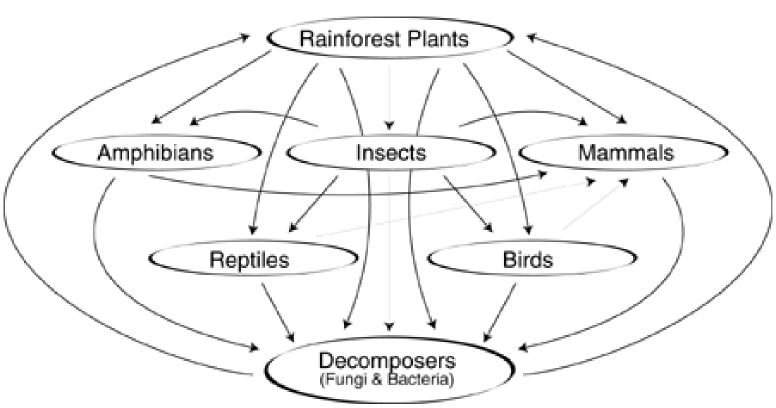


Figure 23. Balanced food webs are important in all ecosystems, as each species performs vital roles within the system. If certain species are removed from forest habitats (eg. due to habitat fragmentation) the food web will become unbalanced and ecosystem functions may become compromised. (**Note**: Figure 23 depicts'Rainforest Plants', but all forests have the same general food web structure) (**Source:** University of Tennessee, 2013)

4.4.2 Biodiversity Loss

When habitat loss or fragmentation occurs, it is almost certain that there will be a reduction in **biodiversity**. This is because wildlife is dependent on trees, shrubs and other vegetation in forest systems for shelter, food and water. When there is a decline or alteration in forest habitat, fewer species are able to survive. Populations can become **extirpated** from an area or species can become extinct. When wildlife populations decline, forest ecosystems also suffer, as wildlife species pollinate forest plants, spread seeds, decompose organic matter and keep food webs balanced.

Forest habitats are vital to the survival of many wildlife species, including this Barred Owl in Ontario. These owls build their nests in trees. (**Photo:** Source: Deviant Art, 2013)

4.4.3 Local Climate Change & Carbon Release

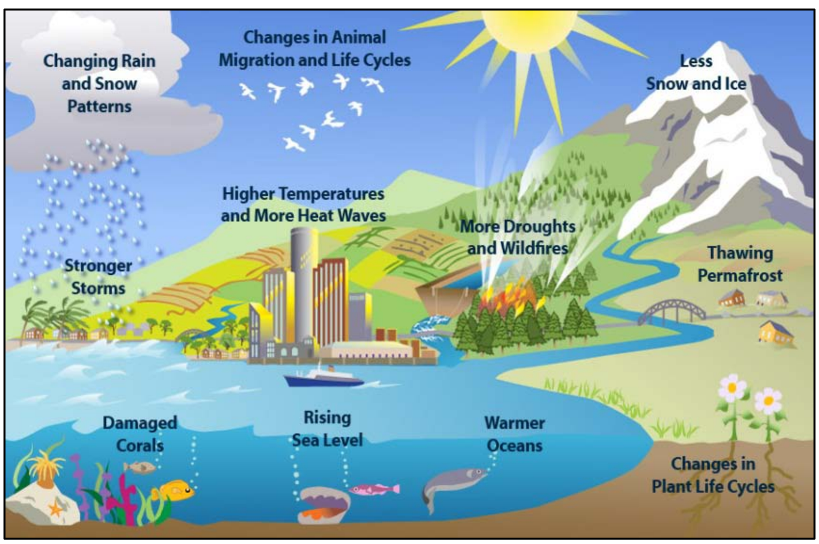


Figure 24. When trees are removed, various effects of climate change can become magnified. (**Source**: Environmental Protection Agency, 2012)

Forests are important components of the hydrological cycle and help produce rainfall. Forests absorb large amounts of water from the soil which gets released into the atmosphere and eventually returns to earth as precipitation. When trees are removed, rainfall is reduced. Trees also help regulate regional temperatures by providing shade and moisture. Without tree cover, regional temperatures increase. Changes in shade cover and regional precipitation will alter the flora and fauna species in the region and affect ecosystems. While clear cutting is a relevant and necessary forestry technique in some cases there are some concerns with their effect on the carbon cycle by disturbing forest soils and removing trees. This can result in the release of stored carbon and a reduction in carbon fixing which can accelerate the effects of **climate change**, including but not limited to, increased temperatures and extreme weather events such as floods and droughts (Figure 24).

4.5 How Forests Support Sustainable Agricultural Practices

Forest ecosystems provide countless services to wildlife and human populations by purifying water, cycling nutrients and providing essential habitats. These forest functions can also increase agricultural productivity if forest vegetation remains intact around or is added to farming operations. These functions have been listed below. Retaining forest cover increases the overall health of the environment and can preserve or improve the fertility of agricultural lands. In turn, crops can become more productive and less land may be needed to grow the same amount of food.

Windbreaks / Shelterbelts

(**Photo:** Source: Grand River Conservation Authority, 2012)

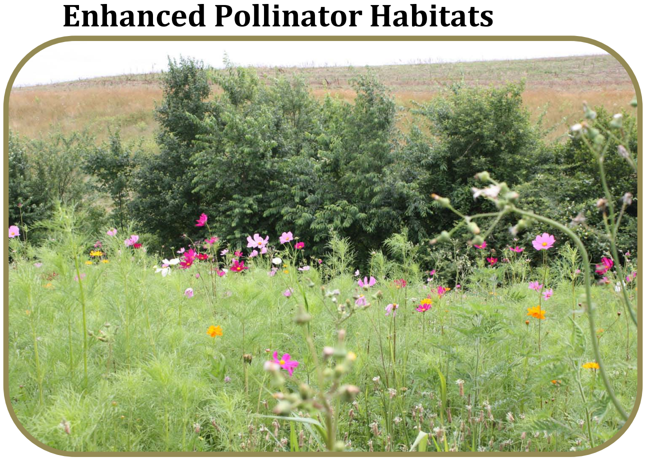
- Protect agricultural soils from wind erosion
- Increase crop yields
- Protect livestock from harsh winds
- Provide habitat for species, resulting in more biodiversity
- Improve crop pollination by insects due to reduced wind speed
- Increase odour, dust, and noise control from livestock operations
- Improve spray applications
- Reduce drifting snow on road
- Reduce energy consumption if farm structures are sheltered by trees

Buffer Strips

(**Photo:** Source: University of Minnesota, 2011)

- Reduce the amount of sediments, nutrients and pesticides that are found in agricultural runoff from entering waterways
- Improve water quality
- Stabilize stream banks
- Increase biodiversity; this can include pollinator species and natural predators of agricultural pests
- Reduce odours from livestock
- Increase water infiltration into groundwater systems

Enhanced Pollinator Habitats



(**Photo:** Source: Grand River Conservation Authority, 2012)

- Increase biodiversity
- Reduce pests by natural predators
- Reduce pesticide use
- Improve crop productivity and quality
- Alternative sources of income from various plants
- Improved environmental health and sustainability

4.6 Case Study

The Steckly Municipal Drain Project

(**Photo:** Source: Wikipedia.com, 2013)

The Farm

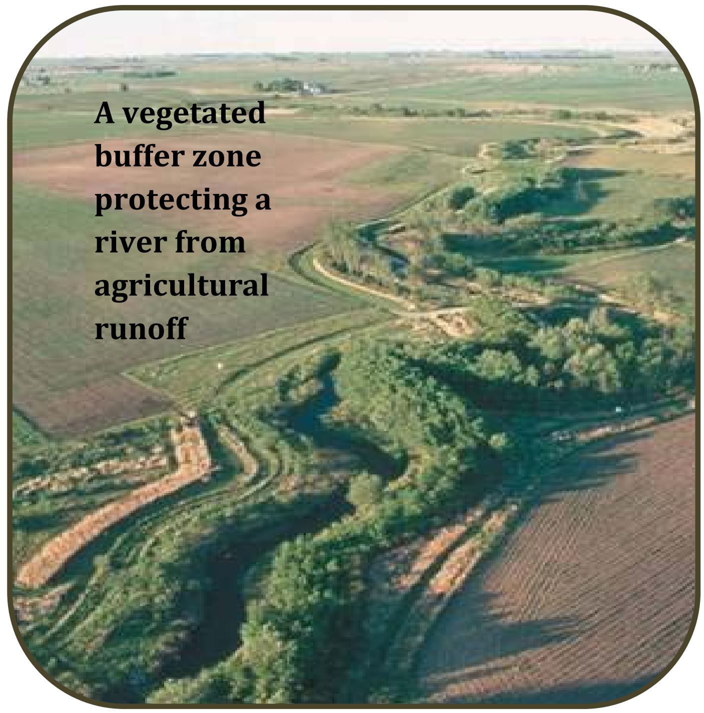
The Wilson Livestock Company operates a family run hog farm located in Perth County, Ontario. The farm includes 700 acres of cropland, which is grown to feed approximately 500 sows.

The Problem

The Steckly Municipal Drain runs through the farm, and as such, is surrounded by row crops. The drain often needed maintenance to remove sediment buildup. Sources of these sediments were from surrounding farms, and contained contaminants from fertilizers and livestock waste. As a result, water quality in the drain was quite poor.

The Solution

In 1991, a vegetated buffer was established alongside the south side of the drain. The buffer was six metres wide and consisted on a mix of trees, shrubs, and grasses. Trees could only be planted on the south side of the drain for maintenance purposes. In lieu of trees, a three-metre wide grass buffer was placed on the north side of the drain, totalling 700 metres in length.



A vegetated buffer zone protecting a river from agricultural runoff

(**Photo:** Source: Wikipedia.com, 2013)

Why Buffers?

Establishing vegetated buffer zones are beneficial for a variety of reasons. Vegetation along streams naturally filter sediments from agricultural runoff, which can carry contaminants such as pesticides, nutrients from fertilizer and manure. As a result, the amount of sediments and pollutants that enter the water source is reduced. They also stabilize stream banks and increase water infiltration into ground water systems which contributes to a healthier environment.

TheResults

In the 15 years following the establishment of the vegetated buffer, the Steckly Municipal Drain did not need to be cleaned once. Farm owners believe that the buffer strip has enhanced their farm. They have attributed the increase in fish and wildlife on their property to the increased habitat the buffer has provided.

Fish surveys conducted in 1991 and 2006 confirmed that there has been an increase in both the number of individuals and number of fish species in the drain since the buffer was established. In 1991, only 25 Brook Stickleback were found in the drain.

In 2006, a total of 372 individuals, representing seven different fish species, were surveyed. These results surprised farm owners because the buffer only ran along nine percent of the drain. If the buffer ran along the entire drain, both the health of the drain and the water quality could be that much better.

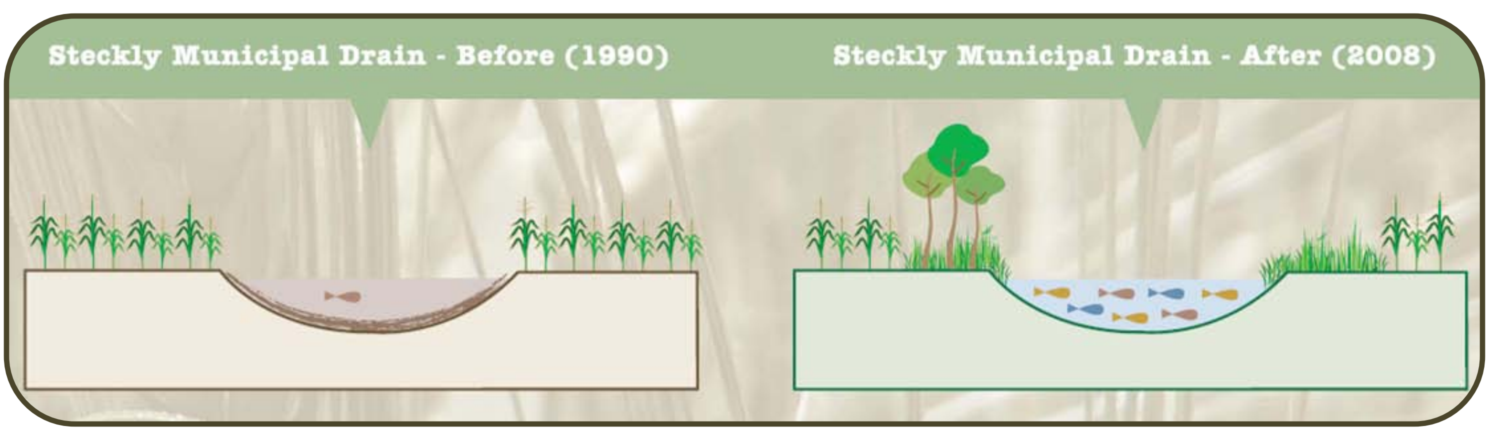
Brook Stickleback

Before...

(**Photo:** Source: Grand River Conservation Authority, 2013)

...After

(**Photo:** Source: Grand River Conservation Authority, 2013)



(**Diagram:** Source: Grand River Conservation Authority, 2013)

For more case studies illustrating the benefits of buffers and windbreaks, please visit the Grand River Conservation Authority link below:
http://www.grandriver.ca/index/document.cfm?Sec=25&Sub1=97

4.7 Activity: Fix the farm

*This activity can be performed individually or in groups in the classroom
*Students will draw upon the knowledge they have gained from reading this study guide and other research. (Be sure to include trees!)

Materials
Blank paper, lined paper and pencil/pen
Plasticine/ Play Dough (at least 3 different colours)

Procedure

1) Recreate the farm described on the right (Under Farm Description) with the plasticine:
   a) Draw the stream on the blank piece of paper (as this feature cannot be moved)
   b) Create the following features out plasticine: the house, barn, fence, agriculture field and livestock.

2) Identify and record the problems associated with the farm's current layout
   (For example, "The barn is not placed in the ideal location because… "
   or "There is a risk of contamination because…"

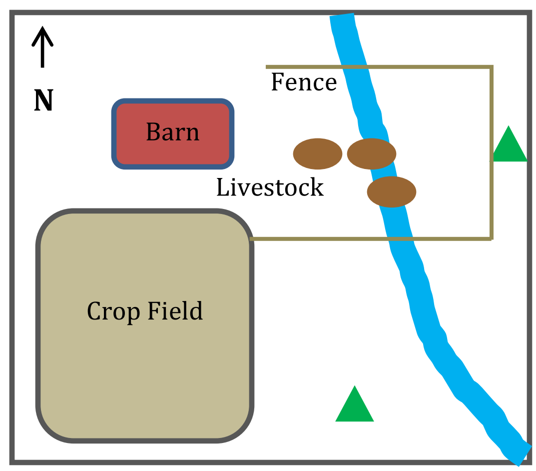
3) Based on the issues you have identified, redesign the farm's layout in an effort to minimize the problems with the farm. *You can mark the locations of each farm feature (eg. barn, fence, livestock placement) on the blank piece of paper with a pencil so you can track the changes you have made*

4) Identify and record the reasoning behind each change in the farm's layout and any benefits that will arise from each change. (For example, if you move the location of the barn, state what problems it may solve and any added benefits that could result from moving it). Provide any recommended farming practices that may benefit the farm (eg. Agroforestry techniques, crop rotation, reduced tillage etc.)

5) Discuss your recommendations with the class.

Farm Description

A new farm has been established in Ontario. It is a large monoculture wheat field and is susceptible to large gusts of wind and heavy rainfall. The barn and grazing area are located near a slope that is 40 m away from a stream that runs through the property. This stream is used to water the crops and to provide drinking water for cattle. Livestock are free toenter the stream. Most of the trees on the property were clear cut.



*If desired, each group can focus on providing recommendations on a specific issue and present their findings to the class. For instance, one group can focus on how to tackle issues with agricultural runoff and another group can focus on biodiversity *

Your recommendations can include methods to:
-Protect the water quality & improve soil quality
-Help attract more pollinators to the farm & minimize the risk of pest infestations
-Improve energy efficiency

Sample Key Terms:
-Conservation tillage
-Crop rotation
-Vegetation buffers
-Windbreakers

4.8 Questions for discussion

1) What ecological functions do forests perform?
2) What ecosystem services do forests provide to people?
3) How can maintaining forest vegetation help agricultural productivity?
4) What are the dangers of deforestation?

5.0 Wildlife

5.1 Introduction to Wildlife in Sustainable Agriculture

Wildlife – any animal life that lives in a natural and undomesticated state. Southern Ontario is home to some of the most productive agricultural land in all of Canada. It is also one of the most biologically diverse regions in the country. There are currently 190 species at risk in Ontario with the many of them being found in Southern Ontario. The reason for the disappearance of many of these species is a loss of their natural habitat. Over the past 50 years urban development has doubled and the agricultural practices have changed focus to produce higher yields and growing cash crops. Since 1981 the amount of farmland in Canada has expanded by 10% and cropland grew by 35%. Conversion of natural landscapes to development or agriculture has led to the fragmentation and degradation of forest, soil, and aquatic systems, which has impacted wildlife in Ontario.

Sustainable agriculture aims to incorporate ecosystems and agriculture to form a more efficient system. The use of sustainable growing practices can provide habitat for specific wildlife that will benefit the agricultural system. This allows sustainable agriculture practitioners to benefit from things like pest control services at a reduced cost. This provides economic and environmental benefits as well as wildlife viewing opportunities.

(**Photo**: Himelfarb, 2012)

5.2 Benefits of Wildlife in Sustainable Agriculture

Wildlife are important in maintaining ecosystem functioning and are vital for agricultural production. Wildlife species are needed for the pollination of agricultural crops and some species provide biological pest control services. Therefore, it is important for wildlife habitat to be incorporated into the agricultural landscape to increase biodiversity. If suitable habitats are present, farms can benefit from ecological goods and services from wildlife species such birds, pollinators and bacteria. Several beneficial functions of wildlife have been described below.

5.2.1 The Benefits of Birds

Species like the Savannah Sparrow, a common mixed farm species, often form mated pairs. A single mated pair can consume 3.7 kilograms or 149,000 grasshoppers per season.

(**Photo**: Vyn, 2013)

It is common practice for farms to use pesticides to kill agricultural pests, which results in the release of toxic substances into the environment. To minimize the need for such chemicals, farms can utilize natural methods of biological control. Many birds in Ontario are **insectivores** and can naturally provide pest control services. These birds, as their name suggests, rely on insects as their main source of food which is especially beneficial in pest control of crop-lands. However, many of the bird species found within farmlands are disappearing in response to modern North American farming practices. For instance, pasture lands and buffer strips that used to be home to ground nesting birds may be removed to increase crop production. This decrease in habitat has reduced bird biodiversity in these **agrocecosystems**. It is important to maintain bird populations in agricultural landscapes as they are an excellent pest management tool. One study in Ontario observed that birds removed over-wintering corn borers by 64% one year and 82% in another year. These statistics are not outliers, but evidence of previous success that can be replicated year after year.

5.2.2 Powerful Pollinators

The agricultural system is dependent on wildlife species to pollinate crops. While a variety of bird and insect species pollinate plants, bees are among the most important pollinators. In Ontario alone, there are approximately 400 species of bees, many of which create their nests in the ground! Unfortunately, pesticide use and habitat loss have been identified as key factors in the decline of bee populations. Therefore, in order to secure crop production on farmland, it is important maintain suitable habitats for bees and other pollinators. Examples of bee habitats include tree **snags** and logs, as well as uncovered patches of soil for ground-nesting species.

5.2.3 Microorganisms: Soil Heroes

(**Photo**: Heipel, 2013)

The soil is what nourishes the plants with minerals, gives the plants a place to take root and holds water for them to take up through their roots. What is often overlooked is that the efficiency with which plants do this is often controlled by **microorganisms** in the soil. The majority of soil microorganisms live within the **rhizosphere** and that is where they provide the most benefit. Microorganisms provide a variety of unseen benefits to crops and plant life in general as outline in Figure 25 They live in every climate on every continent across the world in some of the most extreme conditions and are capable of remediating saline or drought-ridden areas. They do so by providing fertilizers, pest control, nutrient cycling by breaking down organic waste and even aiding in the absorption of heavy metals and other pollutants.

5.2.4 Plant-growth Promoting Rhizobacteria

Rhizobacteria are a type of bacteria that live within the rhizosphere. Plant-growth Promoting Rhizobacteria, (PGPRs), are microorganisms that provide ecological integrity to agrocecosystems to increase crop yield, productivity and health. *Bacilli* and *Pseudomonads* are among the most predominant genera in PGPRs. They can be purchased and spread across agricultural areas and can propagate and spread all by themselves; provided sustainable agriculture techniques are used.

PGPRs are found naturally in the soil and their numbers can be increased through a variety of sustainable agriculture techniques. The most effective methods are conservation tilling, rotational crops, and residue recycling. Using these methods and creating habitat for these organisms will provide incredible benefits in the form of increased soil fertility and health and plant efficiency as well as many others.

5.2.5 Bio-fertilizers

PGPRs also produce phytohormones, such as auxins and cytokinins, to stimulate plant growth. The hormones created by PGPRs are responsible for an increase in root density, root hair density and their presence helps aerate the soil as there are fed upon by other organisms moving through the soil. This movement of larger organism through the soil created tunnels and when it rains water is held more easily. In addition there are phytohormones that use solubilisation to make phosphates more available for plants leading to increased growth as well as increased iron absorption through a specialized set of iron metabolising enzymes. These bacteria also use the same iron metabolizing process to clean up heavy metals and other environmental pollutants.

5.2.6 Environmental Remediation

Using the same processes discussed above involving the metabolization of iron PGPR's are able to absorb heavy metals and contaminants such as toluene and naphthalene. They can be spread and used to clean up gasoline and other chemical spills in a matter of months so that the soil can be used in the future to grow food fit for human consumption.

5.2.7 Bio-control of Plant Diseases

PGPRs also perform a valuable service to agriculture by reducing the spread and severity of diseases. Many diseases that target plants can be spread through the soil through water, the movement of microorganisms or even the air. To combat these diseases PGPRs have developed a few techniques that benefit the rhizobacteria as well as the host plant. The PGPRs use two main methods: the first method is the rhizobacteria secrete several anti-fungal compounds which make the soil unsuitable for certain types of fungi. This chemical acts an inhibitor to fungal

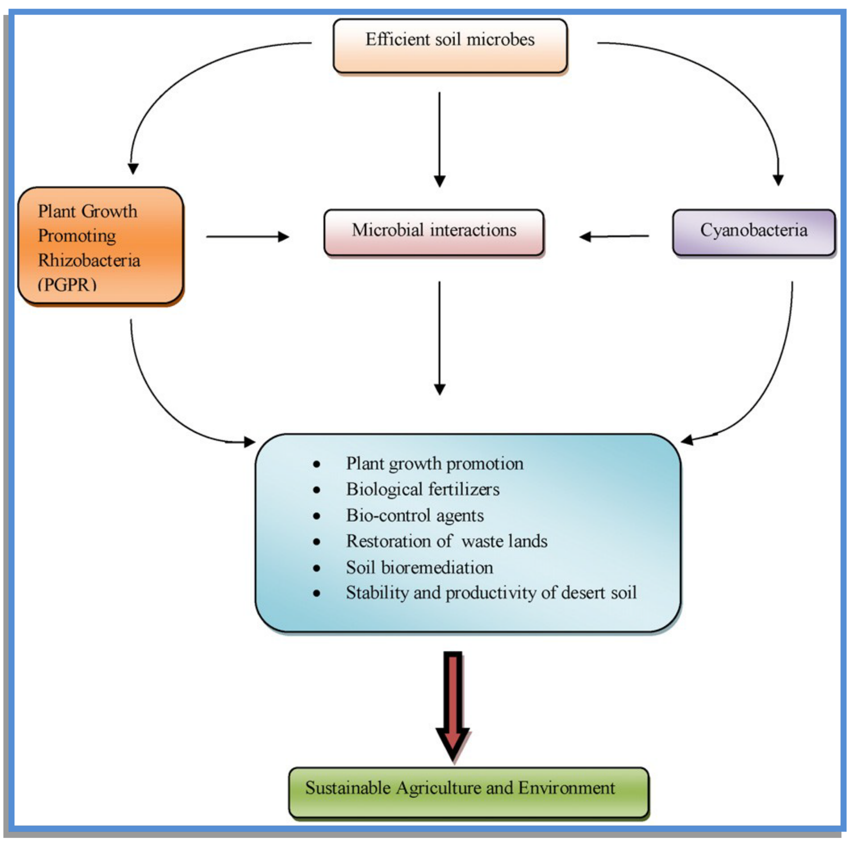


Figure 25: Benefits of Microbes in Agricultural Soil
(**Source**: Sing, Pandey, Singh, 2011)

growth and does not allow them to establish in the immediate area around the colony of rhizobacteria. The second option is the rhizobacteria are carriers of a certain disease but in a less harmful state. The PGPRs introduce their own weaker version of the disease to the host plant and allow it to develop its own defense system. This is similar to a vaccine used in flu shots only plants do not possess antibodies and must find other methods to combat diseases.

5.3 Case Study: Rotational Grazing, It's for the Birds!

Background

The Bruce County Community Pasture was created in 1997. It used to be comprised of roughly 60 hectares of pasture land but was reduced to 28 hectares to protect a local marsh for waterfowl.

The creek that runs through the middle of the reduced pasture land flows into the wetland. It was heavily impacted due to cattle walking through it and the banks were rapidly eroding.

Farmers were concerned that after reducing the area by 48% they would be unable to maintain the weight of their cattle.

Location: Bruce County, Ontario

(**Source:** Elections

Solutions

The smaller pasture was further divided into several sections so a rotational grazing program could be put in place.

A solar-powered electric fence was installed along the creek to keep the cows out. The eroded bank of the stream was restored with a riparian buffer of native trees and shrubs.

In addition water is pumped from the creek to two holding tanks to provide water to the cattle.

Results

Four years after the beginning of the project it was considered a success. The same number of cattle was supported on the land and the quality of the feed was deemed consistently higher.

In addition the stream has shown signs of recovery and the quality of the water has been significantly improved since the exclusion of the cattle.

The protected wetland and buffer strips are now home to some 2,500 migratory and resident birds representing 50 species.

5.4 Activity: Integrated Pest Management Strategy

In this activity the goal is to get students to design an Integrated Pest Management (IPM) strategy. Students will learn the basic elements of an IPM and will apply their knowledge of sustainable agriculture to design on for their farm. Don't forget to use the sustainable agricultural practices described in the other sections to help you out!

IPMs Include:

- **Action Thresholds**: This threshold is set the point where it becomes an economic threat. A sighting of a single pest species does not necessarily require action.
- **Monitor and Identify Pests:** Not all weeds and insects are harmful. It is important to be able to identify pest species and their life cycles.
- **Prevention:** Preventing the spread of pests through methods like crop rotation and rotational grazing can be valuable methods that are cost effective.
- **Control:** Mechanical, Chemical, Cultural and Biological are the three types of controls. Each has their own benefits and costs associated.

(**Photo:**, Farley, 2011)

Activity Situation:
The apple orchard you live on has been infected by infected by codling moth larvae. The infection was not serious this year but you know that next year it could spread and become worse.

Objectives:

- Research a mechanical, chemical, cultural and biological control method for codling moths.

- Create an Integrated Pest Management for your apple orchard based on which method or combination of methods is the most economical and least destructive.

6.0 Conclusion

The emergence of agriculture has provided the means necessary to sustain large populations in permanent locations. However, modern agriculture in North America has become increasingly industrialized, relying heavily on expensive equipment, fossil fuels, pesticides and chemical fertilizers. In addition, arable land and resources, such as water and energy, have been used inefficiently.

These farming methods can have detrimental impacts on surrounding aquatic, soil, forest and wildlife systems through pollution and resource exploitation. However, many farms in North America, including Ontario, have shifted from conventional farming methods to more sustainable farming practices, reduceing the impacts that farming can have on ecosystems. For instance, many farms have adopted the use of vegetative buffer strips to reduce the amount of agricultural runoff from entering waterways and provide additional habitat for wildlife species. Sustainable agricultural practices such as these will help maintain soil fertility and environmental quality.

This is essential as food security for our current and future generations is dependent on the health of our agricultural lands and surrounding ecosystems. Although it will take years for North American agriculture to become sustainable, we have the tools and the knowledge necessary to achieve this goal.