CHAPER 12 METRIC CONVERSIONS

Metric	Imperial Equivalent
5 °C	41 °F
7 °C	45 °F
0.1 m	0.33 feet
1 m	3.3 feet

Conversions in this table are rounded to a convenient number.
See Appendix E for exact conversion factor.

Values from tables and examples are not included in Metric Conversions

CHAPTER 12 TABLE OF CONTENTS

CHAPTER **12**

CLIMATE CHANGE

INTRODUCTION

Agriculture both affects, and is affected by, a changing climate. This chapter discusses farm management practices that provide co-benefits of reducing greenhouse gas emissions that are produced by agriculture and support climate change mitigation and practices, which increase resilience to climate change impacts and support adaptation. Understanding which adaptation measures reduce climate change risks to production is critical to choosing practices that ensure long-term resilience and sustainability of farming and ranching. This chapter also addresses environmental concerns, legislation and beneficial management practices related to:

- Climate change mitigation,
- Climate change adaptation.

Every operation and its location is different, so there is no universal set of climate change adaptation or mitigation practices for agriculture. Options to increase the flexibility and resilience of agriculture under climate change must be evaluated at the farm level and consider changing factors including climate, soils, land use and management patterns, and cost and benefit ratios. In addition to resources listed here, agricultural climate change information is available from the BC Agriculture & Food Climate Action Initiative (CAI), the B.C. Ministry of Agriculture, Food and Fisheries, the B.C. Ministry of Environment and Climate Change Strategy, and other expert sources.

CLIMATE CHANGE FACTORS

Greenhouse Gases (GHGs). When the sun's rays strike the earth, some light energy is converted into heat energy, which can radiate into the atmosphere and be lost. Certain gases block the escape of this heat energy, resulting in a warming of the Earth's atmosphere known as the 'Greenhouse Effect', which is essential for life on earth. Human activities, including agriculture, are increasing levels of these greenhouse gases (especially carbon dioxide, methane and nitrous oxide) contributing to the *Enhanced Greenhouse Effect* which causes more heat to accumulate.

Carbon Dioxide (CO_2). Carbon dioxide is a greenhouse gas accumulating in the atmosphere from increased sources (i.e., combustion of fossil fuels and biomass, decomposition of organic matter) and reduced sinks (i.e., deforestation, draining wetlands and clearing agricultural land). CO_2 is a relatively weak GHG, with a very long atmospheric life span, so CO_2 emissions increase the greenhouse effect for centuries after their release. CO_2 is the reference gas for the global warming potential (GWP x 1) of all other GHGs, which are sometimes measured by their equivalent as CO_2e.

Methane (CH_4). Methane is a powerful greenhouse gas; one kg of methane has the global warming potential of 25 kg of CO_2e (GWP x 25). Methane is produced during anaerobic (in the absence of oxygen) decomposition of organic matter such as manures. Ruminant livestock produce methane during digestion through the process of enteric fermentation. Methane from livestock is the single largest source of GHG emissions from agriculture in B.C. Methane has a strong greenhouse effect but a short atmospheric life span, meaning management to reduce agricultural methane emissions has a more immediate impact to reduce global warming. .

Nitrous Oxide (N_2O). Nitrous oxide is a very powerful greenhouse gas; one kg of nitrous oxide is the equivalent to 298 kg of CO_{2e} in terms of global warming potential (GWP x 298). Nitrous oxide is produced in the soil from the biochemical reduction of nitrate to gaseous nitrogen compounds, a process known as denitrification. Because of its very high global warming potential and relatively long life in the atmosphere, avoiding N_2O emissions has significant and long-lasting climate benefits..

Other Concepts Related to Climate Change

Adaptation. Adjustment in natural or human systems in response to actual or expected climate impacts, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory, autonomous and planned adaptation:

- *Anticipatory adaptation* – Adaptation that takes place before impacts of climate change are observed. Also referred to as proactive adaptation.
- *Autonomous adaptation* – Adaptation triggered by ecological changes in natural systems and by market or welfare changes in human systems. Also referred to as spontaneous adaptation.
- *Planned adaptation* – Adaptation from a deliberate policy or practice decision, based on an awareness that conditions have changed or are about to change and that action is required to return to, maintain, or achieve a desired state.

Carbon Offsets. A carbon offset system is a financial instrument that establishes tradable credits for GHG reductions and is aimed at encouraging cost-effective reductions or removals of GHGs. In most systems, one carbon credit can offset one metric tonne of carbon dioxide (tCO_2) or its equivalent (tCO_2e) in other GHGs, so the net emissions are zero. If carbon credits are retired rather than sold, they represent reductions rather than being offsets.

Carbon Sequestration. Plants and soil organic matter play an important role in removing carbon dioxide from the air and storing it (sequestering) in carbon sinks. Carbon is the main component in plant material and soil organic matter. Any net uptake of carbon dioxide from the air by plant material or soil will only reduce the amount of carbon dioxide in the atmosphere until decomposition.

Fossil Fuel. Fuels such as oil, gasoline, diesel, propane and natural gas are fossilized hydrocarbon deposits, produced from carbon chains stored underground for millions of years. When extracted and burned, CO_2 and other pollutants are released to the atmosphere. The combination of increased fossil fuel emissions and decreased carbon sequestration from deforestation has lead to a net increase in atmospheric CO_2 concentration.

GHG Reduction. Reduction projects are those that reduce or prevent the release of GHGs into the atmosphere to mitigate global warming.

Global Warming Potential (GWP). Each GHG differs in its ability to trap heat energy in the Earth's lower atmosphere. The combination of the GHGs structural ability to trap heat and lifetime in the atmosphere determines the Global Warming Potential (GWP). GWP is a relative unit measured against the baseline of carbon dioxide (CO_2) over a 100 year time span. For example, methane has a GWP of 25 carbon dioxide equivalency (CO_2e) (i.e., 25 times the warming effect of CO_2 over 100 years). One tonne of CH_4 equates to 25 tonnes of CO_2e and one tonne of N_2O equates to 298 tCO_2e..

Mitigation. Projects, actions and management practices that offset, reduce or prevent GHG emissions from farms and agri-food activities or increase the amount of GHGs being taken out of the atmosphere and sequestered for a specified period of time. This is called climate change mitigation.

CLIMATE CHANGE AND AGRICULTURE

What is Anthropogenic Climate Change?

The *Enhanced Greenhouse Effect* has trapped additional heat energy near the Earth's surface which is causing the global climate system to change **(Figure 12.1)**. Anthropogenic or human caused climate change refers to changes in the modern climate as a result of human activities that have increased GHG concentrations in the atmosphere. The scientific community agrees that climate change is caused by human activities, including agriculture, by elevating GHG levels in the atmosphere.

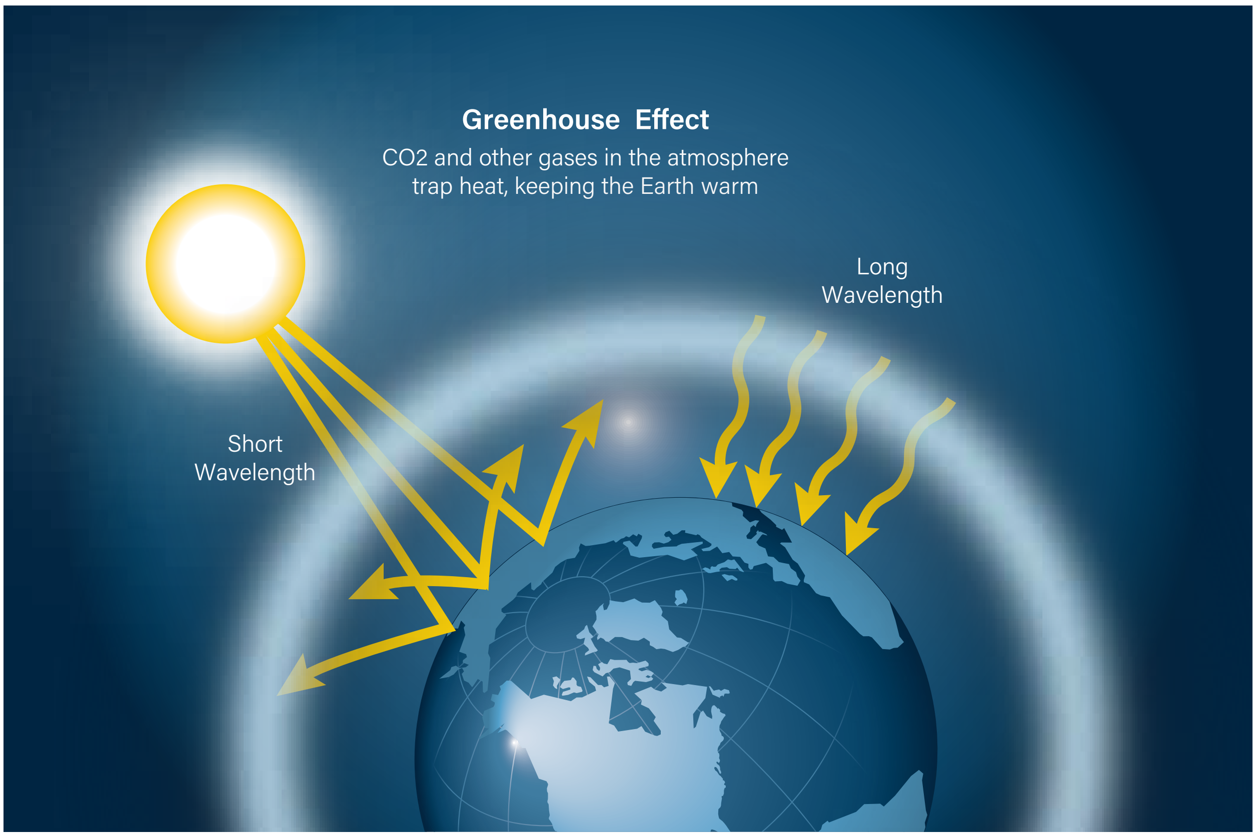


FIGURE 12.1 A simplified representation of the greenhouse effect

Understanding how agriculture contributes to, and is impacted by, climate change, will help the sector to both mitigate the causes of climate change and adapt to the consequences (Figure 12-2).

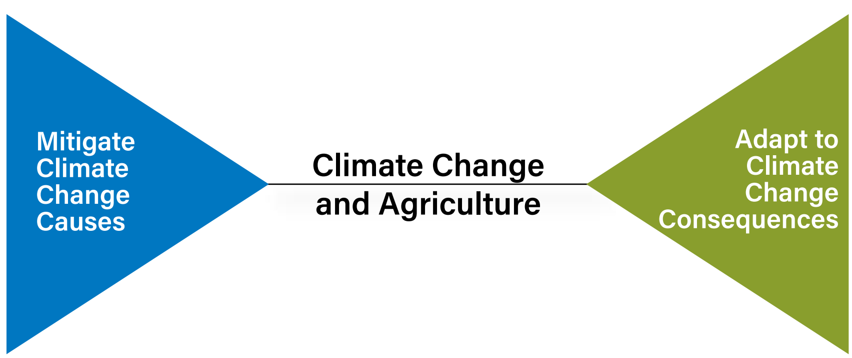


FIGURE 12.2 Schematic relationship between agriculture and climate change adaptation and mitigation.

Many activities from farm operations release GHGs such as CO_2, CH_4 and N_2O, into the atmosphere. While these gases are also naturally exchanged between the atmosphere, the oceans, the soil, and living organisms, additions from human activities are upsetting the natural balance.

Some agricultural practices temporarily store carbon, reducing current levels of carbon dioxide in the atmosphere. Minimizing the release of GHGs while also storing carbon in vegetation and soils can result in farms and ranches having a much lower impact on climate change (**Figure 12-3**).

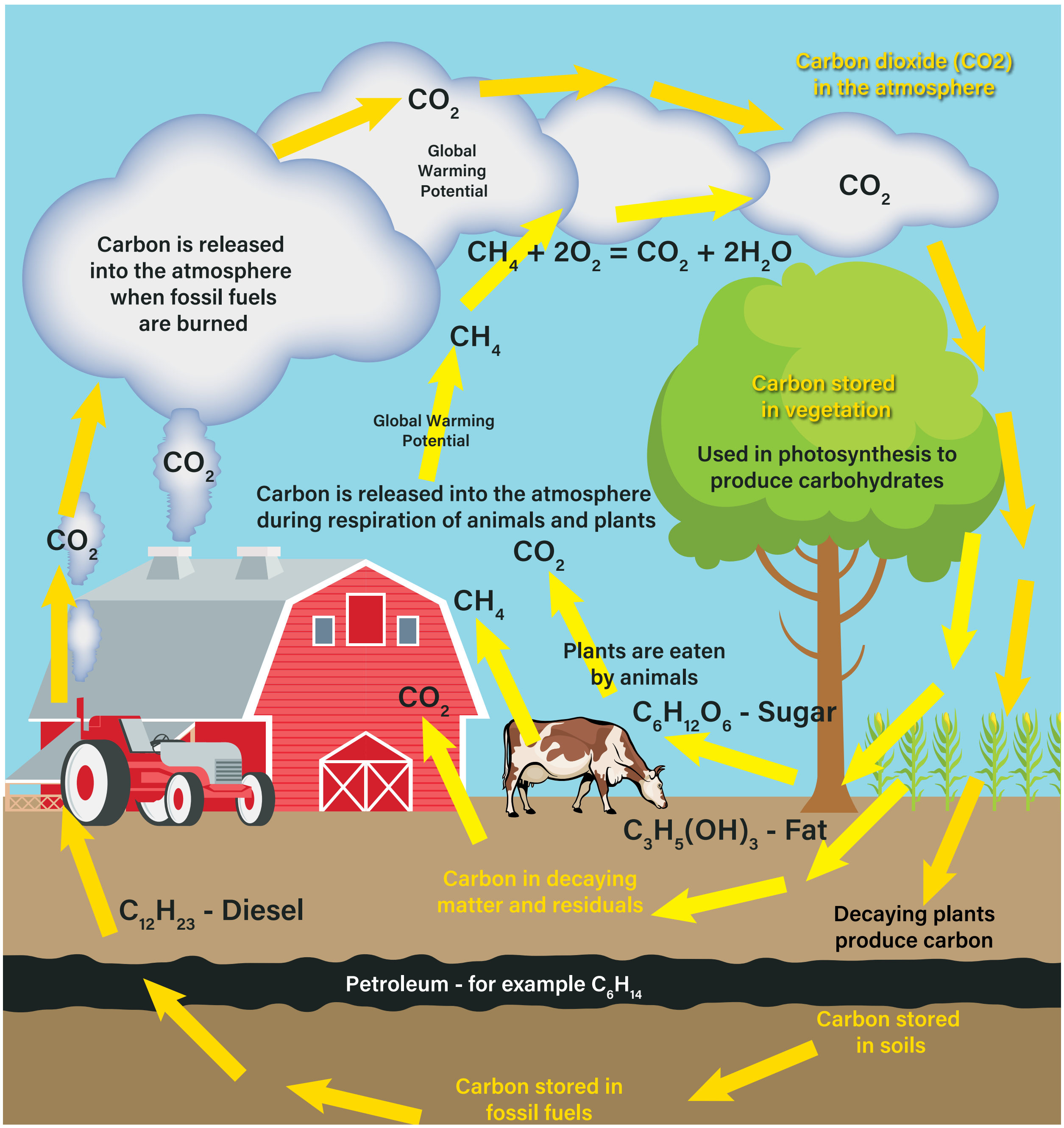


FIGURE 12.3 Example of an agricultural carbon cycle

Climate change has already shifted averages, altered the variability of daily and seasonal temperature and precipitation measurements, and increased the frequency and severity of extreme weather events. While the extent of changes and impacts has varied across the Province, changes have been pronounced in all seasons. In general, B.C. is expected to experience warmer, wetter winters and hotter, drier summers. While averages across seasons tend to minimize what climate extremes are expected, some of the anticipated impacts for B.C. are summarized below. These B.C. average and high range projections are based in the Plan2Adapt tool, and vary considerably across the Province:

According to Canada's Changing Climate report, 2019 there will be:

- Temperature: (avg.) +1.8 to +2.7 (high range) degrees Celsius increase in average annual temperature in B.C. by 2050, and (avg.) +2.7 to + 4.5 (high range) degrees Celsius increase by 2080 (Plan2Adapt, 2018).
- Precipitation: (avg.) +6% to (high range) +12% increase in precipitation by 2050, and (avg.) 9% to (high range) 17% increase by 2080, with the largest changes occurring during the winter (Plan2Adapt, 2018).
- Snowpack: (avg.) -75% to (high range) -95% reduction in the number of glaciers by 2100, decreased snowfall, and earlier snowmelt, leading to reduced snowpack and water shortages and drought during the growing season.
- More frequent and intense extreme weather events and disasters such as flooding, wildfires, drought, and high-intensity precipitation and wind storms.
- Higher intensity rainfall events will lead to increased soil erosion and drainage issues.
- Changes in ecosystems and ecosystem functions resulting in changes in biodiversity and habitats:
    - Greater potential impacts to species at risk and fisheries new pest and disease outbreaks.
    - A 2 to 7 degree Celsius increase in average annual temperature in BC by 2080.
- Increased storm surges in coastal areas and subsequent vulnerability to flooding and erosion (Canada's Changing Climate Report, 2019).
- Sea level: rise of (avg.) 0.74 to (high range) 1.39 m by 2100 (Canada's Changing Climate Report, 2019).

Plan2Adapt

Indicators of Climate Change in BC 2016 Update

BC Government Website: Impacts of Climate Change

Canada`s Changing Climate Report 2019

IMPACTS OF AGRICULTURAL ACTIVITIES ON GREENHOUSE GAS EMISSIONS

Agriculture's Contribution to Climate Change

Overall, B.C. agriculture's contributions to the total GHG emissions in the Province are relatively small and diffuse. Estimating the magnitude of the emissions associated with agriculture is complex because of the range of agricultural practices and other variables such as soil, climate and land cover. The most recent BC Greenhouse Gas Inventory Report 2016 estimates that agriculture was directly responsible for about 3.7% of B.C.'s total GHG emissions. The sources of agricultural emissions identified in the report include:

- Enteric fermentation in ruminant livestock.
- Manure management.
- Soil management and fertilization.

The report attributes 61.1% of B.C.'s total GHG emissions directly produced by agriculture to enteric fermentation, 17.5% from manure management practices and 21.4% from agricultural soil disturbance (e.g., tillage) and applying fertilizer.

Importantly, however, the agricultural sector total does not include emissions related to land use and land use changes (deforestation and grassland conversion to cropland, carbon flux resulting in changes to tillage), or agricultural fossil fuel use associated with farm buildings, equipment operations, and transportion. Therefore, the total GHG contributions of agricultural producers are not fully reflective of the emissions reported for the sector in the inventory report.

Farm Activities and Impacts

Agricultural practices that alter natural ecosystem functions can accelerate or amplify the release of GHGs into the atmosphere. On the other hand, practices that complement or accentuate natural processes can store carbon and decrease GHG emissions.

Other components of the food system that contribute to GHG emissions as sources include:

- Emissions from energy used for food processing.
- Transportation and storage associated with food products.
- Production of chemical fertilizer and petro-chemical based pesticides.

Sources of GHGs attributed to off-farm aspects of the food system will not be discussed in this chapter, as they are largely out of the control of individual farmers. The following are on-farm activities that are known to impact climate change. Activities are listed in alphabetical order.

Clearing Land. Clearing land for crop production releases CO_2 that was previously bound in soil organic matter and biomass such as trees and grasslands. In addition, there are fewer trees to store carbon through their growth so carbon sinks are also reduced. This contributes to a net increase of CO_2 in the atmosphere.

Combustion of Fossil Fuels. The combustion of fossil fuels such as oil, diesel, propane, gasoline and natural gas which are used for heat production, transportation and the powering of farm equipment, increase atmospheric CO_2 concentrations.

Drainage Management. Draining wetlands to create new agricultural production areas increases the decomposition of organic soils and releases CO_2 into the atmosphere. Once in production, incomplete drainage of agricultural soils can create anaerobic conditions (absense of air) that causes additional conversion of nitrogen in fertilizers and manure into CH_4 and N_2O.

Enteric Fermentation. Enteric fermentation is a process that takes place in ruminant livestock which releases CH_4 as part of the natural digestion process of complex carbohydrates. This process contributes to a net increase in atmospheric CH_4 concentrations..

Manure. Anaerobic digestion during storage of livestock manure emits CH_4, contributing to a net increase in atmospheric CH_4 concentrations. Manure also undergoes nitrification and dinitrification, producing N_2O emission during decomposition.

Mineral and Organic Fertilizer Use. In agricultural production, some nitrogen fertilizers may be converted from forms that do not impact GHG emissions to N_2O, increasing atmospheric N_2O concentrations.

Soil Organic Matter Degradation. Soil organic matter degradation is accelerated by various farm practices such as tillage causing less carbon to remain stored in soils. This increases atmospheric CO_2 concentrations..

CLIMATE CHANGE MITIGATION

CLIMATE CHANGE ENVIRONMENTAL CONCERNS

Environmental concerns related to climate change mitigation and GHG emissions from agriculture are:

- Enteric fermentation from cattle and other ruminants resulting in CH_4 emissions.
- Manure production and storage resulting in CH_4 emissions.
- Mineral and organic fertilizer use resulting in N_2O emissions.
- Burning of fossil fuels resulting in CO_2 emissions.
- Uncontrolled open burning or fuel accumulations on the landscape contributing to wildfires that release large quantities of CO_2.
- Clearing land for crop production resulting in CO_2 emissions from carbon that was previously stored.
- Draining wetlands for crop production resulting in CO_2 emissions from carbon previously stored in organic soils.
- Degradation of soil organic matter accelerated by farm activities (e.g. tillage), resulting in CO_2 emissions and reduced carbon storage.

For more information on these concerns:

➔ see Impacts of Agricultural Activities on Greenhouse Gas Emissions, **page 12-5**

CLIMATE CHANGE MITIGATION LEGISLATION

The following is a brief outline of the main legislation that applies to climate change mitigation.

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

Carbon Tax Act

The *Carbon Tax Act* establishes a carbon tax in BC. The carbon tax is a broad based tax that applies to the purchase or use of fuels, such as gasoline, diesel, natural gas, heating oil, propane, coal, and the use of combustibles, such as peat and tires, when used to produce heat or energy. The carbon tax applies to fuels at different rates depending on their anticipated carbon emissions.

Farmers are not required to pay carbon tax on coloured fuel purchased for farming operations.

Environmental Management Act

The *Code of Practice for Agricultural Environmental Management* requires persons to use environmentally responsible and sustainable agricultural practices when carrying out agricultural operations, for the purpose of minimizing the introduction of waste into the environment and preventing adverse impacts to the environment and human health.

The Act also contains the *Waste Discharge Regulation*, which authorizes the introduction of waste into the environment from certain industries, businesses and operations. Proponents of an on-farm anaerobic digestion project will require a waste discharge authorization. Guidelines for on-farm anaerobic digestion are available from the BC Ministry of Environment and Climate Change Strategy.

On-Farm Anaerobic Digestion Waste Discharge Authorization Guideline

Greenhouse Gas Industrial Reporting and Control Act

The Act enables performance standards to be set for industrial facilities or sectors. Single sites which emit 10,000 tonnes or more of CO_2e per year must report their emissions, and those which emit 25,000 tonnes or more will be regulated. There are currently only three agricultural facilities in B.C. that emit over 10,000 tonnes per year and which are required to report their emissions.

The *Greenhouse Gas Emission Control Regulation* under the Act sets out the requirements for GHG reductions and removals from projects or actions that qualify as emission offsets. There are opportunities to develop agriculture-based projects, such as greenhouse operators switching to biomass boilers.

Climate Change Accountability Act

The Act commits B.C. to reductions of GHG emissions by at least 40% (from 2007 levels) by 2030, at least 60% by 2040, and at least 80% by 2050. Agricultural emission reductions are not regulated, but if they do not occur while reductions occur in other sectors, agriculture will produce a greater share of total GHG emissions than it does currently.

Under the Act, public sector organizations are required to be carbon neutral.

In addition, through the *Climate Action Charter* (separate from the Act), a large number of local governments have agreed to become carbon neutral and developed municipal Climate Plans to mitigate emissions. Through this process, local governments may encourage reduction of agricultural GHG emissions in the municipality.

CLIMATE CHANGE MITIGATION BENEFICIAL MANAGEMENT PRACTICES

Greenhouse gas emissions from agricultural activities can be reduced through three general approaches (Figure 12-5):

- Reduce energy use and material inputs, making the most efficient use of inputs and minimizing waste, leakage and loss.
- Replace fossil fuels with renewable energy sources.
- Remove carbon by sequestering it in agroforestry plantings or enhancing soil organics / Restore wetlands, forests and grassland areas that are natural stores of carbon.

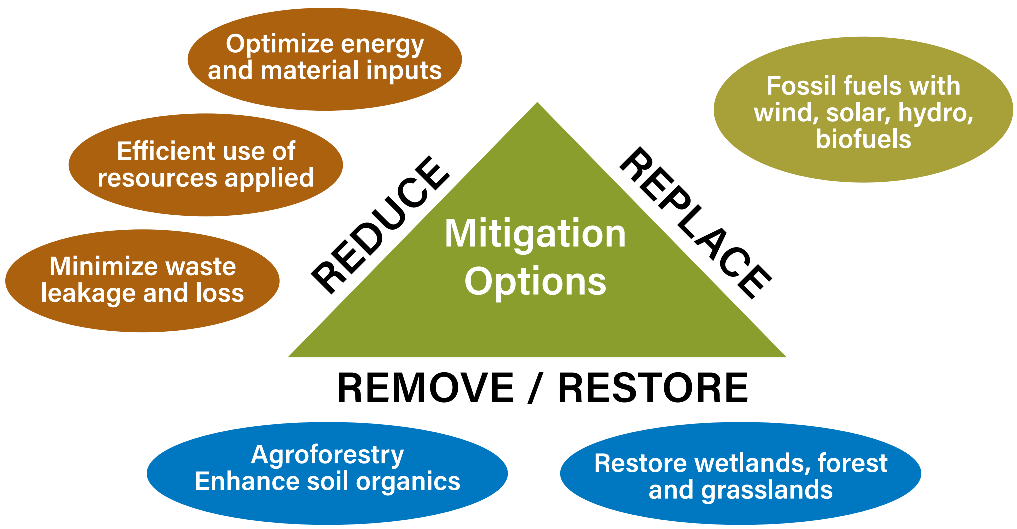


FIGURE 12.4 Mitigation options include reduce, replace, and remove/restore approaches.

Many mitigation actions are linked to improving the overall efficiency and profitability of farming and ranching. The efficient management of the carbon and nitrogen flows within agricultural systems may also help the sector adapt to climate change. Reducing GHG emissions is also an important part of demonstrating responsible environmental stewardship, which helps build the social licence necessary to maintain support for agriculture in society.

There is no universal set of mitigation practices, and the most beneficial option will depend on factors such as regional climate and soils, specific production practices employed, and access to financing and other supports. In prioritizing climate change mitigation actions, consider the warming potentials of the target greenhouse gases. For example, although aiming for an integrated program to enhance on-farm sequestration may have the potential for large reductions in CO_2, investing in modest reductions in N_2O may have a greater immediate impact. This is because of the near 300 fold difference in Global Warming Potential (GWP) between these two gases.

Mitigation planning should also factor in realizing co-benefits. Many of the BMPs for lowering GHGs also benefit water quality, biodiversity or soil conservation. BMP selections should also carefully consider any potential negative trade-offs between adaptation and mitigation actions. For example, vegetative buffers or agroforestry plantings can store considerable amounts of carbon, but may elevate the risks of wildfire impacts around farm structures.

In order to reduce GHG emissions from farm operations, comply with climate change related legislation and, where appropriate, implement the following BMPs.

Note: Most mitigation opportunities use current technologies that can be implemented immediately. Some may require significant capital investments, and innovations can be phased in when replacing existing equipment and infrastructure.

Reduce Energy Use and Inputs

Fuel Switching. The choice of fuel/energy source is important for reducing GHG emissions. For example, using electricity instead of fossil fuels where possible, has a significant positive impact on GHG emissions as outlined in Table 12.1 below..

TABLE 12.1 Greenhouse gas emissions for various fuels and energy types used on farm

Fuel type / Energy type	Type of use	GHG emissions (metric)
Diesel	IC engine *	2.7 kg CO_{2e} / litre
Gasoline	IC engine *	2.3 kg CO_{2e} / litre
Natural Gas	Boiler	49.9 kg CO_{2e} / GJ
Light Oil	Boiler	2.7 kg CO_{2e} / litre
Heavy Oil	Boiler	3.2 kg CO_{2e} / litre
Propane	Boiler	1.5 kg CO_{2e} / litre
Electricity (BC)	Any	2.964 kg CO_{2e} / GJ

* IC engine means Internal Combustion engine, for example a normal diesel tractor engine

Energy Conservation. Minimizing energy use will reduce GHG emissions, particularly when fossil fuel use is reduced. For energy intensive production systems, improved energy efficiency has the potential to yield substantial cost savings. Implement the following practices to improve farm energy conservation:

- Conduct an on-farm energy assessment to highlight opportunities for energy use efficiencies.
- Check for efficiency rebate and incentive programs from your local utility provider.
- Use appropriately sized and efficiently operated heating, cooling and ventilation (HVAC) systems for barns, greenhouses and other production facilities.

➔ see Energy Use in Buildings and Yards, **page 2-56**

  - Use zone controls, timers, sensors or variable speed drives on ventilation, heating, cooling and lighting systems that do not need to operate continuously.
  - Implement thermal energy efficiency improvements that increase insulation.
  - Ensure solid biomass fuels have optimum moisture content.
  - Implement rigorous maintenance programs for all HVAC system components.
  - Use low energy lighting systems where appropriate.
- Replace power take-off (PTO) powered equipment and diesel generators with electrical pumps and engines.
- Ensure that when converting to electrical drive, engines meet the efficiency requirements of *Canada's Energy Efficiency Act.*
- Use energy-efficient equipment and operating practices
  - Use minimum tillage or no-till soil management practices, minimum trimming practices in horticultural operations.
  - Maintain engines in efficient running order and keep tires inflated to the manufacturer's recommended pressure.

➔ see Energy Use in Field Operations, **page 2-57**

  - Use continuous, fuel efficient crop drying and processing systems with automatic controls and moisture sensors.

➔ see Energy Use in Crop Drying and Feed Processing, **page 2-57**

Livestock and Manure Management. Livestock and manure management are important contributors to agricultural GHG emissions. Implement the following practices to mitigate GHG emissions from livestock and manure:

- Select regionally appropriate forages for pastures and grazing land which maximize plant productivity and in turn increases the digestibility of feed resulting in less methane emissions from livestock.
- Implement rotational grazing preventing overgrazing and maximizing digestibility of forage.
- Integrate livestock production and crop production to make efficient use of resources.
- Change feeding practices to reduce CH_4 released from enteric fermentation by using higher quality feed or adding supplements to the diet of ruminants.
- Optimize livestock feeding to minimize waste and maximize feed conversion.

➔ see Nutrition and Ration Management, **page 3-44**

- Use beneficial practices to limit losses and waste from stock water systems.

➔ see Livestock Watering, **page 9-16**

- Manage manure Composting to reduce CH_4 and N_2O emissions:
  - Cover and cool manure storage facilities;
  - Capture CH_4 originating from manure (e.g., by anaerobic digestion) and use it in place of fossil fuels on farm or elsewhere;
  - Separate solids from liquids and use solid rather than liquid manure handling systems (the liquid component will still need to be managed);
  - Apply manure efficiently to match crop needs;
  - Avoid manure or fertilizer application while soil is saturated with water;
  - Make more frequent manure applications at lower application rates using sleighfoot or shallow injection equipment for more efficient use of nitrogen.

Crop and Soil Management. Make the most efficient use of all inputs; minimizing waste, leakage and loss will help ensure the direct and indirect GHG emissions from agriculture are minimized.

- Adopt nutrient management practices that minimize GHG emissions:
  - Improve timing and rates for irrigation and fertilization and improve drainage in fields to minimize water logged conditions;

Drainage Management Guide

  - Use precision farming applications that reduce fertilizer application and overlap;
  - Time input application to minimize losses through runoff and leaching;
  - Reduce the use of excess fertilizer, pesticides and other inputs;
  - Follow a nutrient management plan to optimize nutrient use.

➔ see Nutrient Management Planning, **page 6-30**

  - Implement integrated pest management practices to optimize the use of pest control products.

➔ see Integrated Pest Management, **page 5-7**

  - Use beneficial practices to limit losses and waste from irrigation.

➔ see Irrigation Beneficial Management Practices, **page 9-24**

Replace Fossil Fuels

On-Farm Renewable Energy Production. Renewable energy is produced from naturally occurring sources that are regenerative, including:

- Biomass (e.g., wood residue, manure, food processing waste),
- Flowing water (hydroelectricity),
- Sunlight (solar power),
- Wind power,
- Geothermal power.

Renewable energy sources can displace fossil fuel use, reducing GHG emissions on and off-farm. They can also help decrease reliance on energy sources with volatile prices, and create new economic diversification opportunities for agricultural producers with the opportunity to sell surplus energy back into the 'grid.'

Opportunities for generating or using renewable energy on-farm will depend on the type and scale of operation as well as its location. Some agricultural producers may decide to generate energy or energy feedstock to sell off farm, while others may generate small quantities of energy in the interest of self-sufficiency and reduced energy costs. Renewable energy technologies suitable for on-farm use include:

Anaerobic Digestion. Manure, organic matter and municipal organic wastes are broken down in the absence of oxygen and methane-rich gas is produced and captured for use in a boiler, co-generation facility or upgraded to natural gas for grid injection.

Electricity. Grid electrical power can be generated by utilizing steam produced from fossil fuel combustion, heat released from nuclear reactions, or from other sources such as wind or flowing water (hydroelectric). In B.C., about 88% of the Province's electricity is produced by hydroelectric generation. Hydroelectricity is a renewable energy source which releases negligible amounts of GHGs that contribute to climate change and is therefore a preferred source of power in B.C.

Geothermal Systems. Also known as Geoexchange or Ground Source Heat Pumps, transfer ambient heat to or from the ground. They use the Earth as a heat reservoir in the winter or a heat sink in the summer to provide either baseload heating or cooling.

Gasification. A self-fuelled process where carbon rich feedstocks, such as straw, manure and wood residue, are converted into a gas at high temperatures in an oxygen starved chamber. The produced gas, called syngas, is then burned to produce heat and electricity through co-generation or just heat via final combustion in a thermal oxidizer. The biomass remaining after gasification, referred to as biochar, can be applied as a soil conditioner to enrich soil organic matter.

Wind. Energy from wind is converted to electricity via propeller blades that turn a generator.

Solar. The sun's energy is either captured in heat collectors or other passive systems (e.g., black coil tubing), or is converted to electricity via photovoltaic cells (PV) or captured as heat (Solar Thermal)

Hydroelectric. Energy from running water is converted to electricity via small scale hydro power facilities, such as run-of-river projects.

Pyrolysis. A carbon-rich feed stock, such as manure or wood residue, is converted to oils and high value chemicals at high temperatures (but lower than gasification) in an oxygen starved chamber.

Biofuel. A fuel produced from crops or crop residues resulting in fuels like bio-diesel and ethanol, or from the direct combustion of biomass (wood, purpose grown biofuel crops or crop residues) to fuel biomass boilers. Adhere to all emission standards for biomass boils in use and follow beneficial practices for boil emission reductions.

➔ see Heat Production and Biomass Boiler BMPs, **page 2-58**

On-Farm Energy Production Regulatory Requirements. Some on-farm energy systems may be subject to regulation under the *Code of Practice for Agricultural Environmental Management*, which sets emission standards and testing requirements for boilers and heaters fuelled by biomass.

➔ see Climate Change Legislation, **page 12-7**

Comply with all applicable legislation prior to the initiation of on-farm energy generation facilities. Contact the following agencies, which will evaluate projects on a case-by-case basis for specific regulatory requirements and/or required authorizations:

- Agricultural Land Commission, if the proposed facility is within the Agricultural Land Reserve.
- Local Government, to enquire if an amendment to the solid/liquid waste management plan is required.
- Local Government, to enquire if there are applicable bylaws or if amendment to current agricultural zoning is required.
- Ministry of Environment and Climate Change Strategy, Environmental Management Branch, to enquire if an operational certificate or waste discharge authorization is required.
- Environmental Assessment Office to enquire if the proposed project is of large scale,

➔ see Climate Change Legislation, **page 12-7**

Remove Carbon/Restore Vegetative Cover

Cropping Practices and Carbon Sequestration. Agricultural ecosystems hold substantial carbon reserves, primarily in soil organic matter. Certain farm practices can facilitate increased carbon storage or reduce the loss of stored carbon. This is known as carbon sequestration. Various cropping, nutrient, and tillage management strategies can increase sequestration. Once sequestered, follow beneficial practices to retain soil organics – soil organic additions are reversible and must be maintained.

Implement the following practices to increase on-farm carbon sequestration:

- Adopt cropping management practices that increase carbon storage
  - Select perennial crops where feasible and species that retain a higher proportion of plant reserves in the roots than the shoots.
  - Implement crop rotations.
  - Decrease summer and bare fallow.
  - Use cover crops.
  - Increase soil organic matter.

➔ see Crops Beneficial Management Practices, **page 4-8,** and refer to Cover Crops and Crop Rotation

➔ see Soil Management Beneficial Management Practices, **page 8-11**, and refer to Soil Organic Matter Content

- Adopt tillage and residue management practices that increase carbon storage and reduce GHG emissions.
- Use reduced or no-till systems, particularly in arid regions.
- Avoid burning of crop residues which releases CO_2 .

➔ see Open Burning, **page 10-23**

  - Leave plant residues on the soil surface to build soil organic matter.

Grazing Management and Carbon Sequestration. Proper grazing strategies can stimulate forage growth and reduce greenhouse gas emissions. Forages can also contribute to the reduction of greenhouse gas emissions – feeding high quality forage grasses reduces methane emissions from animals per unit livestock product. The use of many different grazing areas throughout the year, with varying soil and climatic conditions, can make carbon sequestration strategies on grazing lands complex. Always use grazing systems appropriate to the regional climate and soils, and set conservative stocking rates within rotational grazing patterns to aid in building soil organic inputs.

  - Overgrazing is universally recognized as detrimental to soil organic carbon (SOC) reserves.
  - Use management intensive grazing on irrigated, high regrowth pastures to increase SOC.
  - Use low intensity, rotational grazing on rangeland and pastures with low forage regrowth potential to minimize SOC disturbance.

Grazing Management Guidebook

Agroforestry Practices. All agroforestry systems, by virtue of their tree and shrub components, can increase carbon sequestration on agricultural land in comparison to conventional crop and pasture systems. Agroforestry practices offer many other co-benefits including conserving biodiversity, soil conservation, protecting water quality as well as opportunties for production diversification.

Implementation of the following agroforestry practices will increase carbon sequestration:

- Establish integrated riparian management where areas adjacent to watercourses are planted with planned combinations of trees and plant materials, enhancing habitat and providing select timber and non-timber resources.

➔ see Riparian Area Beneficial Management Practices, **page 11-19**, and refer to Riparian Area Management

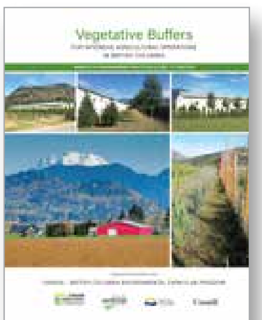
- Establish shelterbelts, timberbelts, hedgerows, or vegetative buffers where managed rows of trees, shrubs and/or grasses are planted adjacent to production areas.

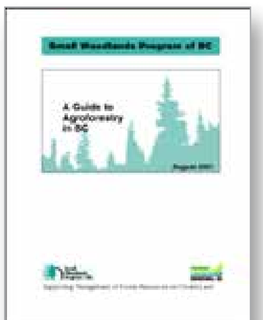
➔ see Buffer Beneficial Management Practices, **page 11-8,** and refer to Windbreaks and Shelterbelts

- Establish silvopastures where managed trees and shrubs are integrated with forage production in pastures.

A Guide to Agroforestry in BC

Vegetative Buffer BMP Guide





Retain or Restore Natural Areas. Retaining or restoring natural areas as part of the agricultural landscape can enhance natural carbon storage potential. Consider incorporating natural areas on farms and ranches as a component of the agricultural landscape:

- Restore marginal pastures or rangeland to native grasslands.
- Convert marginal cropland to forests, shrublands or grasslands.
- Retain or restore wetlands and peatlands. They have very large natural carbon stores in their organic soils and function to help buffer and conserve water flows.

Planning for Biodiversity: A Guide for BC Farmers and Ranchers

CLIMATE CHANGE ADAPTATION

Adapting to climate change is an ongoing process of adjustments in response to actual or expected climate change impacts. Adaptation can be done in anticipation, through proactive adjustments before climate impacts are observed. Adaptation can also be spontaneous or autonomous, sometimes triggered by a natural hazard such as wildfire or flood. Planned adaptation comes from deliberate decisions considering actual or expected changes, and usually aims to return to, maintain, or achieve a novel desired state.

IMPACTS OF CLIMATE CHANGE ON AGRICULTURE CONCERNS

The agriculture sector is one of the sectors most impacted by climate change in B.C., due to its vulnerability to new climate extremes and severe weather events. The timing and extent of climate impacts will very across the Province, but will include:

- Altered length of growing season;
- Extreme weather events altering how farming operations manage risk;
- Increased water management complexity;
- Increased flooding and excess moisture in the shoulder seasons;
- Extended agricultural drought and summer evapotranspiration deficit;
- Changing intensity and distribution of agricultural pests and diseases;
- Increased wildfire events impacting crops, rangeland, livestock, and infrastructure;
- Reduced snowpack, earlier snowmelt, hotter summer temperatures, decreased late summer stream flows, heat stress, and evapotranspiration deficit leading to water shortages for irrigation or livestock;
- Rising sea level combined with larger storm surges altering salinity of coastal floodplains; and
- Increased saltwater intrusion into coastal irrigation water supplies and conveyance systems.

Many of these impacts will lead to serious economic consequences for some producers. However, in some places there will be potential to take adavantage of an extended growing season and wider range of viable crops. B.C. agriculture will continue to succeed by building and reinforcing flexible, resilient production systems and planning for transitions when required.

Strengthening B.C.'s Agriculture Sector in the Face of Climate Change

This chapter addresses planning and beneficial practices on the farm. Other important considerations affecting the ability to adapt not covered here include: participating in multi-stakeholder regional or watershed based planning, accessing credit and financial tools, insurance programs and risk management tools, disaster relief and other support programs, and planning for transformational changes in practices, production or locations.

- Climate & Agriculture Initiative BC
- BC Agriculture Climate Change Adaptation Risk and Opportunity Assessment
- Pacific Institute for Climate Science
- Plan 2 Adapt

Key Concepts Climate Change Adaptation

Adaptive capacity: The combination of strengths, attributes, and resources available to an individual, community, society, or organization that can be used to prepare for and undertake actions to reduce adverse impacts, moderate harm, or exploit beneficial opportunities.

Impacts: Effects on natural and human systems referring here to the effects on natural and human systems of physical events, of disasters, and of climate change.

Maladaptation: Actions, or inaction that may lead to increased risk of adverse climate-related outcomes, increased vulnerability to climate change, or diminished welfare, now or in the future. This includes intervention that could increase the vulnerability of the target group to future climate change or in another location or sector.

Predictability: The extent to which future states of a system may be predicted based on knowledge of current and past states of the system.

Projection: A climate projection is a potential future change, often computed with the aid of a model. Projections are distinguished from predictions to emphasize that projections involve assumptions concerning future socioeconomic and technological developments that may or may not be realized and are therefore subject to substantial uncertainty. Climate projections are usually expressed as a range where considering the 90th percentile values are appropriate when planning critical infrastructure investments.

Resilience: The ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration, or improvement of its essential basic structures and functions.

Transformation: The altering of fundamental attributes of a system (including value systems; regulatory, legislative, or bureaucratic regimes; financial institutions; and technological or agricultural systems).

Vulnerability: The predisposition to be adversely affected.

On-Farm Adaptation Planning Process

Taking on new practices to respond to climate risks requires careful consideration of what adaptations might be needed, when they should be implemented, and prioritizing which will provide the most benefit for immediate and long term goals. A simple framework to guide adaptation planning for agricultural operations is this five-step adaptive planning and management process (**Figure 12.6**):

1. Define goals and objectives.
2. Assess climate impacts and vulnerabilities.
3. Evaluate objectives considering climate impacts.
4. Identify adaptation approaches and tactics for implementation.
5. Monitor effectiveness of implemented actions.

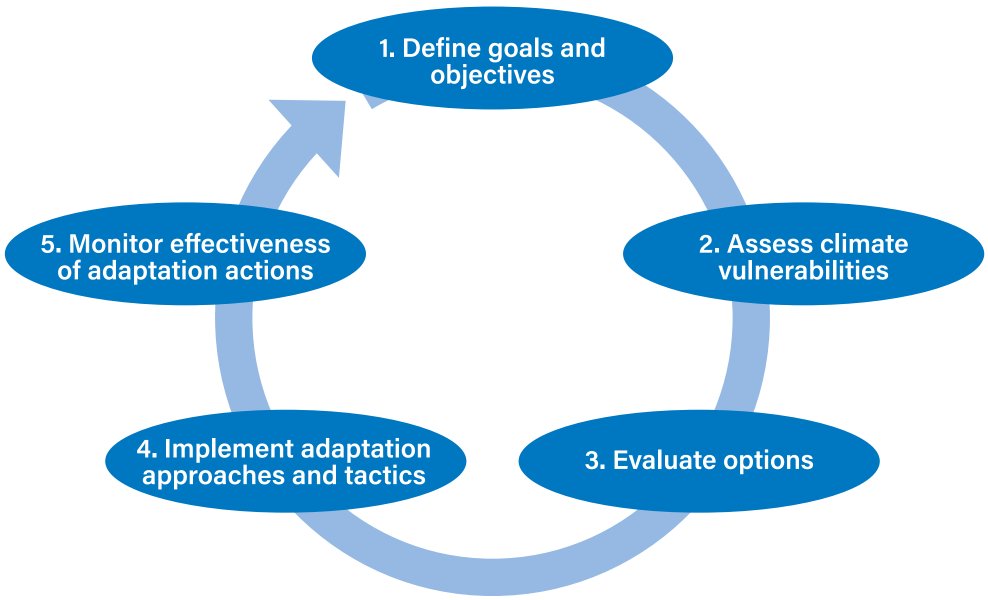


FIGURE 12.5 Five step adaptive planning and management process.

Adaptation Resources for Agriculture. 2016. USDA Technical Bulletin 1944

Following implementation of the prioritized actions, the cycle is repeated to reassess vulnerability in light of the new management practices adopted and changing climate risks. Each of these steps is described in more detail in the sections that follow.

1. Review Options and Set Goals

Define goals and objectives. A good starting point to define current farm management goals and objectives comes from recording fundamental information about the farm. Look at existing management plans or other planning documents and consider discussing this with others to clarify intentions and ensure goals are shared.

Timeframe and Approach. Consider both short-term (0 to 5 years) and long-term goals and approaches to adapt to a changing climate. This may involve decisions regarding how to preserve existing production through changes in practices or additional infrastructure, or over the long term it may be more viable to transition to new commodities, production systems, services produced, or even location.

Emergency and Contingency Plans. Climate variability should factor significantly into risk management strategies. Exposure to new or elevated risks demands robust emergency planning and contingency plans if the worst case occurs. Successful emergency planning will also likely require coordination with regional and provincial emergency plans; consider farm level needs in context of community plans and resources.

Consider completing the following, as appropriate your operation, as part of the adaptation process:

- Contingency Plan – Template for On-Farm Planning
- Emergency Management Planning Workbook for BC Dairy Producers
- Emergency Management Guide for BC Beef Producers
- Emergency Management Guide for BC Pork Producers
- Emergency Management Guide for BC Poultry Farms
- Emergency Management Guide for BC Small Mixed Farms
- Cariboo – Wildfire Preparedness and Mitigation
- Dam Safety Management Binder
- Okanagan Wildfire Preparedness & Mitigation Plan

Management Plans. The resilience of a farm or ranch ultimately rests in selecting from BMPs that will both meet operational goals and provide the greatest flexibility and resilience. Detailed management planning provides options tailored to farm practices and physical conditions and helps identify adaptation approaches and tactics. Management planning that should be considered as part of the adaptation process may include:

- Grazing Management Plan ➔see **page 3-21.**
- Nutrient Management Plan ➔see **page 6-30.**
- Biodiversity Management Plan ➔see **page 7-9.**
- Irrigation Management Plan ➔see **page 9-24.**
- Drainage Management Plan ➔see **page 9-45.**
- Riparian Management Field Workbook ➔see **page 11-21.**

2. Vulnerability Assessment

Assess climate impacts and vulnerabilities. Agricultural production will be affected in may ways by climate change impacts. For this reason, it is critical to think about the general (e.g., regional or provincial) effects and potential impacts of a changing climate, as well as the unique situation for your farm and agricultural production system.

Review Climate Change Projections. B.C. is large and diverse, and there will be regional differences in in the climate change impacts and consequences. Some agricultural operations are already facing climate-related challenges which will shape their short-term adaptation strategy. Long-term goals should also be framed in the context of the regional climate change projections which are usually expressed as a range. For planning, considering the full 10th to 90th percentile values better represents the likely range of changes than simply using an average value. The Pacific Climate Impacts Consortium has published a series of regional climate change projections for B.C.

- Pacific Climate Impacts Consortium Library

Assess Exposure and Sensitivity to Change. Vulnerability is the extent to which an individual agricultural operation and the specific practices employed are susceptible to, or unable to manage, adverse climate change impacts. Climate change vulnerability is influenced by:

- Degree of exposure to the changes - what are the adverse impacts specific to my location: e.g., drought, wind storms, changing pest populations?
- Sensitivity to these changes - what are the impacts to your farm infrastructure, crops, livestock or operating costs when these hazards occur?

Itemize each climate change vulnerability for your operation and rate the sensitivity as either low, moderate, high or extreme. The BC Agriculture & Food Climate Action Initiative has developed a series of regional climate adaptation strategies that include both a summary of projected regional climate change and overviews of the major climate-related vulnerabilities for B.C. agriculture to assist with this planning.

- Regional Adaptation Strategies - Cariboo
- Regional Adaptation Strategies - Cowichan
- Regional Adaptation Strategies - Delta
- Regional Adaptation Strategies – Fraser Valley
- Regional Adaptation Strategies - Okanagan
- Regional Adaptation Strategies - Peace
- Regional Adaptation Strategies – Kootenay & Boundary
- Regional Adaptation Strategies – Vancouver Island

Some of the impacts are complex and may involve multiple-stressors with cumulative impacts. It is therefore important to periodically revisit your exposure and sensitivity assumptions in light of changing information.

3. Evaluate Options

Evaluate objectives considering climate impacts. Based on your management goals and objectives and the likely climate change impacts and vulnerabilities for your area, it is time to identify what climate change related management challenges and opportunities are faced. This is the opportunity to evaluate if objectives are feasible under current management and to alter or refine them to better account for changes in climate.

Review BMP Options based on your goals and detailed management planning. Adaptation can take many forms, and there is no universal set of BMPs applicable to all farming operation.

The EFP process will aid in identifying BMPs appropriate to the specific climate vulnerabilities identified for a given operation.

4. Select and Prioritize Actions

Identify adaptation approaches and tactics for implementation. Addressing climate change impacts and their consequences may require adjusting current practices, trying completely new ones, or starting a whole new system. You can identify and evaluate specific actions that can help prepare for changing conditions given the challenges and opportunities already identified. This will generate adaptation tactics and specific actions that will assist your operation to meet your unique management objectives.

Costs, Benefits and Support Resources. Adaptation can take on many forms, and there is no universal set of BMPs applicable to all farming operations. The ultimate choice of an appropriate adaptation strategy will consider the costs and benefits based on your goals and detailed management planning. It also important, however, to assess the costs and benefits relative to inaction. Consider the following in choosing from your BMP options:

- Adaptations that have mitigation and other co-benefits (water quality, biodiversity).
- BMPs with flexibility to be altered after being implemented.
- Adaptation options that improve price or marketability of production.
- Adaptation options that can utilize and enhance natural assets rather than engineered, constructed assets.
- Not all existing production systems are adaptable; fundamental changes to what and where things are produced may be more resilient.

Regional Planning and Initiatives. Some adaptation approaches are likely only feasible if implemented at a regional or watershed level. Others are far more efficient and effective than when solely focused on individual farms or ranches. Where available, connect to regional planning and management initatives, including:

- Climate monitoring and decision support tools for irrigation or integrated pest management.
- Early warning systems for flood, drought, and fire.
- Plant and livestock breeding programs to create new adapted production choices.
- Broad, pan-agricultural, integrated approaches to pest monitoring.
- Infrastructure for water delivery, drainage or flood prevention.

5. Monitor

Monitor Effectiveness of Implemented Actions. Monitoring is essential to understand what changes are occurring as a result of climate change and whether adaptation actions are positive and effective in meeting management goals and preparing your farm for future conditions. Adaptation efforts with unintended negative consequences are termed maladaptation and must to be corrected as soon as possible. Identify what metrics are realistic to gauge current and future progress when applied to your farm and operations. The aim of this step is a realistic and feasible monitoring scheme that can evaluate management options in the future to account for new information and observations.

Through the Farm Adaptation Innovator Program, producers throughout the Province are evaluating the effectiveness of climate adaptation farm practices. A resource guide has been developed to help producers evaluate and monitor the effectiveness of adaptation practices.

A Guide to On-Farm Demonstration Research

6. Reassess

Reassess. Climate science and adaptation options are continually evolving. Monitor and evaluate the effectiveness of your strategies and tactics; periodically revisit your plans and stay informed and connected to initiatives and support programs. It is recommended that Environmental Farm Plans be updated every 5 years.

BENEFICIAL MANAGEMENT PRACTICES FOR ADAPTATION

Farmstead

- Adopt new building design standards capable of withstanding severe weather (flooding, wildfire, extreme heat).
- Locate buildings and other infrastructure away from flood risk zones or utilize materials and building standards or physical barriers that either seal out (dry flood proof) or withstand flooding (wet flood proof).
- Use 'Fire Smart' practices: prescribed burns, fuel reductions, and create fire breaks around farm and ranch infrastructure.
- Stockpile emergency supplies, keep standby generators with fuel on hand.
- Use vegetative buffers or sheltbelts to protect buildings from wind effects.

➔see **Chapter 2** Farmstead, for more options and information.

Livestock

- Select livestock species and breeds best adapted to local conditions.
- Locate livestock confinement areas away from flood prone zones.
- Ensure adequate ventilation and install fans, misters, soakers, or evaporative coolers to reduce heat stress in barns.
- Use agroforestry plantings or install shade structures to protect outdoor livestock from wind and sun.
- Adjust herd sizes and timing seasonally to account for forage reductions from flooding, fire, drought or pest impacts.
- Bank forages for deficit periods through deferred grazing systems.
- Improve pasture and range quality to extend the grazing season.
- Integrate livestock into cropping systems to make full use of farm resources.
- Use multi-species grazing to make optimal use of different forage preferences.
- Install fencing and use rotational grazing systems.
- Increase monitoring of livestock health and heat stress.

➔ see **Chapter 3** Livestock, for more options and information

Crops

- Select crop types and varieties that are best adapted to changing local conditions.
- Increase perennial crop use, including trees, shrubs in agroforestry systems, and use multi-species plantings.
- Locate production areas away from flood prone zones or choose crops that are resilient to seasonal flood patterns.
- Select drought tolerant crops/varities.
- Adjust nutrient management plans to match changing climate conditions.
- Diversify and use longer crop rotations, include soil and nutrient building species (e.g., nitrogen fixing legumes).
- Minimize or eliminate fallow land.
- Use cover crops, strip or relay cropping.
- Manage crop residues to minimize bare soil and build soil organic matter.
- Protect feed, harvested crops from spoilage in storage.
- Consider expanded refrigeration/on-farm processing to reduce spoilage of high value fruit and filed vegetables.
- Use nutrient and water recovery systems in greenhouses and container production facilities.
- Adjust the timing or sequencing of cropping operations to match seasonal variations in climate
- Consider using minimum or zero till practices, particularly in arid regions.
- Use low displacement equipment for seeding and applying fertilizer.
- Use precision nutrient and pesticide application systems.
- Install windbreaks, hedgerows, and vegetative buffers; use alley cropping or other multipurpose agroforestry plantings.
- Use protective covers or shift production to controlled environments to protect high value horticultural crops.

➔ see **Chapter 4 Crops**, for more options and information

Pest Management

- Increase monitoring for all pests and diseases; share data through regional networks, where available.
- Stay informed of new and emerging pest problems and learn how to identify them.
- Develop rapid response plans for targeted control of new pests.
- Consider shifts in insect vectors of pathogens in pest planning.
- Install a farm climate monitoring station and link it to regional or provincial networks.
- Promote habitat for natural pest controls.
- Manage non-crop pest hosts and control invasive species in non-crop areas.

➔ see **Chapter 5 Pest Management**, for more options and information

Soil Amendments

- Avoid excess nitrogen applications.
- Consider the full range of soils biological, chemical, and physical properties for appropriate amendment levels.

➔ see **Chapter 6 Nutrient Application**, for more options and information

Biodiversity

- Create and maintain haitat for pollinators or other beneficial organisms.
- Manage farms and fields as part of the larger landscape.
- Use temporary set-asides, or restore cropland to native vegetation where erosion risks are elevated.
- Use appropriate strategies to minimize agriculture-wildlife conflicts where fire, drought or flooding change wildlife distributions.
- Avoid altering or removing natural areas (forest, wetlands) that buffer production areas against extreme weather.

➔ see **Chapter 7** Biodiversity, for more options and information

Soil

- Consider using minimum or zero till practices, particularly in arid regions.
- Minimize bare soil at all times; maintain year-round ground cover.
- In certain circumstances, the use of mulch may conserve soil moisture and may reduce soil temperatures. However, caution must be used as the increase moisture may lead to pathogens.
- Deploy appropriate erosion control measures to prevent small disturbances from becoming problematic.
- Maintain riparian vegetation for erosion control.
- Restore degraded crop, pasture and rangeland or remove it from production.
- Build up organic soil matter for improved soil properties (inflitration and water storage) and soil health.

➔ see **Chapter 8** Soil, for more options and information.

Water

- Assess the whole farm water demand: primary / supplemental irrigation; stock water; fire suppression; pesticide mixing; processing needs.
- Participate in regional climate related monitoring programs.
- Assess irrigation system to find options for improvement or expansion if soils have adequate infiltration rates and evaporation rates are minimized.
- Upgrade irrigation equipment to increase the application efficiency.
- Assess expansion of water storage to alivate water supply challenges.
- Consider if deficit irrigation is appropriate for commodities being grown.
- Complete agricultural flood preparedness and mitigation planning.
- Increase soil organic matter to improve water-holding capacity, structure, and water infiltration.
- Participate in regional water management planning with other users, where available.
- Capture and use rainfall, runoff or waste water for use elsewhere in the operation.
- Minimize the surface area of water developments to cut evaporation losses.
- Avoid loss of access to water during low water levels, high water damage, or salt water wedge.
- Drain fields to minimize surface ponding, soil saturation, nitrification.
- Use laser land levelling to prevent ponding.
- Manage sediment mobilized by intense precipitation.
- Use wetlands, swales, and other landscape features to buffer heavy precipitation runoff.

➔ see **Chapter 9** Water, for more options and information.

Climate & Agriculture Initiative BC – Irrigation Resources

Climate & Agriculture Initiative BC - Water Storage Resources

Air

- Avoid burning crop residues.
- Suppress uncontrolled range and pasture fires to conserve soil organic carbon.

➔ see **Chapter 10** Air, for more options and information

Stewardship Areas

- Complete riparian management plans for all aquatic interfaces.
- Use integrated riparian management.
- Use agroforestry practices to both adapt to, and mitigate climate change.

➔ see **Chapter 11** Stewardship Areas, for more options and information