



2017

Sustainable Farming

This study guide will focus on the effects of agriculture on both water and soil systems. It will discuss alternative sustainable and best management practices.



Support for the 2017 Ontario Envirothon has been provided by the following:



Acknowledgements

This Study Guide was compiled by students at Fleming College, Frost Campus, in Lindsay, Ontario. Acknowledgements to Kristen Glass, Michael Ball, Juliana Denardi & William Richmond who contributed to the content of this guide. Thanks also to Sarah Kelly, Credit for Product Coordinator at Fleming College and Dustin Mulock.

Acknowledgements also given to those who reviewed the study guide:

- AgScape
- David Kroetsch
- Farm and Food Care

Table of Contents

2017 Learning Objectives: Sustainable Farming	6
Tools and Apps	7
Envirothon Resources	7
Applications and Interactive Websites	7
Faces of Farming	7
Ontario Curriculum Links	8
1.0 Farming in Canada	10
History of Farming	10
Farming Today	10
Farming Tomorrow	12
1.1 Conventional Agriculture	12
1.2 Organic Farming	13
1.3 Organic vs. Conventional—News Article	14
2.0 Soil Health and Conservation	15
2.1 Soil Characteristics	15
2.1.1 Soil Texture	15
2.1.2 Soil Structure	16
2.1.3 Soil Organic Matter (SOM)	16
2.2 Mapping Soils	17
2.3 Farming Impacts on Soil	18
2.3.1 Soil Erosion	18
2.3.2 Soil Compaction	20
2.3.3 Soil Tillage	20
2.3.4 Addition of Synthetic Fertilizer and Pesticide	21
2.4 Soil Conservation and Stewardship	22
2.4.1 No-till or Conservation Tillage	22
2.4.2 Cover-cropping	23
2.4.3 Crop Rotation	24
2.4.4 Organic Fertilizers and Matter	25

3.0 Water Health and Conservation	26
3.1 Water in Farming	26
3.2 Farming Impacts on Water	26
3.2.1 Drainage	27
3.2.2 Irrigation	28
3.2.3 Groundwater	28
3.2.4 Contamination	28
3.3 Water Conservation and Stewardship	29
3.3.1 Managing Crop Needs	29
3.3.2 Irrigation	29
3.3.3 Permits to Take Water (PTTW)	29
3.3.4 Nutrient Management	30
3.3.5 Pesticides and Water	30
3.3.6 Efficient Tile Drainage	30
4.0 Additional Best Management Practices	31
4.1 Habitat Enhancements	31
4.1.2 Biodiversity Enhancement Plan	31
4.2 Reforestation	32
4.2.1 Tree Shelterbelts and Windbreaks	32
4.2.2 Vegetated Buffer Strips	33
4.2.3 Grazing Management Plan	34
4.2.4 Application of Pesticides and Insecticides	34
5.0 Future of Farming	35
5.1 Emerging Trends in Agriculture	35
5.2 Integrated Pest Management	35
5.3 Precision Agriculture	36
5.4 Greenhouses and Hydroponics	36
5.5 Biogas	36
5.6 Growing Greener Cities	37
5.7 Climate Change and Farming	37
5.7.1 Challenges for Farmers	37
5.7.2 Opportunities for Farmers	38

6.0 Agricultural Conservation Stewardship Programs	39
6.1 Canadian Programs	39
6.2 United States Programs	41
7.0 Careers in Farming	43
8.0 Glossary of Terms	44
Appendix 1: Case Study for Sustainable Farming	46
Appendix 2: Hands-On Activities	48
Activity #1: Soil Health and Water Quality Relationship	48
Activity #2: Poster Challenge	49
Appendix 3: References	50

2017 Learning Objectives: Sustainable Farming

Key Topics

1. Soil and water conservation best management practices related to agriculture.
2. How are soil and water conservation best management practices for agriculture related to the management of wildlife, forestry and aquatic systems?
3. How do agricultural and agri-food producers maintain a balance between their quality of life versus the quality of the environment?

Learning Objectives

1. Understand the importance of the agriculture and agri-food sector to the community and the economy of Canada.
2. Identify and recommend soil and water conservation best management practices.
3. Describe the role of the federal and provincial governments in conservation and identify programs in place that promote and encourage agricultural conservation and stewardship.
4. Comprehension of farming practices that build soil organic matter such as composting, crop rotations, cover crops, conservation tillage, and management of intensive grazing systems
5. Identify the concept of soil quality/health to provide the needed functions for human or natural ecosystems over the long term.
6. Identify various types of soil erosion and utilize different methods to estimate and predict soil erosion to assess land use impacts including:
 - a. USLE and RUSLE equations
 - b. Aerial Photographs
 - c. Topographical Maps
 - d. Soil Maps
 - e. Soil Surveys
7. Explain why land-use planning is important to our ecosystem and to our economy to achieve sustainable agriculture.
8. Understand emerging trends in agriculture that are helping to improve sustainable farming practices.

Tools and Apps

The following tools and recommended resources which can better help you and your team prepare for the Envirothon program.

Envirothon Resources

[What Lies Beneath...Your Feet: Ontario Envirothon Supplementary Resource](#)

Applications and Interactive Websites

[AgScape Teacher Ambassador](#): Bring the environment, food and agriculture into your classroom through the AgScape Teacher Ambassador program. Request a free visit from a certified teacher to learn about a variety of food and agriculture related topics.

[On-Farm Best Management Practices](#): Learn how Best Management Practices are put into places on Canadian Farms on the Ontario Soil and Crop Improvement Association website.

[Virtual Farm Tours](#): You are only a click away from visiting number of real working Canadian and Ontario farms.

Biological Control—Cornell University

www.biocontrol.entomology.cornell.edu/index.php

Faces of Farming

There are over 40,000 farm families in Ontario—to meet some of them visit

www.facesoffarming.ca

The Real Dirt on Farming

Answering all your questions about farming in Canada—www.realdirtontofarming.ca

Ontario Curriculum Links

- **Grade 9/10 Science**

- B1: assess the impact of a factor related to human activity that threatens the sustainability of a terrestrial or aquatic ecosystem; evaluate the effectiveness of initiatives and efforts with respect to an environmental issue that affects the sustainability of an ecosystem
- B2: use appropriate terminology related to sustainable ecosystems; plan and conduct an investigation into how human activity affects soil composition or fertility; analyze the effect of human activity on populations
- B3: identify various factors related to human activity that have an impact on ecosystems

- **Grade 11 Environmental Science—Sustainable Agriculture and Forestry**

- D1: evaluate, on the basis of research, a variety of agricultural and forestry practices with respect to their impact on the economy and the environment; evaluate, on the basis of research, the impact, including the long-term impact, of agricultural and forestry practices on human health
- D2: use appropriate terminology related to sustainable agriculture and forestry; use a research process to investigate environmentally sustainable methods of managing and maintaining healthy and productive agricultural zones and forests; design a landscaping project for their local area, taking into account local conditions and propose a course of action to ensure the sustainability of the project and its healthy interaction with the surrounding environment
- D3: explain the basic principles of various agricultural and forestry practices (e.g., Integrated Pest Management), and identify regulations and regulatory bodies associated with these practices; describe the soil components needed by a variety of plants for optimal growth; explain different ecologically sound practices for improving and maintaining soil structure and fertility; explain agricultural techniques and forestry practices that aim to maintain both biodiversity and long-term productivity; describe sustainable water-management practices in agricultural and forestry settings

- **Grade 11 Biology**

- F1: assess the positive and negative impact of human activities on the natural balance of plants

- **Grade 11 Environmental Science**

- B1: analyze social and economic issues related to a particular environmental challenge and efforts to address it; analyze ways in which societal needs or demands have influenced scientific endeavors related to the environment; use a research process to investigate how evidence, theories and paradigms reflecting a range of perspectives have contributed to our scientific knowledge about the environment and communicate their findings; identify major contemporary environmental challenges and explain their causes; explain how an environmental challenge has led to advances in science or technology; describe a variety of human activities that have led to environmental problems and/or contributed to their solution
- C1: evaluate effectiveness of government initiatives that are intended to reduce the impact of environmental factors on human health
- C3: identify the main pollutants and environmental contaminants that can affect human health

- **Grade 11 Science**

- B1: analyze some of the risks and benefits of human intervention to the biodiversity of aquatic and terrestrial ecosystems
- B3: explain why biodiversity is important to maintaining viable ecosystems
- F1: evaluate the importance of plants to the growth and development of Canadian society; evaluate ways in which different societies or cultures have used plants to sustain human populations while supporting environmental sustainability

- **Grade 12 Biology**

- F1: analyze the effects of human population growth, personal consumption, and technological development on our ecological footprint; assess the effectiveness of some Canadian technologies and projects intended to nourish expanding populations

- **Grade 12 Science**

- F1: analyze social issues related to an application of biotechnology in the health, agricultural, or environmental sector; analyze, on the basis of research, ethical and legal issues related to an application of biotechnology in the health, agricultural, or environmental sector
- F3: describe applications of biotechnology in the agricultural and environmental sector

1.0 Farming in Canada

A century ago, over half of Canada's population were farmers. Today, with a population of 35 million, there are less than 730,000 farmers—just over 2% of the population—across the country (Farm and Food Care Canada, 2014). Despite this, the agriculture and agri-food industry contributes over \$100 billion annually to Canada's gross domestic product (GDP) and worldwide Canada is the 5th largest agricultural exporter (Farm and Food Care Canada, 2014).

Urbanization has led to an increasing disconnect and misunderstanding of where our food comes from and the important role farmers play in providing the food we need to survive. Farmers not only play a critical role in providing us with food, but also act as stewards of the landscape and contribute to conservation efforts which protect and enhance natural ecosystems. Farmers play a vital role in maintaining and improving soil health, water and air quality, providing wildlife and pollinator habitat, carbon sequestration, and conserving water and energy. Voluntary efforts, provincial and federal government incentives, as well as research and innovation help farmers to improve the sustainability of their practices.

Did you know Ontario's farms contribute close to \$12 billion to the provincial economy annually?

History of Farming

In the 1800's farming systems focused on planting a single species (monoculture) every other year and leaving fields without crops (fallow) in between. This method not only wasted land, but also impacted soil health by depleting nutrients. Early methods of crop protection included excessive plowing of the soil and using inorganic chemicals like sulphur, mercury and arsenic to fight pests and disease. Farmers also used to burn some of what remained on their fields to prepare for the following year. Farming has come a long way in the last century, and there is no doubt that it will continue to develop as new research and technology helps to improve efficiency and production (Farm and Food Care, 2014).

Farming Today

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

Sustainable farming (or agriculture) is a way of growing or raising food in an ecologically, ethically and economically responsible manner using practices that protect the environment, safeguard human health, are humane to farm animals, and provide fair treatment to workers. When you eat sustainably, it means you are eating food that is grown or raised according to these principles (Sustainable Table, 2016).

Sustainable farming practices produce large quantities of food without overexploiting resources and strive to have a minimal negative impact on the environment. A variety of methods can be employed to reduce energy and chemical inputs, water usage, pest infestations, pollution, and soil degradation. However, farming systems must also be socially and economically viable to be sustainable. Therefore, it is necessary to consider whether environmentally sustainable farming practices are affordable to farmers and will allow them to maintain a good quality of life. Implementing sustainable farming practices can require significant upfront costs, including costs for new machinery or opportunity costs lost through the change in farming methods. This can be a deterrent for many individual farms. Therefore it is important to educate farmers and municipalities about the long-term benefits of sustainable farming practices and encourage better practices through information or incentives.

Aside from being the world's largest maple syrup producer, Canada is also the largest grower and exporter of flax seed, canola, pulses and durum wheat (Farm and Food Care, 2014). The diversity of soil types, climatic conditions and ecosystems across Canada support a variety of livestock and agricultural crops. Farmers on the east coast of Canada are producing far different products than those on the west coast, and therefore the challenges they face also differ (Figure 1).

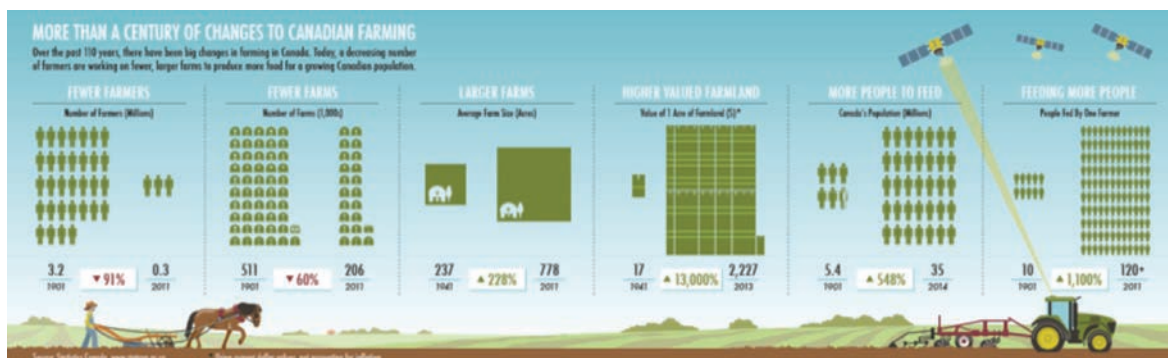
FIGURE 1: What Do We Produce? (*Agriculture & Agri-Food Canada, 2012*)



Farming Tomorrow

With the world's population growing by 75 million per year, there is an ever increasing need to focus on sustainable ways to produce food. Supporting your local farmer is a great way to help ensure that we have local farms producing the food we need. However large farms are also improving their sustainability by incorporating important practices to reduce their environmental footprint while efficiently growing food and livestock (Farm and Food Care, 2014).

FIGURE 2: More than a Century of Change to Canadian Farming (*Statistics Canada, n.d*)



1.1 Conventional Agriculture

Conventional agriculture, also known as industrial agriculture, is a form of modern farming that includes the input of synthetic chemical fertilizers, pesticides and herbicides, and the use of antibiotics or biotechnology (All About Food, 2014). About 98% of farms in Canada farm conventionally (All About Food, 2014). Conventional farming 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 (USDA, 2007):

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

While conventional agricultural advances have enabled farmers to produce large volumes of food some 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. Inputs like fertilizer and pesticides, along with tilling and ploughing can disrupt water and soil nutrient cycles and soil development which can lead to reduced soil **biodiversity**, nutrient availability, and capacity of soil to retain water. These challenges have led to the development of sustainable agriculture practices which aim to maintain healthy relationships between the biotic and abiotic components of the agricultural system.

Common problems associated with conventional farming techniques include:

- **Eutrophication** & water pollution by agricultural runoff (fertilizers, sediments and pesticides)
- **Soil erosion** by water, wind, compaction 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

1.2 Organic Farming

Organic farming is a type of agriculture that focuses on managing crops and soil as an ecosystem avoiding application of synthetic fertilizers and synthetic pesticides (FAO, 2016). 1.8% of farms in Canada farm organically (All About Food, 2014). Organic farming still employs the use of fertilizers and pesticides, but they are limited to natural inputs - those derived from natural sources as opposed to synthetically created. The main goal of all of organic practices is to encourage soil biodiversity, soil formation and healthy soil structure (FAO, 2016). Organic farming incorporates many of the best management practices outlined in Section 2 including cover crops and crop rotation.

To be labeled as certified organic food must be produced by farmers who are certified as organic producers under Canada's Organic Products Regulations (Farm and Food Care, 2014). Organic farming has many challenges including lower and less reliable yields, and more labour intensive work. In addition audits are required to maintain certification.

1.3 Organic vs. Conventional—News Article

New Study Sheds Light on Debate Over Organic vs. Conventional Agriculture

McGill University, Newsroom—April 25, 2012

Can organic agriculture feed the world?

Although organic techniques may not be able to do the job alone, they do have an important role to play in feeding a growing global population while minimizing environmental damage, according to researchers at McGill University and the University of Minnesota.

A new study published in *Nature* concludes that crop yields from organic farming are generally lower than from conventional agriculture. That is particularly true for cereals, which are staples of the human diet - yet the yield gap is much less significant for certain crops, and under certain growing conditions, according to the researchers.

The study, which represents a comprehensive analysis of the current scientific literature on organic-to-conventional yield comparisons, aims to shed light on the often heated debate over organic versus conventional farming. Some people point to conventional agriculture as a big environmental threat that undercuts biodiversity and water resources, while releasing greenhouse gases. Others argue that large-scale organic farming would take up more land and make food unaffordable for most of the world's poor and hungry.

"To achieve sustainable food security we will likely need many different techniques—including organic, conventional, and possible 'hybrid' systems—to produce more food at affordable prices, ensure livelihoods to farmers, and reduce the environmental costs of agriculture," the researchers conclude.

Overall, organic yields are 25% lower than conventional, the study finds. The difference varies widely across crop types and species, however. Yields of legumes and perennials (such as soybeans and fruits), for example, are much closer to those of conventional crops, according to the study, conducted by doctoral student Verena Seufert and Geography professor Navin Ramankutty of McGill and Prof. Jonathan Foley of the University of Minnesota's Institute on the Environment.

What's more, when best management practices are used for organic crops, overall yields are just 13% lower than conventional levels. "These results suggest that today's organic systems may nearly rival conventional yields in some cases—with particular crop types, growing conditions and management practices—but often they do not," the researchers write. Improvements in organic management techniques, or adoption of organic agriculture under environmental conditions where it performs best, may help close the yield gap, they indicate.

"Our study indicates that organically fertilized systems might require higher nitrogen inputs to achieve high yields as organic nitrogen is less readily available to crops. In some cases, organic farmers may therefore benefit by making limited use of chemical fertilizers instead of relying only on manure to supply nitrogen to their crops," Seufert says. "At the same time, conventional agriculture can learn from successful organic systems and implement practices that have shown environmental benefits, such as increased crop diversity and use of crop residues."

Yields are only part of a set of economic, social and environmental factors that should be considered when gauging the benefits of different farming systems, the researchers note. "Maybe people are asking the wrong question," Prof. Ramankutty says. "Instead of asking if food is organically grown, maybe we should be asking if it's sustainably grown."

The results point to a need to get beyond the black-and-white, ideological debates that often pit advocates of organic and local foods against proponents of conventional agriculture, Prof. Foley adds. "By combining organic and conventional practices in a way that maximizes food production and social good while minimizing adverse environmental impact, we can create a truly sustainable food system."

Soil is composed of different particles that can be categorized by size. Particles can be sand, silt, and clay as well as coarse fragments such as gravel. Soil texture is determined by the proportions of each of these particle types. Gravel particles are larger than 2 mm, sand particles are 0.05 – 2 mm, silt particles are 0.002–0.5 mm, and clay is smaller than 0.002 mm (DuPont, 2012).

These particles not only vary in size, but also in shape. Sand particles are more round, whereas silt and clay particles are more flat. Soil with larger more round particles like sand give the soil more room for water and air to be present, which is vital to plant growth (DuPont, 2012). If sand is overabundant there can be too much space and water is able to quickly flow through, thus the soil would have low water holding ability.

The texture of the soil can be easily identified by how it feels between your fingers. Soil that is gritty and coarse is made up mostly of sand, while soil that is light and floury is mostly silt. Clay is usually smooth and greasy. When water is added, silts and clays can be formed into balls and hold their shape. Sand will not hold together when water is added (DuPont, 2012).

2.1.2 SOIL STRUCTURE

Soil structure refers to the arrangement or formation of the soil particles and soil aggregates (DuPont, 2012). Soil structure determines how water and nutrients flow within the soil, which can greatly affect plants ability to grow.

Soil structure is an element that can be influenced through management practices. By adding **synthetic fertilizer** and manure, or plowing and tilling, the structure of the soil can be affected.

Another aspect of soil structure is the formation of **soil aggregates**. These are soil structures that are formed by relationships between bacteria, fungi and root systems (DuPont, 2012). These soil organisms create sticky structures that have space for air and water, and provide ideal growing conditions for plants because they are able to hold nutrients (DuPont, 2012). These structures are strong and can withstand weathering.

2.1.3 SOIL ORGANIC MATTER (SOM)

Soil organic matter (SOM) is the organic component of soil and is made up of plant and animal residues at various stages of decomposition. The addition and conservation of this material is vital to ensuring healthy soil and crops and is an essential component of sustainable farming.

SOM is made up of three different components; living organisms, fresh **organic matter**, and decomposed organic matter (Bot and Benites, 2005). The fresh organic matter can be composed of a variety of substances including dead plant material, dead microorganisms, or fertilizer such as compost or manure (Bot and Benites, 2005). All of these materials can be easily broken down and converted into nutrients and minerals. Decomposed organic matter, also known as **humus**, is resistant to further decomposition (Bot and Benites, 2005). Humus is an important aspect of the soil because it can enhance soils ability to hold nutrients and water.

Living organic matter in the soil includes bacteria, fungi, protozoa, earthworms, and soil insects. These living organisms make up roughly 15% of SOM (Bot and Benites, 2005). In a single teaspoon of soil there can be hundreds of millions or even billions of living microorganisms (DuPont, 2012). These organisms are one of the most vital components of healthy soil. Worms and soil insects are able to shred and break down larger organic material into smaller particles. These smaller particles can then be consumed by bacteria and fungi. Bacteria and fungi release nutrients and other substances that form soil aggregates, and promote plant growth (Bot and Benites, 2005). Other microorganisms like protozoa and microscopic worms eat bacteria and fungi, and produce ammonia. Ammonia is an important source of nitrogen, which is an essential plant growing nutrient (Bot and Benites, 2005).

2.2 Mapping Soils

The provincial soils database is an important tool in land use planning. The database includes descriptive information such as slope classes, Canada Land Inventory (CLI) rankings (see below), stoniness, drainage class, and texture. This information is part of the Soils Ontario project and is used in source water protection, nutrient management, soil erosion modeling, and specialty crop mapping (OMAFRA, 2016).

The provincial soil database is managed by the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) and is shared with Agriculture and Agri-Food Canada. In cooperation with the Ministry of Natural Resources and Forestry, a high quality, detailed, geospatial soils database is being compiled. The digital soils data has been developed from soil survey reports and maps that have been produced over the past few decades (OMAFRA, 2016).

Important Mapping Databases

- [Soils Survey Complex](#)—A database of 44 soil reports and maps for southern Ontario and 12 soil maps for northern Ontario
- [Agricultural Information Atlas](#)—an interactive online tool that allows you to create custom maps and find agricultural information for Ontario; combines agricultural data on soils and drainage, and data layers from other ministries;
- [Agricultural Resource Inventory \(ARI\)](#)—a data set from 1983 that indicates the differences in farm operations over a number of years in southern Ontario; used by farmers, land use planners, municipal officers, policy makers and public to get a general sense of municipal land use practices; important for decision making in land use planning
- [Canada Land Inventory \(CLI\)](#)—a comprehensive multi-disciplinary land inventory of rural Canada with land capability of agriculture, forestry, recreation and wildlife mapped. The CLI indicates the capability of the land to sustain agriculture using a seven class rating (OMAFRA, 2016). Class 1 lands have the highest capability and Class 7 lands have the lowest capability of supporting agricultural activities. Maps were created from the 19060's–1980's however they are being updated with soil surveys.

When do you need soils mapping data?

- Preparing a new official plan or updating an existing official plan that identifies prime agricultural areas
- Seeking an official plan amendment for non-agricultural use
- Applying for a renewable energy contract for a non-rooftop solar facility
- Undertaking an Environment Assessment (EA)
- Applying for approval to operate a pit or quarry
- Undertaking Nutrient Management Planning

2.3 Farming Impacts on Soil

2.3.1 SOIL EROSION

Soil erosion refers to the wearing away of a field's topsoil by natural physical forces of water and wind, or through forces associated with farming activities such as tillage (OMAFRA, 2012). Erosion reduces cropland productivity and can contribute to pollution in local watercourses, wetlands and lakes. Erosion removes topsoil and relocates it elsewhere, either somewhere else on the farm or off-site. While it can be a rapid process, it can often go unnoticed. Other farming practices can also speed up the rate of soil erosion such as soil compaction or low soil organic matter.

Erosion can occur through forces of water and wind. Rainfall, while important for the growth of crops and health of livestock, can also have a significant impact on soil erosion. The force and duration of rain can break down soil aggregates and disperse it (OMAFRA, 2012). In addition, **surface runoff** can carry away soil after rainfall if surfaces are not absorbing the precipitation.

Wind erosion also has a significant impact on crops by causing burial of young plants or exposure of seeds (OMAFRA, 2012). Soil drifting, a result of wind erosion, can impact the quality of soil and cause textural change through the loss of fine particles or organic matter. In addition, the movement of soil could mean the addition of pesticide or nutrients to neighbouring ecosystems.

Types of Soil Erosion

- Sheet Erosion—movement of soil from raindrop splash and water runoff
- Rill Erosion—when surface water runoff concentrates, forming small yet well-defined channels (rills)
- Gully Erosion—advanced stage or rill erosion where surface channels are eroded to the point where they become a nuisance factor in normal tillage operations
- Bank Erosion—progressive undercutting, scouring and slumping of drainage ways (natural streams or constructed drainage channels)

Measuring Soil Erosion

Universal Soil Loss Equation (USLE)

USLE predicts the long-term average annual rate of erosion on a field slope based on rainfall pattern, soil type, topography, crop system and management practices. It only predicts the amount of soil loss that results from sheet or rill erosion on a single slope and does not account for additional soil losses that might occur from gully, wind or tillage erosion.

$$A = R \times K \times LS \times C \times P$$

- **A**—long-term average annual soil loss in tonnes per hectare (tons per acre) per year
- **R**—rainfall and runoff factor by geographic location found online; the greater the intensity and duration of the rain storm, the higher the erosion potential; ranges from 90–120
- **K**—soil erodibility factor; average soil loss in tonnes per hectare (tons per acre) for a particular soil in cultivated, continuous fallow with a slope length of 22.13m and slope steepness of 9%; ranges from 0.04–0.99
- **LS**—slope length-gradient factor found online; represents a ratio of soil loss under given conditions; the steeper and longer the slope the higher risk of erosion
- **C**—crop/vegetation and management factor; used to determine relative effectiveness of soil and crop management systems in terms of preventing soil loss; determined by selecting the crop type and tillage method found online
- **P**—support practice factor; effects of practices that will reduce the amount and rate of the water runoff and therefore reduce erosion

To use the USLE (find all tables and factors online at: <http://www.omafra.gov.on.ca/english/engineer/facts/12-051.htm>)

1. Determine the R factor using the table online.
2. Based on soil texture, determine the K value.
3. Divide field into sections of uniform slope gradient and length. Assign an LS value to each section.
4. Choose crop type factor and tillage method factor for the crop to be grown. Multiply these two factors together to obtain the C factor.
5. Select the P factor based on the support practice used.
6. Multiply the 5 factors together to obtain the soil loss per hectare.

RUSLE2—Revised Universal Soil Loss Equation version 2

RUSLE2 is a computer program that estimates long-term average soil loss erosion caused by rainfall and related overland flow. It helps to guide conservation planning, and predict soil and sediment loads from upland areas. It relies on statistical approach to estimate soil loss from actual field and site situations. It can estimate soil loss from cropland, pastureland, forestland, construction sites, mined land and reclaimed land. RUSLE2 for Ontario uses the same computer program but only includes datasets specifically designed to represent the Ontario environment.

RUSLE2 for Ontario can be found at:

<http://www.omafra.gov.on.ca/english/engineer/rusle2/index.htm>

RUSLE2 is capable of estimating long-term average season, even daily, erosion rates, unlike USLE which is only capable of estimating a long-term average annual erosion rate. In Ontario this is important since much of the sediment loading to Ontario waters occurs during the non-growing season (November through April). By breaking down soil loss estimates by season, seasonal best management practices for protecting soil and reducing sedimentation in watercourses can be identified (OMAFRA, 2014).

2.3.2 SOIL COMPACTION

Soil compaction occurs when large equipment (i.e. tractors, combines), trucks, human traffic, and livestock, compress the soil through constant movement over wet or soft soil, forcing the soil particles closer together. This eliminates or reduced the pore spaces (air and water pockets) that are needed in the soil to successfully grow crops (DuPont, 2012). Compacted soils prevent plant roots from penetrating the soil which results in insufficient nutrient acquisition. Affected plants may be smaller and less healthy, leading to lower crop yields. Compaction also reduces the amount of oxygen in the soil, which can lead to CO₂ build up. This can be toxic to plant roots, and result in crop mortality (DuPont, 2012). Lastly, soil compaction can also reduce the amount of water that is able to penetrate deep into the soil, leading to runoff and subsequently soil drought.

2.3.3 SOIL TILLAGE

Soil tilling is the process of physically manipulating the structure of soil (digging, stirring, overturning) with mechanical equipment. It is used when planting seeds, or distributing and incorporating fertilizer into the soil (Wander and Gruver, 2008). A tiller or plough is pulled behind a tractor; cutting, milling, and breaking up the soil, and inserting seeds and fertilizer (Wander and Gruver, 2008). At the same time tilling incorporates dead crop residue that is left from the previous year's crop. Tilling is thought to increase soil and seed contact when planting crops, and that it will prevent weeds and pests from taking over when crops are absent.

While tilling is important for mixing elements of soil, studies have shown that soil tilling can have negative effects on soil health including:

- Soil compaction
- Creating opportunity for wind and water erosion (Wander and Gruver, 2008).
- Removing a large portion of the SOM, an important part of healthy soil. It also takes the SOM that is still present, and mixes it deeper in the soil, accelerating its decomposition (Wander and Gruver, 2008).
- Altering the soil environment, breaking apart soil aggregates which are home to important soil bacteria and other soil microorganisms. Tilling makes it more difficult for these organisms to survive and ultimately decreases the biodiversity in the soil (Wander and Gruver, 2008).
- Removing crop residues from the soil surface
- Causing tillage erosion, particularly on knolls
- Disturbing soil biology

2.3.4 ADDITION OF SYNTHETIC FERTILIZER AND PESTICIDE

FIGURE 4: Fall strip till into clover (*Food and Farm Care, n.d*)



Synthetic fertilizer refers to fertilizers that are chemically created by humans and contain nutrients that plants need to grow. It is common practice to add this type of fertilizer to crops to accelerate the growing process and generate a higher yield. The main nutrients that fertilizers contain are nitrogen, phosphorus and potassium (Corriher, 2009).

While adding synthetic fertilizer helps to improve yields, it does have the potential to cause several issues including water contamination from runoff, air pollution, and harm to wildlife if incorrectly or over applied. However the main issues with synthetic fertilizers are related to the health of microorganisms. Plants cannot distinguish between organic and synthetic fertilizers. While chemical fertilizers add nutrients to the soil, they do not add anything else. Synthetic fertilizers do not support microbial life in the soil—a critical component of healthy soil. Plants and microorganisms have a **symbiotic relationship**, where plants create oxygen and nutrients that are used by bacteria and fungi in the soil (Corriher, 2009). In return, the microorganisms

convert oxygen and sugars in the soil, into usable nitrogen and phosphorus, as well as other nutrients that are then available to the plants (Corriher, 2009). When synthetic fertilizers are added to a system, the symbiotic relationships are impaired. Since the nutrients are being provided directly to the plants, the microorganisms are no longer provided the oxygen and sugars produced by plants (Corriher, 2009). Therefore careful planning is needed when applying synthetic fertilizers to minimize the impact to the microbial soil ecosystem.

Pests can have a significant impact on the quantity and quality of food produced; therefore they are actively managed, sometimes through the application of pesticides. Protecting crops from pests and disease are important for reducing the risk of food shortages due to crop failures and help to make food more affordable (Farm and Food Care, 2014). The over-application or misuse of synthetic pesticides can impact soil health. Some synthetic pesticides are more toxic to soils while others may break down easily.

Did you know that farmers in Ontario are required to take a course and pass an exam in order to become certified to purchase and use pesticides? At these courses farmers learn about pest management techniques, preventing pest resistance, how to protect the environment and avoid health risks, proper storage, maintenance of application equipment, and the importance of record-keeping. (Farm and Food Care)

2.4 Soil Conservation and Stewardship

The impacts on the environment from conventional farming have highlighted the need for a shift towards more sustainable farming practices to conserve soil. Increased understanding in soil nutrient and water cycles and systems has resulted in the emergence of new conservation and stewardship 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 conservation of soil.

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.

2.4.1 NO-TILL OR CONSERVATION TILLAGE

Historically, farm fields have been ploughed to prepare the soil for planting the next crop; however, this practice destroys soil structure and contributes to soil erosion. New planting equipment technology is allowing farmers to minimize tillage. Conservation tillage refers to tillage that leaves at least 30% of the ground covered in the previous crop's residue. There are many types of conservation tillage, like disking, deep ripping or vertical tillage but one of the most common forms is strip tillage. Strip tillage means that only the thin row in which the subsequent crop will be planted is disturbed. Strip tillage also allows fertilizer to be placed in bands exactly where the subsequent crop will need it.

FIGURE 5: No Till Farming (*Organic Producer, 2013*)



Figure 6: Till Farming (*ICS, n.d*)



No-till is the most extreme form of conservation tillage, in which no soil disturbance takes place. By leaving the soil undisturbed, soil structure is maintained and soil organic matter (and carbon) is not lost. This allows for greater water infiltration, thereby minimizing the potential for surface runoff and soil erosion. The crop residue on the surface also acts as armor to protect soil from weather impacts and keep soil in place.

Without tillage disturbance, soil aggregates remain intact along with the pore spaces from earthworms and roots, which create important pathways in the soil. Fungal networks and microbes in the soil are also maintained; this microbiology helps to break down crop residues and increase organic matter. Higher levels of microbes and organic matter also reduce the need for synthetic fertilizers. So, not only does this benefit the environment, but the farmer saves time and money by reducing fertilizer input costs and fuel costs associated with tillage.

2.4.2 COVER-CROPPING

A **cover crop** is a crop grown for the protection and enrichment of the soil. Cover crops are grown in agricultural fields often for the purpose of improving the physical, chemical, and biological health of the soil. Additionally cover crops can promote biodiversity (i.e. pollinator food source), be harvested to feed to livestock or at breaking pest cycles. Cover crops that are not harvested are either killed or allowed to complete their life cycle and die, so that agricultural crops can be grown in their place (Florentin et al, 2010). Cover crops provide many different benefits to agricultural crops including:

- Providing soil cover, which prevents soil erosion, increases water retention
- Lowering soil temperature in the hot summer months
- Preventing weeds from taking over
- Maintaining soil structure and soil aggregates
- Improving soil nutrient levels (nitrogen and phosphorus);
- Maintaining SOM
- Increasing porosity in the soil
- Maintaining microorganism health and relationship with plant roots
- Sequester atmospheric carbon
- provide food to support soil microbiology

Many different plant species can be used as cover crops, common ones include; barley, oats, and ryegrass (Florentin et al, 2010). Another common group of cover crops are legumes, including clover, vetch, or daikon radish. These plants are ideal because they form a large tap root that is able to penetrate deep into the soil creating space for air and water and (Florentin et al, 2010). Legumes are also able to fix nitrogen in the soil, which is vital for crop growth (Florentine et al, 2010).

In Ontario oats and radishes are common cover crops as they are killed off easily during the winter without herbicides or tillage.

Inter-cropping is another form of cover-cropping, where cover species are planted between the rows of desired crops. This creates more cover, lowering the soil temperature, limiting weed growth between rows, and adds to soil nutrients. 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.

There is also the method of planting into a live green cover crop. Traditionally cover crops are killed before the next crop is planted. This method instead plants right into the live green cover crop and has many benefits including:

- greater above and below ground biomass which helps with water infiltration and reduced erosion
- cover crops such as legumes fix more nitrogen in the soil for the next crop
- cover crops harvest more solar energy and increase total soil carbon

2.4.3 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 soybeans, followed by wheat and later corn (OMFA, n.d).

2.4.4 ORGANIC FERTILIZERS AND MATTER

As mentioned above, synthetic fertilizers add macro-nutrient (nitrogen, phosphorus and potassium) to the soil, but lack many important micro-nutrients (zinc, boron, etc). Organic amendments contribute both micro- and macro-nutrients as well as organic matter, along with beneficial microbes. Organic amendments can include livestock manure, digestate, municipal wastewater biosolids or composted food scraps and leaf and yard waste.

Manure is beneficial to soil, but there is potential for its nutrients to run off into watercourses if not properly applied. Some farmers inject liquid manure into the soil to ensure it cannot run off or that its nutrients cannot volatilize into the air. Others ensure that manure is applied to living cover crops in the summer when there is no threat of rain, in order to decrease potential for nutrient losses.

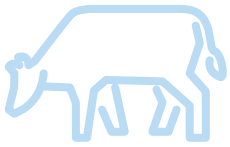
Yet another method to decrease risk of nutrient loss is through composting. Before application, manure can be put through a composting process that will create more stable nutrients that are 'slow release.' Compost (like manure) should be analyzed by a laboratory to determine the batch's nutrient value and ensure its proper use. Even compost can kill plants if over-applied.

Used properly, these organic amendments drastically improve both crop and soil health. It transforms 'waste' into fertilizer and closes the loop of a 'nutrient economy', which is an important component to sustainability.

3.0 Water Health and Conservation

Water Facts

(Farm and Food Care, 2016):



*A dairy cow drinks
80–160 litres of water per day
to produce 27 litres of milk*



*Canadians use up to 350 litres
of water per day per person—the
second highest in the world*



*A single load of laundry can
use up to 225 litres of water*

3.1 Water in Farming

Water is one of the most valuable resources within agriculture. Without access to clean and reliable sources of water, the agricultural industry cannot function as it has a vital role in the growth of crops and **livestock**. Surface (i.e. rivers, lakes) and **groundwater** are common sources of water for farms, however many farmers also depend on natural precipitation for their crops.

Plants absorb water from the soil and use it during **photosynthesis** to produce energy. A growing plant can be composed of anywhere between 80–95% water; therefore cropped fields need large amounts of water to grow food (FAO, 2016). Furthermore, raising livestock (chickens, pigs, cows etc.) requires a significant amount of water, with each species requiring a different volume. Water is necessary for livestock to regulate body temperature, aid in digestion, as well as absorb nutrients.

3.2 Farming Impacts on Water

Farming is a significant user of water in Ontario, but still falls behind municipal use and manufacturing (Loe, Kreutzwiser and Ivey, 2001). While the majority of water accessed is used to grow crops and livestock, a portion of the extracted water is also lost to runoff and evaporation. In Canada, over 90% of farms rely solely on precipitation for watering their crops – but this varies regionally according to climatic conditions (Farm and Food Care, 2014). Below is a quick snapshot of water use across the agricultural sector. The location of farms in rural communities where there are smaller sources of water such as lakes, rivers, groundwater and ponds, means that farms are often in competition with other rural water uses like municipalities, industrial users, golf course, quarries and residents (Loe, Kreutzwiser and Ivey, 2001). Over the past few decades we have seen local water shortages occurring across the province. Working within communities to develop water budgets may be an approach to deal with local water challenges (OFA, n.d.).

Below is a quick snapshot of water use across the agricultural sector.

TABLE 1. Estimated Agricultural Water Use in Ontario (Loe, Kreutzwiser and Ivey, 2001).

Agricultural Sector	Million m3/year	%
Livestock (All)	53.7	31.0
Field Crops	23.6	13.6
Fruit Crops	21.8	12.6
Vegetable Crops	22.2	12.8
Specialty Crops	51.8	29.5
Total	173.2	100.0

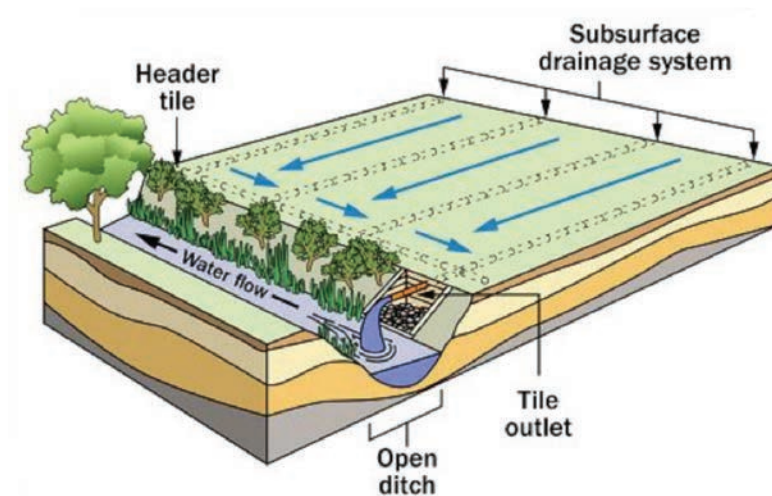
Note that use varies across the seasons, with livestock requiring water year-round, versus field crops which only require water during drier months.

3.2.1 DRAINAGE

When land is too wet to grow crops, farmers can use underground artificial **tile** drainage to remove the excess water. Tiles were traditionally made from fired clay, however today plastic tubing is often used. Tile drainage removes excess water from the crop root zone in the soil. While tile drainage can improve crop productivity and help to prevent flooding it may also have an effect on local water hydrology (Whiteley, 1979).

In Ontario, 43% of land classified as cropland has been tile drained. Tile drainage in Ontario is shallow, within only 3 feet (1 meter) of the surface; in contrast to tile drainage in the US that is significantly deeper (Fraser & Fleming, 2001).

FIGURE. 7: Tile drainage system. (OMFRA, 2016A)



How does tile drainage work? (University of Guelph, 2001)

Think about a bucket filled with a sponge. Initially, the sponge will absorb most added water. When the sponge becomes saturated, excess water will start to collect at the bottom and slowly rise to the top of the bucket. Much time must pass before evaporation appreciably lowers the water level to allow more water to be stored in the bucket. Now consider the effects of drilling a hole in the bucket about halfway up the side. Like before, the water is initially absorbed by the sponge until saturation. After that point, if water rises above the hole, the excess amount will flow out of the bucket until it is level with the hole again. Water is taken out of the second bucket (with the hole) at a much faster rate than from the first bucket which relies on evaporation to lower water levels. After a few minutes, the second bucket will be able to hold more water. In the same amount of time, the bucket with no hole will not be able to hold more water. The same principle applies to undrained and drained fields. A tile drained field is able to remove excess water through the tile drains during wet periods to provide storage volume within the soil profile for the next rainfall. On the other hand, an undrained field must rely on evaporation to remove excess water; this can take weeks. With drainage, it might take a few days.

3.3.2 IRRIGATION

In Ontario, only 13% of farms irrigate their crops, most commonly on high-value and weather sensitive crops such as fruits and vegetables (Statistics Canada, 2015). The method of irrigation is dependent on the crop type.

Irrigation Methods

- Sprinkler—distribute water onto crops in a high-velocity, high-volume spray
- Micro Irrigation—deliver water onto the soil surface very close to the crop or below soil
- Surface Irrigation (flood irrigation)—water flows by gravity over land

Sprinkler irrigation is the most popular irrigation method because it is well suited for irrigating large areas. Water supplies come from a variety of sources including on-farm lakes and rivers, underground wells, groundwater, or off-farm sources.

Irrigation Volume By Province

<http://www.statcan.gc.ca/pub/16-402-x/2011001/m003-eng.htm>

Irrigation has both direct and indirect impacts on the ecosystem. Removing water from sources such as groundwater, rivers and lakes can have an impact on the hydrological cycle by reducing downstream flow, increased evapotranspiration, increased levels in the water table, and increased flow in the irrigated area. Irrigation and pulling from local water sources can have an impact on local wetlands and forests.

3.2.3 GROUNDWATER

Groundwater is water found beneath the surface of the land in the porous spaces in soil and sediment deposits, or the fractures in rock (Environment Canada, 2008). Groundwater is an important water resource for rural families and businesses and in some cases may be the only water source. With increasing impacts of climate change on the quantity of water, managing and protecting groundwater quantity and quality is becoming more important now than ever. Aside from taking groundwater to water crops or provide for livestock, recharging groundwater resources can also become a problem if there is high soil compaction.

Agricultural practices that use high amounts of synthetic fertilizers or pesticides can leach downward and contaminate underlying stores of groundwater. Therefore it is important that proper management practices are taken to prevent contamination. Point source contaminants are when potential contaminants are concentrated or stored in one spot (e.g. manure piles, fuel storages, etc.). Non-point source contaminants are contaminants that are spread out over a greater area (e.g. pesticides, fertilizers).

3.2.4 CONTAMINATION

Water runoff on both agricultural and livestock farming can carry with it contaminants used in these industries. **Pastoral farming** (livestock farming or grazing) can pollute the water through the runoff of **manure** into water bodies if manure is not managed properly. This can occur when livestock are allowed direct access to rivers and streams without any restriction or through the failure to implement adequate manure management. Manure contains nutrients (nitrogen/phosphorous) and bacteria, and in some cases **pharmaceuticals** if they are used to enhance livestock growth or treat sick animals. These materials can have damaging effects

on aquatic ecosystems, especially when the farm is located on the water's edge (Minnesota Shoreline Management Resource Guide, 2016). Synthetic fertilizers and pesticides can also be carried away into local watercourses. Nutrient loads into close water bodies can impact local aquatic ecosystems and wildlife.

3.3 Water Conservation and Stewardship

Efficiency of water use can be improved through **innovation**. Innovation within agriculture is important in order to bring forward new ideas, methods, and technology that can enhance food production and resource efficiency. The need for new innovations and new policies becomes greater every year as the effects of climate change and food demand increase (Frisvold, 2015).

Farmers have a vital role and responsibility in improving the management of water resources given the amount of water consumed in agricultural practices (Kassam et al., 2014). Global food production will require a 60% increase in order to accommodate our rapidly growing population (Mulock, 2016). Solutions to water efficiency will be required to match this increase in production and to ensure that we don't run out of clean, safe water.

3.3.1 MANAGING CROP NEEDS

One of the most widespread conservation practices for watering crops involves monitoring crop needs and watering only when needed, in the evening or morning. Understanding the needs of plants at different stages of growth can also ensure efficient use of water resources. Monitoring water can be done using a number of traditional and innovative technologies including rain gauges, on-farm weather stations or moisture sensors.

3.3.2 IRRIGATION

Efficient irrigation requires farmers to pay close attention to the climate to reduce water loss. This includes monitoring wind, temperature, precipitation, and cloud cover, as well as monitoring soil conditions to apply water when needed. Improved technologies and practices, such as efficient irrigation systems, also help farmers to conserve water. Efficient irrigation systems take crop species, soil type and climate conditions into consideration when developing watering cycles and can make adjustments depending on changing variables (Seametrics, 2015). The implementation of gravity-flow systems and use of water flow meters also help control and conserve the water used in irrigation systems. The understanding of weather conditions and the use of local weather apps will prevent unnecessary application of irrigation water (Assouline et al., 2015). As mentioned above, understanding crop needs goes hand in hand with developing an efficient irrigation and watering plan.

3.3.3 PERMITS TO TAKE WATER (PTTW)

Permits to Take Water (PTTW) are required by the Ministry of the Environment for circumstances that involve removing more than 50,000 litres of water per day from watershed or groundwater sources.

Permits are not given for activities that negatively affect existing users, negatively affect the environment, or remove water from a watershed that already has a high level of use (MOECC, 2016). However, permits are not needed if you intend to take water for livestock, poultry, home gardens and lawns or for firefighting purposes.

3.3.4 NUTRIENT MANAGEMENT

Nutrient management planning includes the management of nutrients in fertilizers, manure and other nutrient sources from farm land. Good nutrient management ensures that crops and soils get all the benefits of nutrients without harming the environment. Farmers manage nutrients by:

- Testing soil and manure to determine current nutrient levels and what is needed in order to apply only what is needed
- Applying nutrients at the proper time of year to maximize use of nutrients
- Managing stored manure and other potential contaminants in a safe way
- Planning for emergencies to respond quickly and effectively

3.3.5 PESTICIDES AND WATER

Between 40-70% of surface water pesticide contamination comes from mixing and filling areas on farms (British Crop Protection Council, n.d.). To help prevent contamination, it is recommended that pesticides are mixed on impermeable surfaces located safely from watercourses or environmentally sensitive areas, and collect any drainage and run-off and dispose of it properly (BCPC 2007). All equipment should also be cleaned away from watercourses. In the case of any spill, it is important to immediately contain the spill to prevent any environmental contamination. It is also important that a minimum distance be kept between pesticide application and any surface water. The risk of drift decreases as distance increases, while rates of runoff increase with slope and higher volume of water during rainfall (OMAFRA 2013).

3.3.6 EFFICIENT TILE DRAINAGE

Managing nutrients in an environmentally responsible way is an important way to reduce the contamination of tile drains. This includes timely application of chemicals to avoid applying after or before a heavy rainfall, and ensuring that tiles are not installed near manure storage areas (University of Guelph, 2001). It is also important to monitor tile outlets for nutrient discharge (OMFRAA).

Other best management practices for nutrient management include:

- increase soil organic matter to help retain moisture
- water or energy saving nozzles and maintenance to prevent leaking
- reduce soil compaction by limiting machine travel routes and staying off soil when it is wet
- cover crops (see section 2)

4.0 Additional Best Management Practices

Best management practices (BMPs) are practical and affordable approaches to conserving farm's soil and water resources without sacrificing productivity (OMAFRA). BMPs are developed by a team of farmers, researchers, extension staff and agribusiness professionals. The goal is provide support in farm planning and decision-making in the short and long term.

4.1 Habitat Enhancements

4.1.2 BIODIVERSITY ENHANCEMENT PLAN

Wildlife is 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 and pollinators.

Birds

To minimize the need for pesticides, 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 experiencing sharp population declines in part because of changing farming practices and a shift away from mixed and pastoral farms to large acreages of cash crops. For instance, pasture lands that used to be home to ground nesting grassland birds may be removed to increase crop production. It is important to maintain bird populations in agricultural landscapes as they are an excellent pest management tool. This can be achieved by ensuring there is adequate habitat and nesting sites.

Pollinator Habitat

FIGURE 8: Adding pollinator habitat to farms helps struggling populations (*Farm and Food Care, n.d*)



The significant decline of insect pollinator populations, such as honey bees, bumble bees, and butterflies, poses a serious threat to 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, hedgerows and cover crops. 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. improved crop productivity and quality
- iv. alternative sources of income
- v. improved environmental health and sustainability

4.2 Reforestation

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.

4.2.1 TREE SHELTERBELTS AND WINDBREAKS

- 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

FIGURE 9: Windbreaks can provide several benefits when used on farms (*Farm and Food Care, n.d*)



4.2.2 VEGETATED BUFFER STRIPS

- 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

FIGURE 10: Example of a riparian buffer strip. (*Farm and Food Care, n.d*)



4.2.3 GRAZING MANAGEMENT PLAN

Overgrazing by livestock decreases plant vigour and growth over time. A grazing management plan looks at four key principles: balancing numbers of animals with forage supply; managing livestock distribution effectively; balancing grazing areas with rest areas to maintain vegetation; and avoid grazing during sensitive periods (OMAFRA, 2012). Rotational grazing can help to achieve these principles and allow plants to recover quickly and provide forage for the future. Additionally, rotational grazing can help farmers prevent livestock from being in sensitive areas such as areas that are too wet or dry therefore reducing compaction and runoff. A healthy pasture also reduces soil erosion (OMAFRA, 2016 B).

4.2.4 APPLICATION OF PESTICIDES AND INSECTICIDES

Honeybees, native bee species and other pollinating insects are critical for pollinating Ontario crops. Pesticides have been strongly linked with reducing these populations, impacting pollination. Timing of insecticide application can help to reduce the impact to pollinator populations. This includes avoiding application during the daytime when bees are foraging. Evening applications are safest when the environmental conditions are appropriate. Applying insecticides in the evening allows it to dry before bees are active again the next day (OMFRA, 2011). Law also requires farmers to not apply insecticides to fruit trees while in bloom because bees are foraging.

Other environmental considerations should be taken into account before application including windy conditions that may cause drift of insecticides to neighbouring farms or natural habitats impacting wildlife and vegetation. It is important that wind conditions are monitored to ensure spraying is not done on windy days.

5.0 Future of Farming

The challenges faced in the past, present and in the future have brought forth innovation in farming to ensure we can continue to provide for our growing populations.

5.1 Emerging Trends in Agriculture

Global food security is expected to face unprecedented challenges if environmental conditions continue to change at the current pace. Mitigating and slowing the increase in atmospheric CO₂ has been a significant point of concern in agriculture over the last few decades, as the industry has come to recognize the threats of climate change to their own longevity. An important piece of the food security puzzle is ensuring that sources of carbon sequestration are not disturbed or destroyed as much as is possible.

In some areas, changes in weather patterns have had continually worsening effects on agriculture. It has been recognized that with an increase in global temperature, the change in climate will give rise to new pests and diseases that interfere with agricultural production. As a result, there are various geographic areas in which farmers are facing urgent needs for more resilient and hardy crop systems in order to be able to withstand potential climatic changes. For example, California was once the most agriculturally productive state in America but now faces major obstacles with changing distributions of pests, diseases and water shortages (Lobell, 2016). It has also recently been discovered that many types of diseases that affect our crops are developing resistance to the chemicals used to control them (Kirchmann, 2000). Solution-oriented actions need to be implemented today to start working towards permanent solutions to these problems. Within this chapter, innovative technology and methods currently being used in North America to combat climate change will be discussed.

5.2 Integrated Pest Management

Across the globe, agricultural pests and diseases are controlled by a variety of methods to protect crop yield. There are a number of approaches that can be implemented for agriculture management, each with their respective economic and environmental advantages (Mulock, 2016). In the past few decades many farmers use pesticides to maintain high enough yields to stay competitive in today's farming industry. These chemicals have had a positive impact economically by nearly guaranteeing a successful crop each year; however the ecological impacts have become apparent. A well known example of this would be the pesticide DDT which was applied widely in North America and negatively impacted pollinator populations and caused deformities in birds of prey (Baker, 1974). Additionally DDT and similar **organochlorine** pesticides have the ability to **bioaccumulate** in the food chain affecting multiple trophic levels, especially apex predators. The observed effects have caused a considerable change in people's attitudes towards the use of these chemicals and providing political pressure for policy makers to enforce conservative use.

Integrated Pest Management (IPM) is a way of controlling disease and pest levels. It uses techniques like crop rotation, physical barriers, and use of beneficial insects and fungi as an integrated approach to managing pests. The system works with nature, with farmers monitoring fields closely to determine when, or if, pest levels reach a certain level that action needs to be taken. This may include mechanical means (tillage), cultural (bugs), or chemical (pests) (Farm and Food Care, 2014). By monitoring and choosing the right method of action, a more targeted approach can be taken to manage pests and disease.

Some pest management researchers have seen success in the application of biological control. **Biological control** is the use of natural enemies, such as herbivores, predators, parasite and pathogens to reduce pest populations.

5.3 Precision Agriculture

The applications of Global Positioning Software (GPS) and **multispectral** data in assessing **microclimates** and conditions of fields has the potential to minimize waste in fertilizer, seeds, pesticides, and other costly inputs. The soil and slope in any given area can affect the way that water moves over the land by either allowing water to absorb more quickly or by allowing it to runoff the field. This means that in some areas the healthy top layer of soil that contains all of the nutrients needed for growing is **eroded** more rapidly than in others (Barnes, 1996). To reduce unnecessary use of water and fertilizers, farmers and scientists are beginning to develop systems which analyze the geology and hydrology of their farms and adjust the usage of these products accordingly. After analyzing the conditions of the soil, data can be entered into the computers within the farm's machinery that specifically controls the release of products onto the field. Using this up-and-coming software, farmers can save time and money, and minimize their crop losses, as the site-specific methods allow for an advanced control of pests and disease (Barnes, 2016). The potential for growth in this field is vast, as more satellite technology, such as green leaf indexes and **infrared sensing**, can also be incorporated and provide an even more accurate picture of each individual farm.

5.4 Greenhouses and Hydroponics

A **greenhouse** is a building covered in glass, plastic, or fiberglass where most growing conditions can be controlled such as temperature, humidity, light, carbon dioxide and water (Farm and Food Care, n.d.). Hydroponics is a production method where plants are growing using water and nutrients instead of soil. Hydroponics and controlled greenhouse environments grows uniform products that minimize waste and maximize yield and quality (Ontario Greenhouse Vegetable Growers, 2016). There are over 200 greenhouse growers in Ontario that grow tomatoes (36.7%), peppers (35%) and cucumbers (38.3%), contributing to over \$840 million annually (Farm and Food Care, n.d.). Greenhouses provide vegetables with a longer growing season and provide Ontarians with local food almost year round.

While this type of growing can provide some foods almost year round, because of colder winters in Canada, the cost of heating may outweigh the cost of food production over the winter months. Therefore some greenhouses do not operate year round.

5.5 Biogas

Electricity can be generated through cattle manure in a process known as anaerobic digestion. This involves the decomposition of organic matter such as livestock manure, plant material and food waste, in an oxygen-free environment to produce methane-rich-gas (biogas). Biogas is a renewable gas that produces heat and electricity. The remaining waste can be used as fertilizer or animal bedding (Farm and Food Care, 2014). Farm-based biogas systems represent a significant opportunity for the agricultural industry to treat manure to reduce odour while capturing new value from byproducts (OMFRA, 2016 C).

5.6 Growing Greener Cities

With the rise of urbanization and urban sprawl, former farming communities in Southern Ontario and all across North America are undergoing big changes as they become impacted by urban expansion. This expansion can lead to environmental issues with groundwater recharge, surface water contamination, and polluted soil – conditions which may cause some big problems in the neighbouring ecosystems.

In response to this issue some cities across Canada and the U.S., are exploring urban agriculture as a tool to reduce the environmental impacts of urban sprawl. Urban agriculture is an umbrella term for growing food or raising livestock within the city limits. There are many ways this can be accomplished – green roofs, working lawns, community gardens or in some cases vertical gardens! Urban agriculture has positive impacts on soil and water conservation because it takes land within city limits that is otherwise unused or serving only aesthetic purposes, and uses it to produce food. This practice benefits the health and well-being of people, and on a large scale could feed many families while using less land—reducing the need to import food.

5.7 Climate Change and Farming

Food production is highly dependent on our climatic conditions; therefore the threat of climate change in changing weather patterns and growth conditions can have an impact on the availability of food in the future. Increased temperatures and carbon dioxide can be beneficial for some crops, but it has to work in conjunction with other basic needs that plants require such as nutrients and water. A changing climate means that distribution of some plants and animals could shift, or that it may change the ability for some plants to grow in their current location (EPA, 2016).

5.7.1 CHALLENGES FOR FARMERS

Challenges for crops (EPA, 2016):

- higher CO₂ levels can increase yield, but other growing factors may not work in conjunction with this ultimately inhibiting growth
- extreme temperatures and precipitation; increased frequency of storms
- drought and water availability
- weeds, pests and fungi may thrive under warmer conditions and increased CO₂ levels
- Challenges for livestock (EPA, 2016)
- heat waves could threaten livestock; overheating and heat stress
- drought can threaten pasture and feed supply
- increased prevalence of parasites and disease because of early onset of spring and warmer winters

5.7.2 OPPORTUNITIES FOR FARMERS

- Expansion of the growing season may mean that farmers are able to operate for longer. In addition, the change in climate could support the growth of new crops or livestock in Canada. A warming climate may also help to reduce energy costs required to operate greenhouses or heat livestock over winter months (Agriculture and Agri-Food Canada, 2015).
- Our current method of annual crop production may be changed to perennial crops (lives for more than two years) or convert some land to grazing lands. This means that soil quality could improve and carbon sequestration may be enhanced.

6.0 Agricultural Conservation Stewardship Programs

There are multiple Conservation Stewardship Programs available to farmers in Ontario, Canada and the USA. Conservation Stewardship programs are put in place to help agricultural producers maintain and improve their existing systems and adopt further conservation undertakings to address resources concerns.

6.1 Canadian Programs

Canada—Ontario Environmental Farm Plan

Agriculture and Agri-Food Canada, Ontario Ministry of Agriculture, Food and Rural Affairs

The Canada-Ontario Environmental Farm Plan (EFP) program is a voluntary self-assessment conducted by farmers to increase their environmental awareness. During the EFP process, farmers attend workshops and fill out risk assessment worksheets to highlight their farm's environmental strengths, identify areas of environmental concern and set realistic goals in an Action Plan with timetables to improve environmental conditions. Farmers may choose to submit their Action Plan for an independent review. The Environmental Farm Plan can be used in combination with cost-share programs to facilitate implementation of goals from the Action Plan. Action Plans focus on areas of the farm that would benefit from changes and reduce potential environmental risk. This federal and provincial plan allows for farms to be more environmentally aware and encourages sustainable farming practices.

Step 1: Attend an EFP Workshop delivered by the Ontario Soil and Crop Improvement Association —information provided on risk assessment and how to develop the Action Plan.

Step 2: Submit EFP Action Plan to the Ontario Soil and Crop Improvement Association for review

Step 3: Begin implementing the EFP Action Plan.

Species at Risk Farm Incentive Program

Environment Canada and Ontario Ministry of Natural Resources & Forestry

This program consists of a unique tiered cost-share structure that is tailored to farms and provides farm businesses funding to implement practices that protect, enhance or restore habitat for species at risk (SAR). This incentive program offers cost-share opportunities for farm-based stewardship projects such as improved stream crossings, fencing, habitat restoration, tree planting, invasive plant species removal and other Best Management Practices (BMPs) that could support SAR. This incentive program, funded through the Ministry of Natural Resources and Forestry (MNRF) and Environment Canada and delivered by the Ontario Soil and Crop Improvement Association, supports conservation efforts for species at risk.

Alternative Land Use Services

ALUS, the Alternative Land Use Services Program, is a community-developed, farmer-delivered program that provides support to farmers to enhance and maintain nature's benefits on their lands. It rehabilitates life-support processes, such as water filtration and purification, nutrient cycling and carbon sequestration, and helps restore declining biodiversity. Natural benefits include habitat for fish and wildlife including waterfowl, species at risk and native pollinator insects, cleaner air and water, and sustainable food production on working landscapes. For more information about the ALUS program visit <http://www.alus.ca>

Great Lakes Agricultural Stewardship Initiative; Farmland Health Incentive Program

Ontario Ministry of Agriculture, Food and Rural Affairs, Agriculture and Agri-Food Canada

The Great Lakes Agricultural Stewardship Initiative (GLASI) focuses on helping Ontario farmers improve soil health, water quality and pollinator health in the Lake Eries, Lake St. Clair and the southeast shores of Lake Huron watersheds. It is a multi-faceted program that offers both educational and financial support programs. GLASI is delivered by the Ontario Soil and Crop Improvement Association on behalf of OMAFRA.

The Farmland Health Check-Up is the main educational component of GLASI. It allows a farmer and a Certified Crop Advisor time to discuss the overall health of the farm property, using a workbook to keep the discussion focused on key topics. The results of the discussion are assessed, and areas for improvement are noted. Best Management Practices (BMPs) that will help address the specific need of each individual farm property are suggested.

The Farmland Health Incentive Program offers financial support to help implement the BMPs identified as part of the Farmland Health Check-Up. Higher levels of support are available to help implement BMPs that are identified as being of higher priority on the individual farm property. This allows the highest levels of support to go to the practices that should see the greatest impact, while still supporting the many great actions being implemented in less critical areas of the farm.

GLASI is also offering programs in highly targeted geographies that are encouraging a high density of BMPs in very small areas. These sub-watershed level projects are being heavily monitored to gauge how effected agricultural stewardship is at reducing phosphorus loss from the agricultural landscape.

Two other funding programs have been offered as part of GLASI; The Dust Deflector Program and the Manure and Biosolids Management Program. The Dust Deflector Program, which ran in 2015, allowed farmers to upgrade their planting equipment to reduce the impacts of insecticide seed treatments on pollinator populations. The Manure and Biosolids Management Program allowed business who custom apply manure and other organic amendments the opportunity to upgrade their equipment to allow more efficient use of these resources while reducing the potential environmental impacts. A custom applicator is hired specially to spread manure and other organic amendments, which means they work on several farms, allowing these improvements to equipment to benefit large areas of the province.

6.2 United States Programs

Conservation Reserve Program

United States Department of Agriculture

The Conservation Reserve Program (CRP) is a land conservation program overseen by the Farm Service Agency (FSA) and the United States Government. In exchange for a yearly rental payment, farmers enrolled in the program agree to remove environmentally sensitive land from agricultural production and plant species that will improve environmental health and quality. Contracts for land enrolled in this program are 10-15 years in length. The long-term goal of the program is to re-establish valuable land cover to help improve water quality, prevent soil erosion, and reduce loss of wildlife habitat. The Conservation Reserve Program initiatives include; Bottomland Hardwoods Initiative, Duck Habitat Initiative, Honeybee Habitat Initiative, Longleaf Pine Initiative, Pollinator Habitat Initiative, and Upland Bird Habitat Initiative to name a few. This program encourages sustainable farming and conservation efforts to farmers throughout the United States.

Environmental Quality Incentives Program

United States Department of Agriculture

This program provides technical and financial assistance to farmers and ranchers to implement conservation practices on their lands. Practices are based on national priorities that are reflective of the priorities in each state. These include: reduction of point- and non-point source pollution to watersheds and groundwater; water conservation; reduction of soil erosion; and promotion of wildlife habitat for at-risk-species. These priorities all affect the sustainability of the farm, and because of the Environmental Quality Incentives Program conservation efforts can now be implemented to improve the effects to the surrounding area.

2014 Farm Bill

United States Department of Agriculture

The 2014 Farm Bill combines conservation programs for feasibility, accountability and adaptability at the local level. This program builds upon previous successful partnerships and encourages agricultural producers and partners to design conservation projects that focus on and address regional priorities. This program thoroughly explores the topics of sustainable agriculture and conservation of agricultural land.

Conservation Stewardship Program

National Sustainable Agriculture Coalition

This innovative program was designed around the belief that we must enhance natural resource and environmental protection while producing profitable food and energy. By providing comprehensive conservation assistance to farms, the Conservation Stewardship Program offers farmers the opportunity to earn payments for actively managing, maintaining, and expanding conservation activities like cover crops, rotational grazing, ecologically-based pest management, even while they work their lands for production. This conservation initiative allows farmers to continue with their regular practices while implementing conservation practices and creating a sustainable farm.

Natural Resources Conservation Service; Agricultural Management Assistance
Federal Government of United States

This program pays financial assistance of up to 75% of the cost of installing conservation practices to currently operating farms. The total Agricultural Management Assistance program payments will not exceed \$50,000 per participant for any year. Farmers may undertake any of the following

- Construct or improve water management structures or irrigation structures;
- Plant trees for windbreaks or to improve water quality;
- Mitigate risk through production diversification or resource conservation practices, including;
 - Soil erosion control;
 - integrated pest management;
 - Transition to organic farming.

This program fully supports sustainable agricultural and conservation efforts in the United States.

7.0 Careers in Farming

Your typical farming career has changed from the traditional farmer—however these types of careers are still in high demand. Below are some examples of careers found online at AgCareers.com.

1. Research and Development

- Research Associate—use research equipment and lead computer related activities, work closely with research sites
- Research Agronomist—manage and conduct field research projects

2. Plant and Animal Health

- Animal Welfare Auditor—conduct animal handling/welfare audits and food safety audits

3. Environment, Conservation, Ecology and Stewardship

- Sustainability Specialist—implementing, developing and monitoring progress of the sustainability strategy

4. Financial Services and Computer Programming

- Agriculture Account Manager—professional relationship management, financial advice, portfolio management and risk mitigation

5. Marketing, Advertising and Communications

- Customer Marketing—responsible for the development and execution of customer campaigns
- Online News Reporter—report news accurately, understand types of stories that engage readers
- Branding and Content Specialist—develop communications to promote brand

6. Government, Policy and Regulations

- Corporate Affairs Manager—maintain relationships with policy makers; monitor and identify issues and suggest strategies

7. Food Processing, Distribution and Retail

- Agriculture Equipment Technician—diagnose and inspect equipment, repair and adjust, inspections
- Farm Manager—oversee the management of growing crop or livestock
- Farm Equipment Operator—equipment operations and farming, maintenance

8.0 Glossary of Terms

Agriculture- the science or practice of farming, including cultivation of the soil for the growing of crops and the rearing of animals to provide food, wool, and other products

Agricultural Hydrology- is the study of water balance components intervening in agricultural water management, especially in irrigation and drainage

Arable Farming- is growing crops in fields, which have usually been ploughed before planting

Bioaccumulation- refers to the accumulation of substances, such as pesticides, or other chemicals in an organism.

Biodiversity- a variety of different species in a particular environment and their interactions with each other and the physical environment

Conservation- the careful utilization of a natural resource in order to prevent its depletion.

Cover crop - crop grown for the protection and enrichment of the soil

Drainage System- is a system by which the water level on or in the soil is controlled to enhance agricultural crop production

Detritus- matter composed of plant parts, animal remains, waste products, and other organic debris

Efficiency- achieving maximum productivity with minimum wasted effort or expense

Eroded/ erosion- the action of surface processes that removes soil, rock, and dissolved materials about on the earth's surface.

Green roof - a building that is partially or completely covered with vegetation and a growing medium. It may also include additional layers such as a root barrier and drainage and irrigation system.

Greenhouse - a building covered in glass, plastic, or fiberglass where most growing conditions can be controlled such as temperature, humidity, light, carbon dioxide and water

Groundwater- the water beneath the surface of the ground, consisting largely of surface water that has seeped down

Horticulture- the branch of agriculture that deals with the art, science, technology, and business of growing plants.

Humus- non-living, finely broken down plant and animal substances

Innovation- the act of innovating; introduction of new things or methods

Irrigation- artificial application of water to the land or soil. It is used to assist in the growing of agricultural crops

Leaching- the loss of water-soluble plant nutrients from the soil; or applying a small amount of excess irrigation to avoid soil salinity, the loss of mineral and organic solutes due to percolation from soil

Livestock- the horses, cattle, sheep, and other useful animals kept or raised on a farm

Microbe- a microorganism, especially a bacterium causing disease or fermentation

Microclimate- a small area with climate that is different from the areas around it. It may be warmer or colder, wetter or drier, or more or less prone to frosts, and can be extremely small. A good example is a side of a building with minimal sun exposure. The shade creates different plant communities than the sunnier areas around it.

Mixed Farming- an agricultural system in which a farmer conducts different agricultural practices together, such as cash crops and livestock

Monoculture- the cultivation of a single crop in a given area.

Multispectral- a form of image that captures image data at specific frequencies across the electromagnetic spectrum. Filters or instruments which are sensitive to the particular wavelengths separate the image data.

Nutrient Cycle- how nutrients move from the physical environment into living organisms, and subsequently are recycled back to the physical environment

Organic Matter- anything that contains carbon compounds that were formed by living organisms

Organochlorine - a class of compounds with a similar chemical structure that persist in the environment and in the bodies of humans and other animals long after their use

Pastoral Farming- a form of agriculture aimed at producing livestock, rather than growing crops

Pesticides- a chemical preparation for controlling plant, fungal, or animal pests

Resources- money, or any property that can be converted into money or assets

Runoff- something that drains or flows off, as rain that flows off from the land in streams

Soil Aggregates- groups of soil particles that are more strongly bound together than other particles, by organic matter and substances created by bacteria and fungi

Stewardship- the management or care of something

Surface runoff – excess water on a slope that is not absorbed into the soil or is trapped on the surface

Sustainability- the quality of not being harmful to the environment or depleting natural resources, and thereby supporting long-term ecological balance

Symbiotic Relationship- a relationship between two or more organisms, needed to complete certain biological processes

Synthetic fertilizer- “man made” inorganic compounds. Also referred to as commercial fertilizer

Tile Drainage- practice that removes excess water from soil subsurface

Appendix 1: Case Study for Sustainable Farming

Mulock Farms Ltd.

Dustin Mulock is a second generation farmer, with a passion for promoting regenerative agriculture on a local and global scale. Located near Woodville, Ontario, Dustin is Director for the Innovative Farmers Association of Ontario (IFAO), an organization with the goal of sharing knowledge and introducing innovations amongst farmers in Ontario. He also runs a two-thousand acre farm, where he has tested and applied many innovations related to regenerative agriculture - a sub-component of sustainable agriculture. Dustin draws inspiration from his father, Carl Mulock, who has been leading his community towards alternative farming practices for decades.

Innovation

Throughout the many years of their operation, the Mulock family has explored and innovated with different methods in order to increase their crop yield and decrease their environmental impact. Their end goal was to decrease environmental impacts, produce better food, decrease production costs, and create a self-sustaining ecosystem. Some examples of innovative methods being used by Mulock Farms include:

- No-till
- Cover cropping
- Controlled traffic
- Banding

No-till is a form of conservation tillage, which is the method of leaving crop residue on fields when there are no crops planted. This allows natural processes to take effect, and preserves microbial bridges within the soil. Various species of bacteria, protozoa and fungi are left undisturbed by practicing no-till, which leads to a higher amount of nutrients left in the soil. The relationship between these organisms is extremely beneficial for soil quality, as the protozoa feed on the bacteria and release nutrients into the soil when they kill them. Fungi form a symbiotic relationship with plant species, helping to create an information sharing network through mycelium threads. Plants are therefore able to communicate with each other, warn each other of threats, and strengthen their immune systems. No-till leads to healthier soil maintained while crops aren't planted, preparing the soil for a more productive upcoming growing season. Mulock Farms rarely uses their tilling equipment, and have seen a significant increase in soil quality as well as a 30-40% increase in yield.

Cover-cropping is the method of using alternative plant species amongst their harvested species. Planting these cover-crop species increases the biodiversity within the field, leading to a suppression of weeds and resilience to disease and pests. The cover-crop species currently being used at Mulock Farms include barley, oats, and rye. These species are not harvested, but only serve as an ecological function. However, the crop efficiency for harvested species is greatly improved by preparing the soil and helping root structures.

Banding is a method of fertilizer application with an overall goal of minimizing the amount of fertilizer applied. It involves controlling how much fertilizer is used as well as where it is applied. Specialized farm equipment is used on Mulock Farms in order to choose precisely where fertilizer is applied, and to ensure a high amount of efficiency occurs with only small amounts of phosphorous and nitrogen used. An example of this equipment would be the FLEXICOIL 1720 air cart, which injects fertilizer right into the soil rather than allowing any runoff. Banding works cohesively with the controlled traffic method, which is the process of ensuring that farming vehicles only drive on a field when needed. Reducing the amount of driving on a field is important, since the compaction of soil caused by machines can be detrimental to soil health. The simple process of reducing the amount of driving lanes within a field goes a long way towards improving soil quality and reducing fuel costs for farmers.

FIGURE 11: FLEXICOIL 1720 air cart used on Mulock Farms.



Appendix 2: Hands-On Activities

Activity #1: Soil Health and Water Quality Relationship

The purpose of this activity is to demonstrate the importance of maintaining soil health, as well as the effects of disturbed soil on water quality. Participants will also gain knowledge on the types of sites and ecosystems which contain poor soil health. This activity was inspired by a demonstration done by Ray Archuleta, on the relationship between soil health and water pollution. To perform this activity, you will need the following materials:

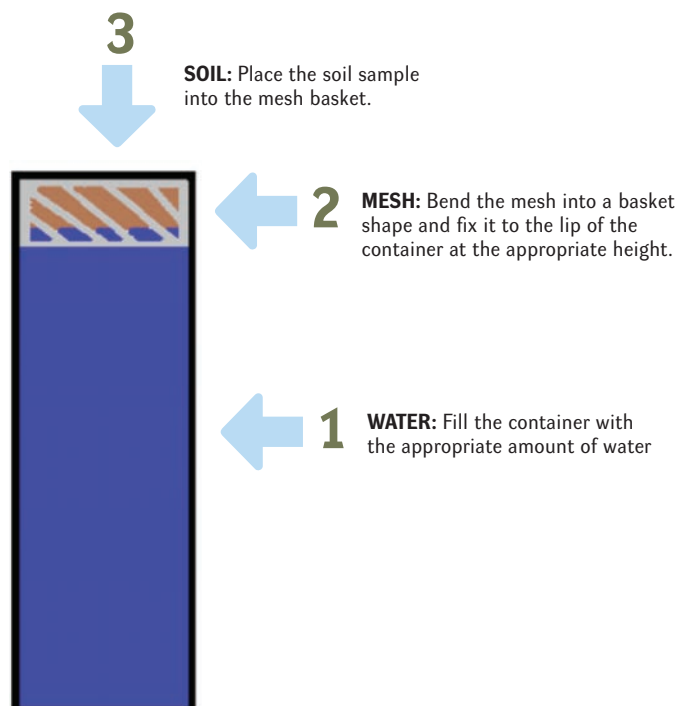
- Water
- 2 pieces of $\frac{1}{4}$ inch wire mesh, approximately 11/2 x 6 inches
- 2 soil samples from separate sites
- 2 transparent containers (i.e. graduated cylinders, beakers, glass jar)

**** Examples of sites to collect soil samples: lawns, orchards, pastures, forests, trails, tilled farm fields, non-tilled farm fields, forests, construction sites****

Shape the wire mesh into a basket which will sit only about an inch below the rim of the container. Then fill the container with water so that the water level surpasses the mesh. Simultaneously drop each soil sample into the mesh basket of a water container. Observe the effects that the different soil samples have on the water in each container.

Consider the following questions:

- Did both soil samples react the same way?
- What was the effect on the water?
- What can we conclude about the relationship between soil health and water quality?



Activity #2: Poster Challenge

Part of the challenge of sustainable agriculture is communicating the benefits of switching to more sustainable practices. In this activity create a poster that touches on soil conservation, water conservation, programs that could support the changes made to the farm and some innovative methods that could be use to improve the farm. You will then present the poster to potential farmers. Make sure to emphasize all the benefits that would be received by the environment and the farmer.

Prepare the class with sample questions from the community. Possible examples include:

- How does conserving the health of soil and water affect me and my business?
- My family has farmed here for two generations; my father and I have both made a decent living to support our families. How will conforming to these conservation initiatives impact our means of supporting ourselves?
- How will one farm making this change create a positive impact that really makes a difference?

Appendix 3: References

- Agriculture and Agri-Food Canada. (2015). Impact of Climate Change on Canadian Agriculture. Accessed from:
<http://www.agr.gc.ca/eng/science-and-innovation/agricultural-practices/climate/future-outlook/impact-of-climate-change-on-canadian-agriculture/?id=1329321987305>
- Agriculture and Agri-Food Canada. (2014). Issues, Management Problems and Solutions for Maintaining a Zero Tillage System and Other Beneficial Soil Management Practices (4 of 10). Government of Canada. Accessed from:
<http://www.agr.gc.ca/eng/science-and-innovation/agricultural-practices/soil-and-land/soil-management>
- All About Food. (2014). The Facts about Conventional and Organic Agriculture. Accessed from:
<http://allaboutfood.aitc.ca/article/the-facts-about-conventional-and-organic.php>
- Assouline, S., Russo, D., Silber, A., & Or, D. (2015) Balancing water scarcity and quality for sustainable irrigated agriculture. *Water Resources Research*. 51 (5): 3419 – 3436. doi: 10.1002/2015WR 017071
- Baker, K. F., & Cook, R. J. (1974). *Biological control of plant pathogens*. WH Freeman and Company.
- Barnes, E. M., Moran, M. S., Pinter, P. J., & Clarke, T. R. (1996). Multispectral remote sensing and site-specific agriculture: examples of current technology and future possibilities. *Precision Agriculture*, (precisionagricu3), 845-854.
- Bernacchi, C. J., Hollinger, S. E., & Meyers, T. (2005). The conversion of the corn/soybean ecosystem to no till agriculture may result in a carbon sink. *Global Change Biology*, 11(11), 1867-1872.
- Bot, Alexandra and Benites, Jose. (2005). The importance of soil organic matter: Key to drought-resistant soil and sustained food production. Food and Agriculture Organization of the United Nations; Annex 1. 61-69
- Chartzoulakis, K. & Bertaki, M. (2015) Sustainable water management in agriculture under climate change. *Agriculture and Agricultural Science Procedia*, 4: 88 – 89, doi: 10.1016/j.aaspro.2015.03.011
- Climate Institute (2016). Water and Climate Change. Retrieved from:
<http://www.climate.org/topics/water.html>
- Corriher, T. (2009). How Chemical Fertilizers Are Destroying Your Body, The Soil, and Your Food - The Health Wyze Report. Retrieved from:
<http://healthwyze.org/reports/100-how-chemical-fertilizers-are-destroying-your-body-the-soil-and-your-food>

DuPont, S. Tianna. (2012). Introduction to Soils: Soil Quality. Pennsylvania State College of Agricultural. Accessed from:

<http://extension.psu.edu/business/start-farming/soils-and-soil-management/soil-quality-introduction-to-soils-fact-sheet>

Environmental Protection Agency (EPA). (2016). Climate Impacts on Agriculture and Food Supply. Accessed from:

<https://www3.epa.gov/climatechange/impacts/agriculture.html>

FAO (2016). Organic Agriculture. Food and Agriculture Organization of the United Nations. Accessed from:

<http://www.fao.org/organicag/oa-faq/oa-faq1/en/>

Farm and Food Care. (n.d.). Facts & Figures About Canadian Greenhouse Vegetables. Accessed from:

<http://www.farmfoodcare.org/canada/wp-content/uploads/2016/03/Fact-Sheet-GreenhouseVeg-2016.pdf>

Farm and Food Care. (2014). The Real Dirt on Farming. Accessed from:

www.realdirtontfarming.ca

Fraser, Heather and Flemin, Ron. (2001). Environmental Benefits of Tile Drainage: Literature Review. Accessed from:

http://www.ridgetownc.uoguelph.ca/research/documents/fleming_drainage.pdf

Frisvold, G. B. (2015). Water, agriculture, and drought in the west under changing climate and policy regimes. *Natural Resources Journal*, 55(2), 293-328.

Florentin, M. A., Panalva, M., Clegari, A., & Derpsch, R. (2010). Green manure/cover crops and crop rotation in Conservation Agriculture on small farms. *Integrated Crop Management*, 12.

Kassam, A., Derpsch, R., & Friedrich, T. (2014). Global achievements in soil and water conservation: the case of conservation agriculture. *International Soil and Water Conservation Research*, 25-13. doi:10.1016/S2095-6339(15)30009-5

Kirchmann, H., & Thorvaldsson, G. (2000). Challenging targets for future agriculture. *European Journal of Agronomy*, 12(3), 145-161.

Lobell, D. B., Field, C. B., Cahill, K. N., & Bonfils, C. (2006). Impacts of future climate change on California perennial crop yields: Model projections with climate and crop uncertainties. *Agricultural and Forest Meteorology*, 141(2), 208-218.

Loe, Kreutzweiser and Ivey. (2001). Agricultural Water Use in Ontario. Retrieved from:

<http://www.tandfonline.com/doi/pdf/10.4296/cwrj2601017>

MgGill News (2012) New Study Sheds Light on Debate Over Organic vs. Conventional Agriculture. Retrieved from:

<https://www.mcgill.ca/newsroom/channels/news/new-study-sheds-light-debate-over-organic-vs-conventional-agriculture-216138>

Minnesota Shoreline Management Resource Guide (2016) Effects of agriculture near water. *Quick and Easy Answers*. Retrieved from:

<http://www.shorelandmanagement.org/quick/ea.html>

Ministry of Environment and Climate Change (MOECC). (2016). Permit to take water.

Retrieved from:

<https://www.ontario.ca/page/permits-take-water>

Mulock, D. (2016, February 8th) Personal Interview.

Mulock, D. (2016, March 22nd) Personal Interview

Ontario Federation of Agriculture (OFA). (n.d.). Water Policy. Retrieved from:

<http://www.ofa.on.ca/issues/overview/water-issues.aspx>

OMAFRA. (2016 A). Operating and Maintaining a Tile Drainage System. Accessed from:

<http://www.omafra.gov.on.ca/english/engineer/facts/10-091.htm>

OMAFRA. (2016 B). Rotational grazing in Extensive Pastures. Retrieved from:

http://www.ontariosoilcrop.org/wp-content/uploads/2015/08/rotational_grazing_in_extensive_pastures.sm_.pdf

OMAFRA. (2016 C). Biogas Incentives and Requirements: Building a Farm-Based Biogas System in Ontario. Retrieved from:

<http://www.omafra.gov.on.ca/english/engineer/biogas/incentives.htm>

OMAFRA. (2014). RUSLE2 for Ontario. Retrieved from:

<http://www.omafra.gov.on.ca/english/engineer/rusle2/index.htm>

OMAFRA. (2013). Pest Management Infosheet #20. Retrieved from:

<http://www.ontariosoilcrop.org/wp-content/uploads/2015/08/EFPIinfosheet20.pdf>

OMAFRA. (2012). Soil Erosion—Causes and Effects. Retrieved from:

<http://www.omafra.gov.on.ca/english/engineer/facts/12-053.htm>

OMFRA. (2011). Using Pesticides in Ontario. Retrieved from:

<http://www.omafra.gov.on.ca/english/crops/resource/using-pesticides.htm>

Ontario Greenhouse Vegetable Growers. (2016). Fact Sheet. Retrieved from:

<http://ogvg.com/pdf/2016-Fact-Sheet.pdf?version=7.2>

Seametrics Blog (2015) Five effective water conservation tools for farmers. *Technology With A Mission*. Retrieved from:

<http://www.shorelandmanagement.org/quick/ea.html>

Sharma, R. R., Singh, D., & Singh, R. (2009). Biological control of postharvest diseases of fruits and vegetables by microbial antagonists: A review. *Biological control*, 50(3), 205-221.

Staropoli, N. (2015). No-till agriculture offers vast sustainability benefits. So why do Organic farmers reject it?. Genetic Literacy Project. Accessed from:

<https://www.geneticliteracyproject.org/2015/07/12/no-till-agriculture-offers-vast-sustainability-benefits-so-why-do-organic-farmers-reject-it/>

Statistics Canada. (2015). Agricultural Water Use in Canada. Retrieved from:

<http://www.statcan.gc.ca/pub/16-402-x/2011001/part-partie1-eng.htm>

United States Department of Agriculture (USDA). (2007). Sustainable Agriculture: Definitions and Terms. Retrieved from:

<http://www.nal.usda.gov/afsic/pubs/terms/srb9902.shtml>

University of Guelph. (2001). Tile Drainage—Questions and Answers. Accessed from:

http://www.ridgetownc.uoguelph.ca/research/documents/fleming_faqs123.pdf

Wander, Michelle and Gruver, Joel. (2008). Soil Quality: Tillage. Soil Quality. Accessed from:

<http://soilquality.org/practices/tillage.html>

Wang, T., Park, S. C., & Jin, H. (2015). Will farmers save water? A theoretical analysis of groundwater conservation policies. *Water Resources and Economics*, 1227-39. doi:10.1016/j.wre.2015.10.002

H.R. Whiteley (1979) HYDROLOGIC IMPLICATIONS OF LAND DRAINAGE , *Canadian Water Resources Journal / Revue canadienne des ressources hydriques*, 4:2, 12-19, DOI: 10.4296/cwrj0402012