STUDY GUIDE 2021

Nature-Based Solutions for Climate Change

FORESTS ONTARIO

ONTARIO ENVIROTHON 2021

Acknowledgements

The following study guide was created by a team of students from the Ecosystem Management Technology Program at Fleming College. The team comprised of Nicole Bitter, Lisa Browning, Allie Hjort, and Stephanie Zsolnay. The purpose of the study guide is to provide high school students with study materials that reflect the 2021 Ontario Envirothon Current Issue Topic: Nature-based Solutions to Climate Change. Key topics and learning objectives and interspersed throughout this document and are accompanied by various case studies and hands-on activities.

This study guide was produced for and edited by Forests Ontario with the support of Forest Ontario's Education Outreach Coordinator Madeleine Bray, and Education Manager Allison Hands.

Special thanks are also given to Sara Kelly, faculty member of the Ecosystem Management program at Fleming College.

Support for the 2020 Ontario Envirothon Study Guide has been provided by:

MAPLE LEAVES
FOREVER

Acknowledgements also given to those who reviewed the study guide:

- Eric Miller, Ontario Network of Ecosystem Services
- Heidi Breen, The Regional Municipality of York
- Jacey Moore, Alderville First Nation Black Oak Savanna
- Jackie Hamilton, Greenbelt Foundation
- Jade Schofield, Town of Whitby
- Jennifer Court, Green Infrastructure Ontario Coalition
- Sean Rootham, Ducks Unlimited

Table of Contents

2021 Learning Objectives

KEY TOPICS

1. Climate change and its impacts.
2. How natural systems can be used to adapt and reduce the effects of climate change.
3. The role of Indigenous knowledge in nature-based solutions to climate change.
4. Policies, regulations, and laws that promote the use of nature-based solutions to climate change.
5. The role of various levels of government, businesses, individuals, and Indigenous groups in implementing nature-based solutions for climate change.
6. How environmental values and goals can be incorporated into the economy.

LEARNING OBJECTIVES

1. Describe climate change and the process through which it occurs.
2. Analyze the impact that climate change has on the diversity of living things and systems.
3. Define and understand key terms including ecosystem services, Indigenous knowledge systems- (IK), afforestation, agroforestry, assisted migration, carbon sequestration, sustainable economy, transdisciplinary.
4. Define nature-based solutions and list their key benefits.
5. Understand the importance of natural systems and how they can be utilized to mitigate climate change.
6. Understand the role of IK in identifying climate change impacts and informing sustainable solutions and strategies for mitigation.
7. Understand how regulations and laws at all levels of government can promote nature-based solutions and ecological services.
8. Intersection of government, public, non-profits, Indigenous groups, and business in developing inclusive, efficient solutions to climate change.
9. Describe the role nature-based solutions play in developing a more sustainable economy and the changes required to sustain it.
10. Understand how ecosystem services can be valued and the ways in which they are incorporated into economic plans and policy.

Tools and Resources

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

Climate Atlas of Canada - The Climate Atlas of Canada combines climate science, mapping, and storytelling to bring the global issue of climate change closer to home for Canadians. It is designed to inspire local, regional, and national action that will let us move from risk to resilience.

Intact Centre of Climate Adaptation - The Intact Centre on Climate Adaptation (Intact Centre) is an applied research centre with a national focus located within the Faculty of Environment, University of Waterloo. The Intact Centre helps homeowners, communities, governments, and businesses to identify and reduce risks associated with climate change and extreme weather events, such as flooding.

NASA's Climate Time Machine - Check out NASA's climate time machine for visuals of sea ice, sea level, CO_2 and global temperature over the years and an interactive representation of global climate change.

Northern Peatlands in Canada - Wildlife Conservation Society Canada has created a story map that will take you on a journey through the northern peatlands of Canada.

The Nature-based Solutions Evidence Platform - This is an interactive map linking nature-based solutions to climate change adaptation outcomes based on a systematic review of peer-review literature.

An Economic Impact Assessment of the Green Infrastructure Sector in Ontario

VIDEOS

- Nature-based solution in the fight against climate change
- Nature-based solutions to the hazards and impacts of climate change (animation)
- Nature-based solutions for Climate Recovery
- IUCN: Championing nature-based solutions
- The teen fighting to protect Canada's water – meet Autumn Peltier
- Autumn Peltier and Greta Thunberg | Special Event | TIFF 2020
- Nature-based climate solutions: Canada's huge potential
- Nature-based solutions: What is a Carbon Sink?

1.0 Introduction to Nature-based Solutions

Climate change is a global issue with environmental, social, cultural, and economic impacts. It affects every ecosystem from cities to forests and as a result all sectors of business and research that support societal development. A changing climate and new, unprecedented changes in weather patterns are creating situations that natural systems cannot adapt to in a reasonable timeframe.

With such complex and widespread problems, society needs solutions which address these issues from all angles. Mimicking and utilizing nature in environmental management plans has been a successful approach for building sustainable and self-sufficient systems. Nature-based approaches and outlooks on topics such as stream health, forestry, and agriculture are often more effective, efficient, and inexpensive at tackling environmental degradation than engineered solutions. This approach has grown into an area of research and application known as nature-based solutions.

Nature-based solutions are a broad category of actions that work with and help enhance natural features to help address challenges such as a loss of biodiversity, degradation of ecosystems, and the impacts of climate change. Each year, there is increasingly more data that shows the benefits of these solutions. They alone cannot solve every problem related to climate change, but when used in conjunction with other practices, nature-based solutions can impart resilience into systems (natural or otherwise), create more adaptive systems, and mitigate the impacts of climate change, with the potential to sequester carbon as a side-effect.

While these solutions are commonly used in the environmental field, they are also gaining recognition for addressing socio-economic issues. Nature-based solutions are being employed across industries and nations to reduce environmental impacts and to improve human health and economic stability.

It is important to explore the influence of collaboration when implementing nature-based solutions. Without involving all stakeholders, we cannot hope to achieve the immense change that is needed to tackle climate issues. Incorporating **Indigenous knowledge** systems from Indigenous Peoples and others who are closely interconnected with the land is crucial. Countries must be held accountable for their actions and unique, locally appropriate, strategies should be developed to create a global front against climate change. If no action is taken, countries across the globe will experience, among others, degraded water supplies, reduced biodiversity, and increased threats to human health because of smog and increase of disease.

2.0 Climate Change

Climate vs Weather - what's the difference?

While climate and weather are closely connected, the two are not the same.

Weather describes the day to day events happening in the atmosphere, from rain to snow to a hot, sunny day. These are short-term changes.

Climate describes a pattern of weather over a long period of time. Seasons are a common way to describe the climate in a location over the course of the year, but the climate also includes average precipitation, humidity, windiness, etc. This is a long-term trend, often relying on data collected over decades.

In short, climate is an average of the weather typical in a time and place, versus weather, which is what actually happens in that time and place.

Climate change is characterized by an alteration in global or regional climate patterns. Throughout history, Earth's climate has changed many times. Most climate changes are due to small variations in the earth's orbit and orientation in relation to the sun which gradually change the level of solar radiation that the planet receives over the span of thousands or tens of thousands of years.

The Earth receives solar radiation from the sun and emits infrared radiation from its surface. Molecules in our atmosphere called greenhouse gases (GHGs) absorb some of the infrared radiation and re-emit it into the atmosphere. This is called the greenhouse effect, and it is responsible for a relatively stable atmosphere that maintains a climate appropriate for supporting life. Without it, Earth would be cold and void of life.

In the last 650,000 years, there have been seven cycles of glacial advance and retreat. The modern climate era and the start of human civilization began at the end of the last ice age, approximately 11 700 years ago (NASA, 2020). The climate changes occurring today are a dramatic shift from these predictable patterns caused by the Earth's orbit and are occurring at an unprecedented rate. It is widely accepted that these trends are a result of human activity.

Up until the 19th century, the only major contributors that influenced the concentration of carbon dioxide (CO_2) in the atmosphere were volcanoes, mineral weathering, and the evolution of photosynthetic plants (the latter occurring over a long geological time scale). In the mid-1800's, the Industrial Revolution catalyzed human innovation and development with the large-scale consumption of fossil fuels such as coal, which drove the levels of GHGs to increasingly higher levels each successive year.

Record-breaking temperatures from the Arctic to Australia are becoming the new reality, causing changes to aquatic and terrestrial systems. Emissions caused by human activities such as the burning of fossil fuels, land use change and waste generation have amplified the greenhouse gas effect. These actions have immeasurable and often synergistic consequences for ecological, social, and economic systems.

2.1 Anthropogenic Sources of Atmospheric Carbon

The most abundantly produced GHG emission in Canada and globally is CO_2, with methane (CH_4) as the second. Though CO_2 is released into the atmosphere in greater quantities, methane is 28-36 times more efficient at trapping radiation.

Carbon dioxide is naturally present as part of the carbon cycle, but within the natural system, its release is balanced with its uptake from photosynthetic organisms. Excess CO_2 is emitted into the atmosphere through human activities such as the combustion of fossil fuels for energy, decomposition of solid waste, and the result of some chemical reactions (i.e. manufacturing of cement) (Environmental Protection Agency, n.d).

Methane is similarly a natural, but lesser, part of the carbon cycle. On a global scale, human activities are responsible for over 60% of total methane emissions. Despite methane's shorter lifespan than carbon dioxide, it is a more potent GHG. As such, it poses a higher global warming threat.

Greenhouse gases can be created or released through a variety of human activities. Fossil fuels and their use have been some of the greatest contributors to the increase in atmospheric carbon. Derived from the fossilized remains of prehistoric plants and animals, they have been burned to generate most energy used since the industrial revolution. As these fossils are carbon based like all other life on Earth, they release large quantities of CO_2 into the atmosphere after undergoing combustion.

Fossil fuels have a wide variety of forms and are used for many things such as transportation, industry, and general household use. While efforts are being made to reduce their use in certain sectors, they are still ubiquitous.

Natural features, such as forests and bogs, are typically **carbon sinks**. The plant life in these ecosystems take in carbon dioxide from the atmosphere and through photosynthesis, creates carbohydrates necessary to grow. This carbon is then stored within the plant itself, in its roots, or in the resulting organic matter left behind upon its timely end. This is a key component to the carbon cycle. However, should these natural features degrade or undergo changes that impact their functionality, they can serve as carbon sources. Land-use change is a serious contributor to greenhouse gas emissions.

Forests are one of the most visible carbon sinks. The conversion of forested land to agriculture or other human uses and natural disasters such as forest fires both lead to the release of CO_2 and the loss of the landscape's ability to capture and retain carbon in an inert state for a long period of time.

Like forests, bogs are an invaluable carbon sink, with layers of partially decayed peat moss and other organic material kept underwater in an anaerobic (or oxygen-free) environment. As there is no oxygen, decay of organic material produces methane in these environments, which is subsequently trapped under layers of moss and partially decayed organic matter. Methane can be released through the conversion of bogs and other wetlands to create roads, subdivisions, and other human developments.

Historically, temperate wetlands in Ontario have experienced high pressures from land use changes. There has been a dramatic loss in natural wetland area since European settlement. Their potential to sequester carbon in the ground has been lost to human development in Southern Ontario (Byun et al, 2018).

Agricultural practices such as livestock production accounts for a large amount of methane released into the atmosphere. Through their bodily functions, livestock animals produce over 40% of all atmospheric methane (Kovács et al., 2019).

2.2 Ecological Impacts

Holocene & Anthropocene

Geologic time is measured out in eras, epochs, and ages. Our current epoch, the Holocene, began over 11000 years ago after the last glacial period.

Recently it has been theorized that we have entered a new geological epoch called the "Anthropocene"; a distinct geological age characterized by the impact of human activities on the Earth. These impacts include but are not limited to changes to landscapes, ecosystems, and the atmosphere from industrialization and climate change.

While this is not an officially recognized term, it has been informally used when discussing the massive impact of human behavior on the Earth, and is increasingly common in discussions about modern times.

Changes in climate, big or small, can impact ecosystems at various levels. Individuals, species, ecosystems, and entire **biomes** can all be impacted in different ways (Bellard et al., 2012). As the climate changes, species must find strategies to adapt to new conditions. If changes occur too rapidly, plants, animals, and all living things could be unable to adapt to their new environments. This can lead to a decrease in population and ultimately extinction. When many extinctions occur in a short period of time it is referred to as a mass extinction. It is generally accepted that we are currently in the middle of a mass extinction, called the sixth extinction or Holocene extinction, caused by many of the same drivers as climate change and made worse by the impacts of the changing climate (Ripple et al, 2017).

For more information on the ecological impacts of climate change, see the 2018 Ontario Envirothon guide to Climate Change

2.2.1 Climate Change Impacts on Soils

Soil is an important component of ecosystems that includes living (biotic) and nonliving (abiotic) components. It plays an important role in climate change. It can serve as both a GHG source and sink, especially for carbon, methane, and nitrous oxide. These gases are natural by-products of soil microbial processes. If the equilibrium of these processes is disrupted, for example because of stress/death of soil organisms from drought, the rate of greenhouse gas emissions could change rapidly.

Soil properties and formation can be influenced by climate through precipitation, temperature, and wind. These processes have impacts on soil properties and fertility (Hamidov et al., 2018). As the climate continues to warm, soil temperatures will also increase. This increase in soil temperature has started the poleward retreat of permafrost from northern Canadian soils. As permafrost melts, carbon is released as methane (CH_4) into the atmosphere contributing GHGs (Zhang, et al. 2012).

For more information about soil and climate change, check out "What Lies Beneath...Your Feet!" (Forests Ontario, n.d, b)

Biodiversity

Biodiversity is a measure of the variety of living species within a specific ecosystem or the earth. It is measured in relation to species diversity, genetic diversity, and ecosystem diversity.

Check out the TED-Ed video Why is Biodiversity so Important? by Kim Preshoff for a more detailed description of biodiversity.

2.2.2 Climate Change Impacts on Forests

Forests are important habitats for wildlife and are vital components of the natural carbon cycle. How forests are utilized, managed, or conserved can play a role in climate change mitigation by improving the carbon storage potential.

Like other living things, forests will be affected by impacts of climate change like increases in air temperature, changes in seasons, and fluctuations in precipitation levels and timing. For example, trees and other vegetation are experiencing longer growing seasons. As climates shift, the composition of trees and wildlife found in the forest may favour species that are better suited to the changing environment. This means that different species will grow in areas they never have before, at the exclusion of others, impacting the overall biodiversity of the forest. Some of the other key impacts on forests due to climate change are:

- Tree growth and mortality rate (e.g. trees may grow faster, live shorter lives)
- Disturbance patterns (e.g. dry conditions can lead to fires; floods can kill forest stands)
- Stand resilience (e.g. forests may become less diverse as unfit species die off, making them more susceptible to pests)
- Distribution of tree species (e.g. tree species may no longer be able to survive in the south of their range and may increase their range in the north
- Timing of plant flowering and seeding (e.g. flowers could be produced earlier or later than their native pollinators, called phenological mismatch. This could mean trees are not able to produce viable seeds)
- Loss of cultural keystone species to local Indigenous peoples

Some changes may be drastic and occur suddenly, whereas others will be gradual and occur over time. These impacts can have a cascading affect, such as insect damage causing die-off and providing **ladder fuels** that create an increased risk of wildfires and can heighten their intensity by allowing fire to climb from the ground to the canopy.

Indigenous and other communities dependent on forestry are the most impacted by the loss of timber supplies and other forest ecosystem services. There have been documented changes in Canadian forests due to recent climate changes, such as increased fires in the western boreal forest and aspen dieback in the prairies (NRCan, 2020b).

2.2.3 Climate Change Impacts on Wildlife

Global climate change is already having significant effects on species biodiversity. Effects include:

- Shifts in species distribution
- Changes on demographic rates (fertility and survival)
- Increased spread of zoonotic diseases
- Spread of invasive species (Bellard et al, 2012).

Climate change is shifting ecosystems, increasing air and water temperatures, and changing precipitation levels. These impacts are pushing plants and animals outside of their natural habitat ranges. Terrestrial mammals face considerable challenges when adapting to changes in their own ecosystems. Habitat loss and fragmentation isolate land mammals and create barriers preventing migration to more suitable climates as their natural range is upset.

Changes to climate can affect seasonality, disrupting predictable seasonal patterns that plants and wildlife rely on and causing an ecological mismatch. This shift in **phenology** has already disrupted the timing of plant and floral growth, the migration patterns of birds, and the emergence or migration of insects in the spring. Birds that depend on high-elevation forested habitat, migrate over long distances, and rely on coastal breeding grounds are the most at risk from climate change (Walsh and Servison, 2017).

Insects and pollinators are particularly vulnerable to these seasonal shifts, as the relatively short lifespans of insects may no longer align with the flowers they use as food sources. (Cohen et al., 2018). An impact to insect life is also an impact to birds, as some species have been found laying eggs before there is a reliable insect population to feed their young. (Horton et al., 2020).

Figure 1: Bee collecting pollen.

2.2.4 Climate Change Impacts on Aquatic Environments

Aquatic ecosystems in Canada have been strongly affected by climate change. Not only have warming air temperatures affected these ecosystems, but radiative forcing (or climate forcing, the process by which the Earth receives more incoming energy from the sun than it radiates back to space) has created **positive feedback loops** that amplify the already harmful impacts.

Sea ice is a key example of a positive feedback loop in aquatic systems. Because it is white, it reflects more light than it absorbs (or, it has a high albedo). This contrasts the ocean, which absorbs sunlight and therefore heat. As temperatures in polar regions increase, more sea ice will melt, reducing the reflective surface area of the ice and allowing the ocean to gain area and absorb more heat. This increase in ocean temperatures will then lead to more melting ice, a greater ocean surface area, and more heat absorption in a perpetual positive feedback loop.

Nutrient cycling in aquatic systems is dependent on water temperature. Bodies of water are made up of layers which are separated by temperature. These layers are divided by a thermocline, which is defined as the largest temperature change with increasing water depth. With increased temperatures due to climate change, the thermoclines may not exist. This would cause nutrient cycling to constantly occur, disrupting aquatic systems, impacting water quality, and preventing a variety of species from being able to inhabit and thrive in waters that they were once suited for (Forests Ontario, 2018). Rivers in Canada have seen an increase in summer water temperatures which causes stress on cold water fish species such as brook trout (*Salvelinus fontinalis*) (Forests Ontario, 2015). Higher water body temperatures mean a change in biological cycles, seasons, and biodiversity (Fisheries and Oceans Canada, 2018).

Climate change accounts for increased concentration of nutrients and contaminants in aquatic ecosystems through desalinization, the process through which salt and minerals are removed from a water system through evaporation or freezing. Water movement through systems is impacted by temperature and salinity (i.e. colder, saltier water is more dense than warm fresh water). The rapid melting of sea ice decreases the salinity of the ocean, disrupting this system of movement with the potential to halt it.

Coastal sea level is projected to continue rising, posing an increased risk of shoreline erosion and damage to coastal ecosystems (Fisheries and Oceans Canada, 2018). Sea level rises due to the melting of sea ice, glaciers, and ice sheets, as well as the thermal expansion of warming water (NOAA, 2019).

These physical changes also lead to chemical and biological impacts to aquatic environments. Species biodiversity and species distribution are already being affected which in turn impact human communities and infrastructure (Fisheries and Oceans Canada, 2018).

2.2.5 Extreme Weather Events

Extreme weather events are defined as being unusual, unprecedented, or otherwise severe. This can include but is not limited to prolonged periods of drought, unseasonal weather, and heavy downpours. Climate change has increased the frequency and occurrence of many extreme weather events. This is because our atmosphere is a system and changes to inputs in energy (heat) can lead to various changes in the amount of moisture in the air leading to periods of low (drought) and/or high precipitation (storms). In response to this, cities have needed to develop and plan stormwater management systems that can manage increased rainfall in hopes of preventing flooding (Forests Ontario, 2018).

Extreme weather events alone are a cause for concern, but side-effects of extreme weather such a forest fires are also a key concern. Forest fire seasons are lasting longer than in the past, and fires caused by lightning strikes have increased in frequency. These types of fires can be dangerous, as they can go unnoticed for longer than fires started around towns and cities and ultimately lead to larger fires.

2.3 Economic Impacts

Climate change poses multiple risks to global and local economies. Such impacts can be direct, such as flooding, or indirect, impacting humans by limiting the goods and services provided to society from damaged natural systems. In Canada specifically, the Council of Canadian Academies (CCA) (2019) identifies twelve major areas vulnerable to climate change resulting in high economic costs:

1. Physical infrastructure
2. Coastal communities
3. Northern communities
4. Human health and wellness
5. Ecosystems
6. Fisheries
7. Agriculture and food
8. Forestry
9. Geopolitical dynamics
10. Governance and capacity
11. Indigenous ways of life
12. Water

Of these, the first six listed were determined to be most at risk. The costs related to these impacts include damage, insurance claims, business and supply chain disruptions, reduced property values, impacts on recreation and tourism, invasive species and disease control and lower quality and quantity of natural resources. A single event can lead to immense losses felt across the economy.

Case Study: Fort McMurray

Figure 2: Destruction due to wildfires in Fort McMurray. Source: Franson, 2016

Extreme weather events and natural disasters are a key concern for forests, especially as climate change is increasing their frequency and intensity over time. Forest fire seasons are lasting longer than previously observed and lightning-strike fires have also increased in frequency. As forests burn, they emit carbon they were storing, leading to increased CO_2 in the atmosphere.

Analyzing the full economic impact of a major natural disaster is difficult as multiple groups may be affected, and the impacts can be endured for years after the event. The wildfires of Fort McMurray can be studied to better understand these impacts and the costs to our economy.

Though the initial source of the Fort McMurray fires is debatable, climate change has increased the severity and risk associated with natural disasters such as intense wildfires (Chong et al., 2017). April 2016 continually broke temperature records, leading to dry forest conditions and extreme heat. Poor fire mitigation and oil sands expansion have also been documented as key factors for the fire's intensity (Stirling, 2017). The economic costs from this unprecedented wildfire are widely studied and continue to be evaluated.

Fort McMurray is an area of high oil production and therefore many evaluations consider costs associated with this industry. In total, 7.6 million hours of work were lost in the area and the production of 1.2 million barrels per day ceased over a 2 week span, amounting to a $985 million loss in **gross domestic product** (GDP) (CAA, 2019; The Conference Board of Canada [CBC], 2016).

Within the town of Fort McMurray, 2,400 structures were destroyed, causing an insured loss valued close to $4 billion (Westhaver, 2017). Air pollution from the fires was found to impact populations within a 300 km radius (de Azevedo et al., 2016). Evacuees have reported respiratory health effects from the event and mental illness including anxiety/depression (Cherry & Haynes, 2017), post-traumatic stress disorder, and insomnia (Belleville et al, 2019). Human health impacts such as these put an increased strain on the health system and have caused a change in work status for a quarter of those affected (Belleville et al., 2019; Cherry & Haynes, 2017).

DISCUSSION QUESTIONS

Q1: What were the factors and conditions that contributed to the intensity of the Fort McMurray wildfires?

Q2: In what ways did these wildfires affect the Alberta economy?

Q3: Are there any other ways the economy may be indirectly affected because of wildfires?

2.4 Social Impacts

Climate change causes many other issues in addition to the impacts on natural systems. The wellbeing of human communities is reliant on environmental stability and as such social issues arise or are magnified due to climate change. These impacts can be seen in all communities, from heavily urbanized settings to remote, resource-dependent communities.

While often hard to quantify and recognize, social impacts should be equally considered and accounted for in mitigation strategies.

UNEQUAL ACCESS TO ADAPTION

Climate change impacts the resilience of our natural systems. Developing countries and **marginalized** communities have limited access to **infrastructure**, financial resources, and technology that are needed to adapt. Colonialism, environmental racism, and exploitation of these communities and nations has led to more basic resource needs, like food security, going unaddressed. This leaves little resources for infrastructure to help adapt to climate change like building a sea wall to address rising sea level. These countries and communities often contribute small amounts of GHGs per capita to the atmosphere because they have far smaller consumption and waste habitats that require less fossil fuel. Yet, developing countries and communities are often the places most affected by the negative impacts of climate change (Byrd & DeMates, 2014).

Figure 3: A resident of Tuktoyaktuk, NWT creates a makeshift barrier as protection against extreme coastal erosion. Source: Murray, 2019

Frequently climate change unfairly impacts Indigenous and remote communities in Canada. An example of this can be seen in Tuktoyaktuk, an Indigenous community in the Northwest Territories of Canada. It is situated along the shores of the Beaufort Sea, and is one of the six communities in the Inuvialuit Settlement Region. The community relies on ice road access in the winter months, meaning any impact on ice conditions impacts a main source of travel. The community has experienced long-term pressure on infrastructure and municipal services due to coastal erosion and instability of permafrost (see Figure 3) (Andrachuk & Smit, 2012).

HUMAN HEALTH AND SPREAD OF DISEASE

With a changing climate, diseases that are typically associated with warmer locations may expand outside of their natural range into places where they were once unable to thrive. Ticks that carry diseases are a prime example of diseases spreading northwards. Whether they travel on migratory birds or linger on deer through the winter, difference species of ticks are being found increasingly further north each year. Ticks can transmit a wide variety of bacterial, viral, and protozoan pathogens to hosts. As the temperatures in the southern parts of eastern and central Canada increase, ticks have a greater ability to survive, reproduce, and increase in numbers.

In Ontario, there has been a notable rise in cases of Lyme disease in recent years. Lyme disease is carried by black-legged ticks, or Deer Ticks (*Ixodes scapularis*). With climate continuing to warm, black-legged ticks are projected to continue spreading northwards through Ontario and Canada, putting the health of Canadians at risk (Bouchard et al., 2019).

2.5 History of Action: Past, Present and Future of Climate Change Action

TIMELINE OF EVENTS

1712 The first widely used stream engine was invented by Thomas Newcomen, paving the way for the Industrial Revolution (BBC, 2013)

1800 The world population reached one billion (BBC, 2013)

1824 The earth's natural greenhouse effect was described by Joseph Fourier (BBC, 2013)

1856 Eunice Foote demonstrated that water vapour and other gases create the greenhouse effect (Smithsonian Magazine, 2016)

1896 Svante Arrhenius stated that industrial-age coal burning will enhance the natural greenhouse effect (BBC, 2013)

1927 Industry and fossil fuel burning reached one billion tonnes/year of carbon emissions (BBC, 2013)

1960 The world population reached three billion (BBC, 2013).

1970 The global CO_2 abundance hit 325 PPM (NOAA, 2020).

1972 United Nations Scientific Conference - First Earth Summit (Stockholm). The Declaration that resulted from this conference established principles for preservation and enhancement of the human environment. It was the first time climate change was raised, warning governments to be mindful of activities that could contribute to climate change (Jackson, 2007).

1975 The term "global warming" was brought to the public in a scientific paper by Wallace Broecker (BBC, 2013).

1987 The global CO_2 abundance reached 350 PPM (NOAA, 2020). The **Montreal Protocol** was signed by Canada September 16, 1987, an international agreement ensuring the protection of the earth's ozone layer by phasing out ozone-depleting substances (Environment and Climate Change Canada, 2019a).

1988 **Intergovernmental Panel on Climate Change** (IPCC) - created by the World Meteorological Organization (WMO) and the **United Nations Environment Programme** (UNEP), the IPCC's objective is to provide all levels of government with scientific information to help develop climate policies (IPCC, n.d).

1989 Industry and fossil fuel burning contributed 6 billion tonnes/year of carbon emissions (BBC, 2013).

1994 The **United Nations Framework Convention on Climate Change** (UNFCCC) entered into force on March 21, 1994. The goal of the Convention was to stabilize greenhouse gas concentrations at levels that would prevent dangerous anthropogenic interference with the climate system. Today, almost all countries are parties to the Convention (UNFCCC, n.d.,a).

1997 The **Kyoto Protocol** was adopted on December 11, 1997. Due to a complex ratification process, it entered into force on February 16, 2005 (UNFCCC, n.d.,b). The Kyoto Protocol was the first agreement between nations to establish country-by-country reductions in GHG emissions.

1999 The world population reached 6 billion (BBC, 2013).

2006 The global CO_2 abundance reached 360 PPM (NOAA, 2020). An Inconvenient Truth was released, a film that helped move international public awareness of global warming (The Climate Reality Project, 2017).

2008 The term "Nature-based Solutions" appeared in a report by the World Bank (Cohen-Shacham et al., 2016).

2015 The **Paris Agreement** is adopted by consensus at the 21st **Conference of the Parties** (COP) and signed in 2016. This agreement builds upon the UNFCCC and its central aim is to strengthen the global response to climate change with a target of keeping the increase in global temperature below 2 degrees Celsius (UNFCCC, n.d.,c).

2019 In September 2019, a record of 7.6 million people took to the streets in a youth-led strike for climate action (Global Climate Strike, 2019).

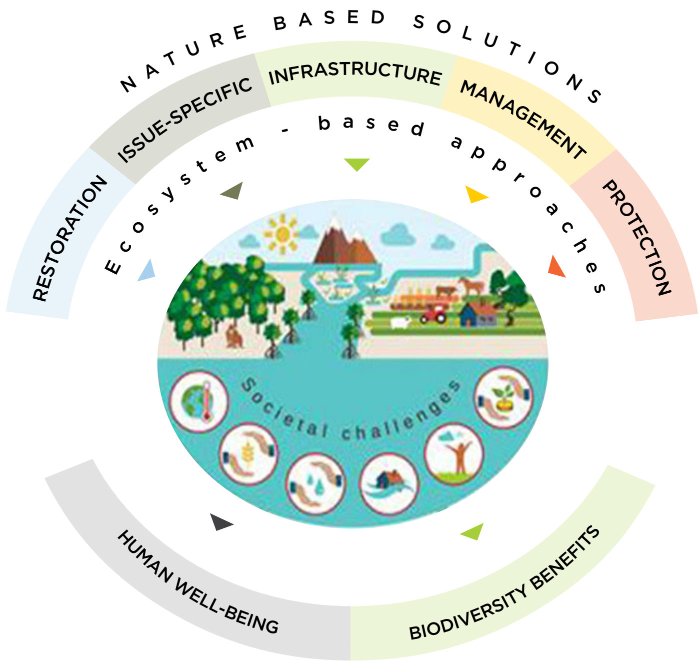
2020 The world population is over 7 billion (Worldometer, 2020) and the global CO_2 abundance is 414 PPM (NOAA, 2020).

3.0 Nature-based Solutions

With the growing concern of climate change and its impacts, there is a need to implement more environmentally aware practices. One opportunity for addressing the climate crisis is to use nature-based solutions (NbS). The **International Union for Conservation of Nature** (IUCN) defines nature-based solutions as “actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits” (Cohen-Sacham et al., 2016).

When used in conjunction with a sustainable economy and policy changes, nature-based solutions can help mitigate the impacts of climate change and allow systems to adapt.

Figure 4: Nature Based Solutions at a glance (IUCN, 2016).



3.1 Benefits and Uses

Nature-based solutions are cost-effective as they use natural systems, either pre-existing or restored, to deal with climate change impacts. These solutions provide ecological and socio-economic benefits simultaneously and build resilience and stability within systems (Raymond et al., 2017a).

ENVIRONMENTAL BENEFITS

There are many direct and indirect benefits to be gained from nature-based solutions. A goal of these solutions is climate change adaptation and mitigation, where the impacts from climate change are easier to overcome and/or lessened in the targeted areas. A side-effect of putting these solutions in place can be carbon **sequestration** and the removal of GHGs from the atmosphere. While not the ultimate goal of nature-based solutions, reducing total GHG emissions may contribute to slowing rates of warming.

Terrestrial and aquatic ecosystems play an integral role in the global carbon cycle, and when properly preserved act as carbon sinks and stores. By capitalizing on these benefits, nature-based solutions can address extreme weather and disturbance events, protect biodiversity, regulate ecosystems, support livelihoods, and supply goods and services that are able to drive sustainable growth (IUCN, 2016).

In general, nature-based solutions rely on the effective integration of healthy natural areas in and around where people need them. By protecting and investing in nature, ecosystem functions are better supported. An increase in species survival leads to greater biodiversity and species richness which makes these systems more resilient. Nature-based solutions provide a means for nature and humans to become resilient to climate by mitigating future impacts and stress while adapting to current changes (Raymond et al., 2017b).

SOCIAL BENEFITS

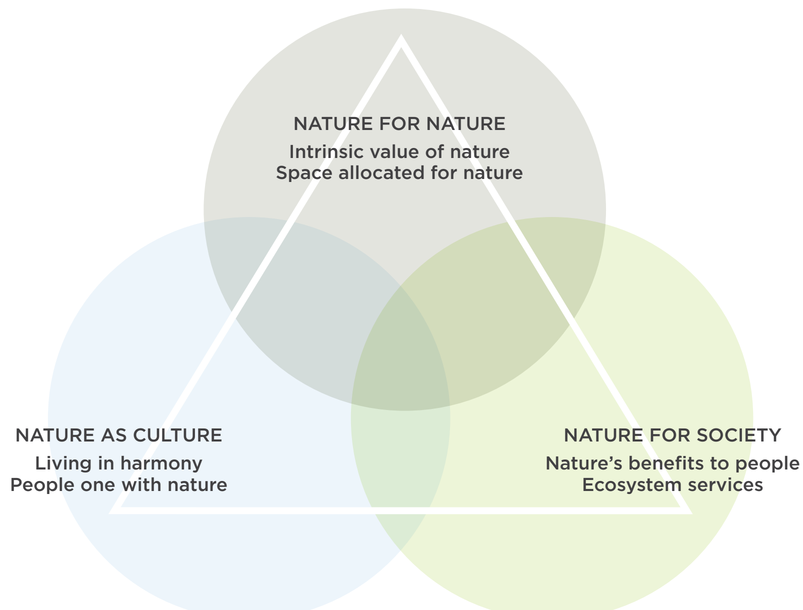
Nature-based solutions can have co-benefits related to physical, social, and mental health through increased access to green space, reduction of urban heat island effect and increased economic opportunities, to name a few.

When implemented at a local-level, nature-based solutions can increase a community's sense of ownership and connection to natural areas. Involving those who are directly impacted by the problem, increases understanding of nature and climate change impacts in addition to providing a means for communities to gain new skills and better support their well-being and prosperity. These interactions provide opportunities to build trust, tolerance, and respect between groups of people. Nature-based solutions, if designed right, could reflect the needs and interests of social groups who are typically excluded (Raymond et al., 2017b).

ECONOMIC BENEFITS

Investing in nature-based solutions promotes job creation in **green infrastructure** and ecosystem restoration. This can include construction, delivery, maintenance, monitoring, and analysis of solutions (Raymond et al., 2017b). By addressing climate change through nature-based solutions on a large scale, we could reduce the frequency and magnitude of natural disasters occurring in the world. The impacts of natural disasters cost billions, and include repairing damages and providing relief for the people and businesses affected. In 2019, severe weather such as rain, snow, flooding, and windstorms, cost Canada $1.3 billion in insured damages (Abedi, 2020). This made 2019 the 7th most costly year in Canadian history (Abedi, 2020). Using nature-based solutions to minimize natural disaster impacts will not only reduce relief costs but allow this money to be put to good use elsewhere.

Figure 5: A diagram showing the multiplicity of relationships between people and nature (IPBES, n.d)



3.2 Nature-based Solutions in Action

Nature-based solutions can be powerful tools in the fight against climate change by adapting to and mitigating the impacts of dramatic global changes. It is a broad field in which there are always new studies and data being made available on various nature-based solutions, whether they focus on forests, watersheds, or engineered urban centres. The beauty of nature-based solutions is in just how many services they can provide at once. Allowing a system to better adapt to the impacts of climate change is never the sole result of implementing a nature-based solution, but it is the focus of this guide.

Determining how to prioritize nature-based solutions and where to focus efforts requires a great deal of consideration, such as a vulnerability assessment, modelling of potential scenarios, and feedback from the local community to find a way forward.

Assessing risks and vulnerabilities to climate change in a community is a key step that can help identify current climate change risks and determine what future challenges may be. This assessment cannot focus solely on how climate change will impact the environment but must also look at the region's potential to adapt and how the climate interacts with socio-economic issues. (Climate-ADAPT, n.d)

Modelling potential scenarios is the next step once the vulnerabilities of a system have been analyzed. This modelling determines the potential benefits that different types of natural infrastructure would impart on the area in question. For example, if the local area is at risk of flooding, a model will help determine if a wetland of a given size would be able to reduce the flood risk on its own, or if a secondary measure such as building a sea wall or relocating houses would also be required.

Working with local communities to determine a way forward can and should be done in a democratic process and can use tools to help visualise trade-offs of different scenarios. By providing local stakeholders with information on the pros and cons of various scenarios and potential adaptive measures, they will have a chance to understand and accept the proposed solutions and reach a consensus on how best to address their needs (Adem Esmail & Geneletti, 2018).

While nature-based solutions can be used in all settings, there are difference in how issues in each may be addressed. In the following three sections, this guide will showcase some of the considerations and solutions being put in place in conserved or restored ecosystems, agricultural land, and urban environments.

4.0 Ecosystems as Nature-Based Solutions to Climate Change

Protecting, monitoring, and restoring ecosystems are the most common nature-based solutions, as the concepts of conservation and restoration are universal. Whether a forest is planted in a fallow field, or an animal's territory remains protected and uninterrupted, natural ecosystems are the ultimate nature-based solution.

4.1 Forest Protection, Conservation, and Management

Forests are a stabilizing force for the global climate. As both a source and sink of greenhouse gas emissions, their role in climate change is double edged. Forests are one of the most important solutions to addressing climate change. Approximately 2.6 billion tonnes of CO_2 are absorbed by forests each year, which is approximately 1/3 of all CO_2 emissions released over the span of an average year (IUCN, 2017a).

Forests need to be protected and maintained when possible, restored when necessary, and created where needed. Examples of how forests can help mitigate climate change can be seen through examples of forest protection or restoration, afforestation, agroforestry, and urban forestry.

4.1.1 Forest Conservation & Protection

Forest conservation is the range of activities, tools, and approaches that are used to achieve forest health and biodiversity objectives including managed forests where harvesting occurs. These activities are set out in sustainable forest management plans and are enforced by law. Conservation efforts may be in the form of provincial guidelines that forest companies must follow such as retaining trees used by wildlife during harvesting, creating a mix of tree species type and age, and ensuring that sections of the forest remain connected to maintain wildlife habitats (NRCan, 2020c).

Forest protection often refers to the legal, permanent protection of forested lands. This can be in the form of protected areas such as parks that do not permit industrial activities, such as logging (NRCan, 2020c). The expansion of protected areas, including Indigenous land, privately owned land, and conservation areas should be done in ways to enhance the landscape's resilience and help to stabilize and store carbon, and the decisions about these protected areas must be undertaken in partnership with, or lead by, local communities (IUCN, 2017a).

Ontario's Greenbelt consists of 2 million acres of lands that are protected from development. The Greenbelt is composed of forests, wetlands, and agricultural lands that sequesters $51.94 M worth of carbon per year (Friends of the Greenbelt Foundation, 2016). These lands have been protected since 2005, providing permanent protection to the ecological and hydrological features and functions in Ontario's Golden Horseshoe from urbanization and other negative impacts. There are two major components to the Greenbelt – the agricultural system and the natural system. The natural system, composed of terrestrial and aquatic components, provide a wide range of ecosystem services to the communities that dwell in and around the Greenbelt (Government of Ontario, 2017).

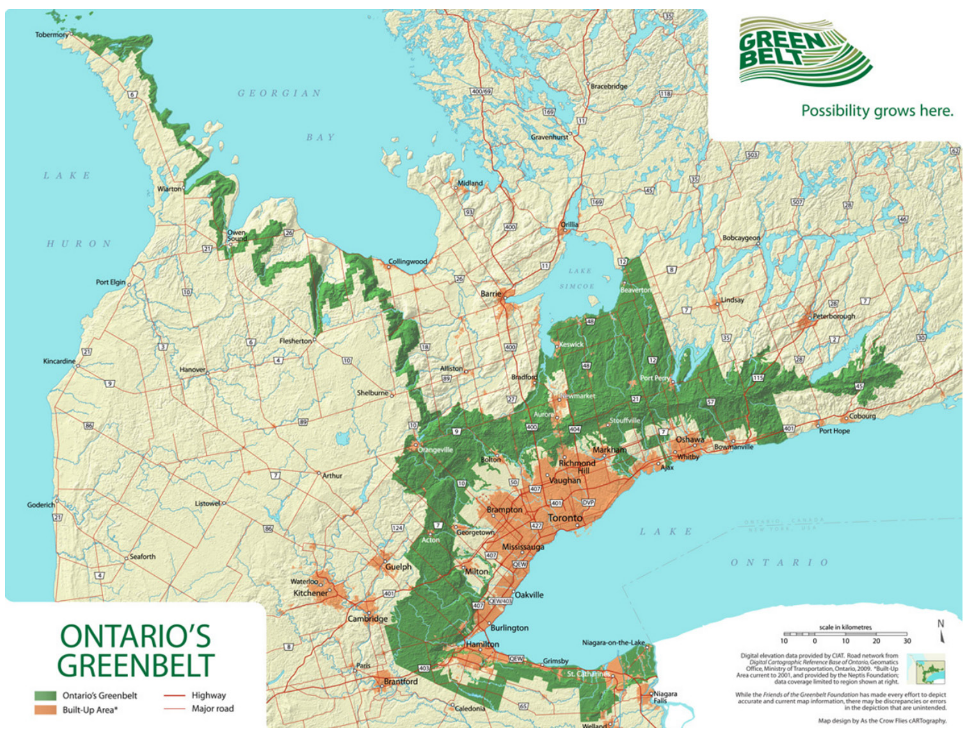


Figure 6: A map showing the extent of the Ontario Greenbelt (Friends of the Greenbelt Foundation, 2016)

4.1.2 Afforestation

Afforestation is the conversion of croplands and marginal land into forests, or the establishment of trees on land that has not been forested for at least 50 years. In addition to their ability to sequester carbon, planted forests can purify the air and water, protect from erosion, provide wildlife habitat, and regulate a microclimate within the forest. In Ontario, afforestation has been implemented by different agencies and research groups including the Ontario Ministry of Natural Resources and Forestry, Canadian Forest Service, and the University of Guelph's Department of Food, Agriculture & Resource Economics (Gale et al., 2013).

The 50 Million Tree Program is a tree planting program run by Forests Ontario. This program reduces the cost of large-scale tree planting for landowners, providing them with both financial and technical assistance to increase forest cover on their land. Landowners who have been involved with this program are able to increase the value of their land, improve soil quality, enhance recreational opportunities, increase wildlife habitat, and improve the health of their local environment. Forests Ontario works with more than 80 partners to deliver the program, including private tree nurseries, conservation authorities, stewardship groups, Indigenous communities, forest consultants and municipalities (Forests Ontario, n.d.,a).

Figure 7. The number of trees planted throughout various locations in Ontario through the 50 Million Tree Program. Source: Forests Ontario, n.d,a

By the Numbers:

- As of 2019, Forests Ontario has planted more than 30 million trees through the program and produced 15,500 hectares of new forest areas (Figure 7).
- The trees planted through the program now sequester over 22,000 tonnes of carbon each year
- The forests planted to date under the program now generate over $83 million in annual ecosystem services (i.e., pollination, recreation, water supply regulation, and aesthetics)
- The 50 Million Trees Program supports more than 300 full-time seasonal jobs in Ontario annually (Forests Ontario, n.d.,a)

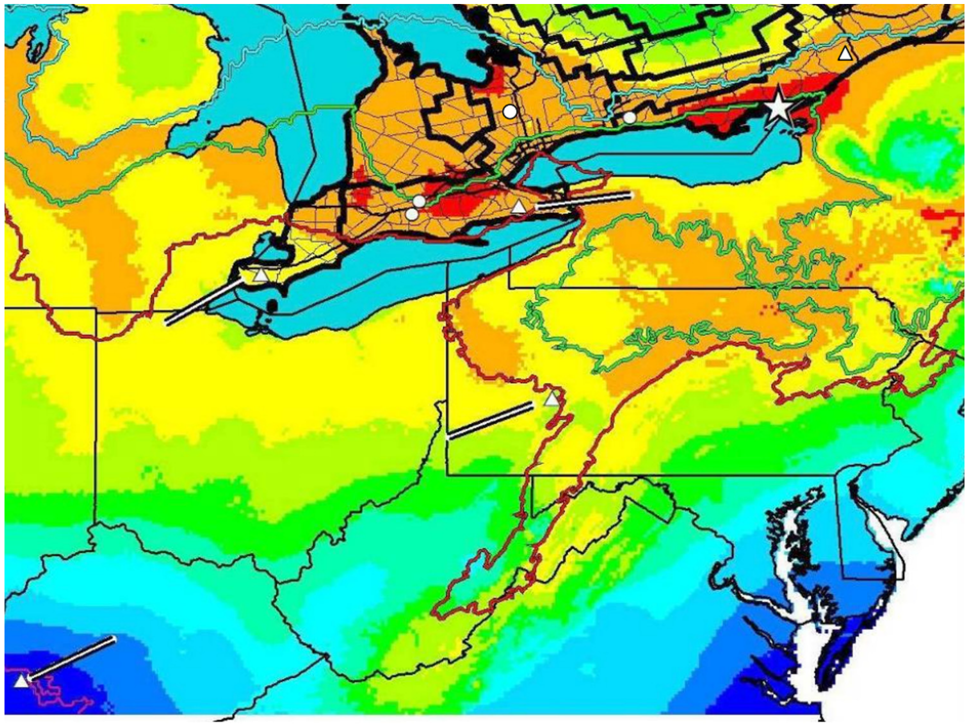
4.1.3 Assisted Migration

Climate change is forcing plants and animals rapidly adapt to new conditions or migrate elsewhere. As the climate is changing rapidly some species or populations may not have the ability to adapt to their new conditions in a reasonable timeframe (Forest Gene Conservation Association, 2019).

Assisted migration is the human-assisted movement of plants or animals to more climatically suitable habitats, generally northwards or to a higher altitude where site conditions may best suit their needs. This strategy can be used to maintain stand health and productivity and meet conservation goals to save a species from an increasingly unsuitable climate and habitat (NRCan, 2020a). By planting trees and other plants outside of their original range, the plants are ensured a chance to thrive for a longer period time and generate seeds for successful future generations of plants (Forest Gene Conservation Association, 2019).

An assisted migration trial has been conducted at Lemoine Point in Kingston, Ontario. Figure 8 shows the current climate of the Lemoine Point Trial, indicated by the star, in comparison to greater eastern North America. Areas shown in red have a similar climate to the trial site, including factors such as growing season length, winter precipitation, and temperature. The triangles represent the seed sources considered for the trials, and the circles show other locations of assisted migration trials (NRCan, 2020a).

Figure 8: Assisted migration trial climate analysis and seed source selection at Lemoine Point, Kingston, Ontario in seed zone 36. Map produced using the NRCan GIS Tool - Seed Where (Forest Gene Conservation Association, 2019).



Case Study: Alderville Black Oak Savanna: Grassland Restoration

The Alderville Black Oak Savanna (ABOS) is a nature preserve located in Alderville First Nation, Ontario (Figure 9). Its mission is to preserve, restore, and expand rare grassland habitats and provide a site for research and education. The ABOS values the local Indigenous Knowledge of Alderville First Nation community members to ensure that appropriate management strategies are used.

The Black Oak Savanna site supports two types of endangered grasslands: tallgrass prairie and oak savanna. These types of grasslands once spanned across eastern North America and were maintained by Indigenous communities until European colonizers began to convert the land for agricultural use and restricted the use of fire for prescribed burns. As of 2019, less than 3% of these habitats remain in Ontario. Their protection and restoration are important as they act as carbon sinks and provide habitat to many endangered species.

These habitats are well adapted to natural disturbances. The Alderville Black Oak Savanna undergoes controlled burns to preserve these ecosystems. The fire acts as a rejuvenating force, burning off dead plant material that has not been broken down by microorganisms and releasing the stored nutrients back into the soil for new plants. This creates space for dormant seeds to germinate, allowing for a new generation of grassland plants to rise from the ashes (Odolczyk, 2019).

Tallgrass environments act as carbon sinks, able to sequester 1.7 metric tons of CO_2 per acre, per year on average. Based on this calculation, ABOS can sequester 91.8 metric tons of CO_2 per year. Unlike forests, where the bulk of the plant material is above ground, grasslands have extensive root systems that store considerable amounts of carbon. Compared to a forest fire, a grassland fire will release less CO_2 into the atmosphere and instead keep it stored underground. (Alderville First Nation, 2016).

ABOS uses many practices to establish species-at-risk habitat. These include gathering and planting seeds to turn agricultural fields into tallgrass prairie habitat, connecting oak and pine savannas, constructing snake hibernacula, and breeding rare plant species (Odolczyk, 2019). Over 800 species have been documented at the ABOS site. By restoring these rare ecosystem habitats, it provides habitat for species at risk such as grassland birds or pollinator species. The Eastern Meadowlark (threatened) (Figure 10) and the Mottled Duskywing (Endangered) are known to use the ABOS as habitat.

Figure 9. The Alderville Black Oak Savanna, native grassland habitat in Ontario (Alderville Black Oak Savanna, 2019).

Figure 10: An Eastern Meadowlark at the Alderville Black Oak Savanna (Alderville Black Oak Savanna, 2019).

DISCUSSION QUESTIONS

Q1: How can controlled burns restore grasslands?

Q2. Why is IK important for the preservation of natural ecosystems? Why is it important to combine Indigenous and Western knowledge systems when restoring ecosystems?

Q3. What are the differences between grassland and forest carbon sequestration, with regards to ecosystem restoration? In your opinion, which habitat type is more efficient at sequestering carbon?

4.2 Wildlife

As the climate is changing, the environment is being altered in substantial ways that impact wildlife. Many species are at risk to the impacts of climate change. Species may move or adapt, though the speed of adaptation might not match the speed at which their habitats are changing. Wildlife and their habitat play a critical role in ecological and biological processes essential to all life on Earth. Processes such as pollination, seed dispersal, germination, nutrient cycling, waste breakdown, soil generation, and pest control are all key to the maintenance of healthy habitats (Egan et al., 1995). By protecting habitats, we are also protecting the ecosystems that support human well-being and our economies.

Wildlife provides countless ecosystem services. Through the protection of wildlife habitat, both the plants and animals living within the habitat and the climate are also protected. Climate and biodiversity loss are undeniably linked - one cannot be solved without the other. Biodiversity needs to be maintained to stabilize the climate, but to maintain biodiversity, the climate needs to be stable (Bittel, 2019). Examples of how wildlife can be incorporated into nature-based solutions include:

POLLINATORS

Pollinators ensure the reproductive success of plant species and the survival of wildlife that depend on those plants for food and shelter. They provide billions of dollars' worth of ecosystem services to the North American economy. Limiting the use of neonicotinoid pesticides, creating pollinator habitat, and planting native species can help to protect pollinators and the critical services they provide (Ontario Nature, 2020).

WOODLAND CARIBOU

The cold temperatures of the boreal habitat of Woodland Caribou allow for a slow rate of decomposition, which creates carbon-rich soils. As such, the boreal forest can store a large amount of carbon in more than just the trees. If these forests are logged or developed, their ability to absorb carbon is either lost or reduced, and carbon is released upon the damage to the forest (CPAWS, n.d). By protecting caribou habitat, not only do the caribou benefit, but the carbon stored in those regions is maintained.

BIRDS

Birds provide many ecosystem services including pollination, seed dispersal, insect control, and generally act as ecosystem engineers (Whelan et al., 2008). The protection and restoration of bird habitat is a win-win situation for both the birds and the climate (Birds Canada, 2020). For example, waterfowl and water birds can transport a host of organisms from wetland to wetland, including frog eggs, insect larvae, aquatic plant seeds, and fish. This transportation of species can help establish restored wetlands as biodiverse ecosystems, diversify the gene pool, and even allow for the expansion of species' ranges northward as the climate changes (Rae, 2020).

A keystone species is an organism that has a large effect on its natural environment and holds that ecosystem together. Without its keystone species, the ecosystem would be dramatically different and may cease to exist.

In comparison, a cultural keystone species is a species with exceptional significance to a culture or people. They play a fundamental role in the diet, materials, medicine, and/or spiritual practices of a culture.

4.2.1 Cultural Keystone Species

Cultural keystone species support the survival of many individuals, and as a result should be given the same weight as species at risk when making management decisions. Though these species play a key role in ecosystem function, resource planners may lack the understanding of how the removal of even a single cultural keystone species can have significantly negative impacts on the cultural and daily survival of Indigenous peoples.

An example of a cultural keystone species is white birch (*Betula papyrifera*), as it is the primary material used in the construction of birch bark canoes. First Nations people have historically relied upon these canoes for activities such as travel and hunting and have an important role in their cultures. Depending on the geographical location of where a canoe is crafted, up to 14 different plant species can be used to form a single canoe. If one of those species is missing from the local ecosystem, then the livelihoods or daily survival of people living in that area would be impacted.

Figure 11: This paper birch, or white birch tree (*Betula papyrifera*) stands out in a forest of brown trees. After many years, it may have suitable bark to make a canoe.

4.3 Wetland Conservation & Restoration

Wetlands are valuable ecosystems that contain some of the most diverse habitats and broad range of biodiversity. These are lands that are covered by shallow water (either seasonally or permanently), or where the water table is close to or at the surface. The soils in these environments are waterlogged, favouring the growth of water loving or water tolerant plants. (OMNRF, 2017). From the **peatlands**, bogs, and fens in the north to the swamps and marshes spread about the southern end of the province, Ontario's wetlands provide valuable ecosystem services that citizens depend on for their health and wellbeing such as greenhouse gas sequestration, climate moderation, flood control, water quality, and general recreational value (Tozer, Steele, and Gloutney, 2018). As transitional habitats between terrestrial and aquatic systems, these hotspots of biodiversity contain a host of plants, insects, amphibians, fish, birds, and other animals unique to their conditions. Many rare species or species at risk can be found in wetlands. There are 350,000 square kilometers of wetlands in Ontario, which accounts for approximately 25% of wetlands in Canada (OMNRF, 2017).

Wetlands play a crucial role in maintaining natural cycles (carbon, nutrient, and water cycles) and climate systems. They can clean water, regulate temperature, reduce the heat island effect, slow the impacts of drought, and reduce flood and erosion risks – all critical in adapting to and mitigating the effects of climate change (OMNRF, 2017). Restored wetlands can also increase the amount of carbon stored in the landscape, especially in peatlands where dead plant matter is stored under waterlogged conditions, unable to fully decompose (Byun et al, 2018). It is estimated that peatlands in northern Ontario sequester about a third of Ontario's total carbon emissions each year.

Protecting and restoring wetlands (wetland conservation) strengthens biodiversity across the landscape and provides resiliency to environmental changes such as water quality and quantity impacts. An example of a wetland conservation plan focused on wildlife is the North American Waterfowl Management Plan (NAWMP), designed to conserve wetlands and upland habitats for migrating and breeding waterfowl (i.e. ducks, geese, swans) (NAWMP, 2012). While this plan focuses on waterfowl, there are dozens of non-waterfowl marsh-breeding birds such as grebes, bitterns, terns, and rails in addition to various amphibians that also benefit from this conservation effort.

The natural flood management services provided by wetlands is an important topic in the field of nature-based solutions. Wetlands can be a cost-effective complement to traditional infrastructure designed to protect communities from flooding while increasing grey infrastructure life cycle. By incorporating this natural infrastructure into flood and asset management plans, Ontario municipalities can plan for a future more resilient to increased flooding events (Page et al., 2020). For more information of natural infrastructure in stormwater management plans, see section 6.2.

4.4 Peatland Restoration

Peatlands are a type of wetland that cover 12% of Canada's land surface, and 3% of the earth's surface (Tarnocai, 2009). A healthy peatland typically has a high-water table, moisture content, and acidity, with low oxygen and nutrient availability as most of the ecosystem is submerged in an anaerobic environment underwater. These conditions allow for a unique community of plants, consisting primarily of mosses and vascular plants that cannot be found in other ecosystems (Minayeva & Sirin, 2012).

Sphagnum moss, commonly known as peat moss, is a dominant vegetation of peatlands that supports the buildup of soil over thousands of years reaching depths over 5 meters. Peatlands are responsible for the storage and sequestration of 30% of the world's soil carbon (Burns Bog Conservation Society, 2019). Some plants in peatlands also absorb heavy metals from water, providing invaluable water purification services. Peat soil is also very absorbent – it can act like a sponge to reduce flood risks and provision water in times of drought (Canadian Wildlife Federation, n.d.).

Humans have exploited peatlands all over the world for agriculture, forestry, and urban and industrial development. Peat has also been used as an energy source, as dried bricks are carbon-rich and can burn for extended periods of time. To extract peat, peatlands must be drained. During this process, peatlands become a source of GHG emissions as both carbon dioxide and methane are released. Restoration work is conducted all over the world by rewetting peatlands in hopes that the CO_2 emissions released during peat extraction can be offset by restoring carbon storing potential and will continue to have long-term benefits of carbon sequestration (Burns Bog Conservation Society, 2019).

Burns Bog is a peatland covering 3,000 ha of the Fraser River Delta in British Columbia (D'Acunha et al., 2019). Burns Bog was disturbed by peat mining and agriculture in the 1950s and 1960s, where half of the sphagnum mosses that had built up over 3000 years were destroyed. Other damages included surrounding development and the construction of Highway 91 in 1986, cutting directly into the bog and harming the bog's water table.

In 2004, four levels of government came together to purchase 2,025 ha of the land. The following year, Burns Bog was officially designated as an Ecological Conservancy Area (Burns Bog Conservation Society, 2019) and has been in the process of restoration ever since (D'Acunha et al., 2019).

Figure 12: Dam used in ecohydrological restoration of Burns Bog, British Columbia, Canada (Society for Ecological Restoration, n.d.)

Restoration of Burns Bog involved reflooding the peatland by implementing a large-scale ditch blocking program. This reduced the amount of water drained from the bog and maintained the high-water table necessary to accumulate peat and grow sphagnum moss (Dilley, 2014). The rewetting recreated the anaerobic environment that the peat soil originally dwelled in, which decreased the rate of peat organic matter oxidizing, reducing the amount of CO_2 released into the atmosphere (Knox et al., 2014).

A study conducted on the bog from 2016-2017 found that there was a net increase in carbon stored in the bog over the year, and that the CO_2 uptake was highest in warmer temperatures (D'Ancunha et al., 2019). This shows that peatlands can be restored to act as carbon sinks, prevent CO_2 release, and provide habitat for wildlife.

DISCUSSION QUESTIONS

Q1: Why is assisted migration being used as a solution to climate change? What is an example of a location where assisted migration would be beneficial?

Q2: As a new concept/practice, what do you think some of the risks of using assisted migration are?

Q3. How can Indigenous and Western systems of knowledge work together to develop holistic solutions to climate change?

Q4: Protection of wildlife is often a co-benefit of nature-based solutions to climate change projects. Give an example of how nature-based solutions can protect wildlife.

Q5: Describe how forests, grasslands, and wetlands store carbon. In what ways are they similar or different? Which ecosystem has the greatest carbon storage capacity?

5.0 Nature-based Solutions to Climate Change in Agriculture

While preserving and restoring ecosystems is commonly viewed as the ultimate nature-based solution, it cannot be extended to arable land being used to grow important crops necessary to feed our communities. The demand for locally sourced foods and the maintenance of Ontario's agricultural industry requires that farmland remains as such.

Though managed, agricultural lands provide a host of ecosystem services of their own, including stormwater retention and runoff control, water filtration, and pollination (Ontario Federation of Agricultural and Environmental Defense, 2015). Areas such as the Greenbelt found in southern Ontario are protected and maintained to support long-term agricultural activity and economic support while also serving as a natural space.

There are areas in which agricultural practices can be modified or improved to provide a greater benefit to their surrounding areas. In this section, some methods of using agricultural lands in nature-based solutions are presented, though the list is not exhaustive.

5.1 Agroforestry

Agroforestry is characterized by the merging of cropping systems and tree plantations in the same area for both positive environmental effects and net economic return (Abbas et al., 2017). By planting or maintaining woody plant species through agroforestry, it is possible to capture and reduce emissions from the agricultural landscape. In Canada, common systems such as shelterbelts, hedgerows, and silvopasture are seen in the prairies and alley cropping is used in Eastern Canada (Baah-Acheamfour et al., 2017). For more information about Agroforestry techniques refer to section 5.0 of the 2019 Current Issue Guide: Agroecology.

5.2 Permaculture

Like agroforestry, permaculture also takes a holistic approach to agriculture and society. Applicable in both urban and rural contexts permaculture principals focus on diversity, sustainability, resilience, and the incorporation of ecosystem services into thoughtful planning. Permaculture techniques have been used to manage stormwater, prevent erosion, and improve soil health often using natural solutions or systems such a perennial crops and swales (Friends of the Greenbelt Foundation, 2018).

5.3 Soil Health

Intense agricultural farming practices can degrade soil conditions and reduce their capacity for storing carbon. Historic losses of soil carbon due to agricultural activity around the world are massive, ranging from 55 to 78 gigatonnes globally. In Canada, 93.4 million ha of cropland has depleted pools of **soil organic carbon** (SOC). This loss of carbon is related to the removal of tree cover and the intense tilling of land for crop cultivation.

SOC pools are created by the breakdown and digestion of organic matter in the humus layer. In fields and pastures filled with photosynthetic plants, the remnants left behind after harvest, such as the roots, stems, chaff, and leaves, feed the microbial community living in the soil. These communities in turn leave behind any excess nutrients and stored carbon in the soil, for the nourishment of future crops. The SOC pool that is in the uppermost layers of soil increases as organic materials are added, but the microbes are sensitive to disturbances. Over time, the carbon stored in the soil can move into deeper soil layers through an accumulation of new materials and is thus more securely stored away from the immediate effects of weathering or tilling.

Canadian naturalized grassland projects (about 12.2 million ha in 2018) act as carbon sinks when managed properly and are at or near their carbon sequestration potential (Wood-Bohm, 2018).

6.0 Nature-Based Solutions to Climate Change in Urban Centres

Urban centres with large populations stand to benefit from nature-based solutions, not only due to the issues presented by relying solely on **grey infrastructure**, but also because of the number of people that will be impacted by climate change in densely populated areas. Often, these areas have high demands for greenspace to be available for public use, particularly in southern Ontario. As the population increases, this demand continues to grow (Green Infrastructure Ontario, 2019).

Large natural areas around cities can provide critical services to the population, such as the Greenbelt or other undeveloped land. Within cities, smaller-scale nature-based solutions can be utilized. Innovations such as green roofs, urban parks, and street trees can provide important services by cooling neighbourhoods, helping to manage stormwater onsite, and providing connections to nature in cities.

Cities are generally much hotter than surrounding rural areas due to the replacement of vegetation with hard surfaces such as asphalt and concrete. These modifications create what is known as an urban heat island, as man-made structures typically absorb solar radiation and therefore cause surface temperatures and overall ambient temperatures to rise. The impact of heat is a silent one, as it affects the human body much more than the built environment, but it is not immediately visible like a natural disaster might be. A solution to the urban heat island effect is to increase tree cover and natural spaces, as vegetation can naturally cool cities by shading surfaces and cool through evapotranspiration. Reforestation efforts in suburban neighbourhoods have been shown to make it feel up to 11 ˚C cooler during a heat wave, reducing the stress on people in the neighbourhood. (Greenbelt Foundation, 2020)

6.1 Urban Forestry

Urban forests are an asset for communities across Ontario. Large, healthy trees and shrubs impart many benefits in an urban landscape, from improving air and water quality, conserving energy, reducing noise pollution, improving wildlife habitat, reducing temperatures, increasing property value, and aiding the psychological well-being of those living around these lush landscape features. Urban forests are a part of the larger community complex and are critical parts of infrastructure that has multiple uses and benefits, versus infrastructure such as road that, while also critical, have a single purpose.

Urban forestry as a field of study began in Ontario, with research being conducted at the University of Toronto in 1965. Over time, there has been an increased understanding of the benefits that urban forests can impart, and that policies and practices must be put in place to properly manage them. Municipalities have a responsibility to provide for their citizens, but the management of urban forest falls also on the shoulders of private citizens, institutions, industry, and provincial and federal governments (Green Infrastructure Ontario, 2016).

Many cities in Ontario are now applying a climate lens to their policies and are creating climate change plans. The Climate Change Master Plan in Ottawa, for example, has an overarching goal to reduce greenhouse gas emissions and respond to the current and future effects of climate change. Within this Master Plan, Ottawa has recognized the value of carbon sequestration in both the city's Urban Forest Management Plan and the Significant Woodlands Policy. Nature-based solutions using carbon sequestration methods are described as being complementary to the actions needed to mitigate climate change and transition away from fossil fuels. The nature-based solutions outlined in the plan include understanding and quantifying the climate benefits of trees, forests, and wetlands to support the active management of these features (The City of Ottawa, 2019). Initiatives include:

- Inventorying forests as carbon sinks
- Monitoring and evaluating changes in carbon in agricultural soils
- Mapping wetlands as functioning carbon sinks
- Preserving existing natural heritage systems wherever possible
- Exploring carbon market options

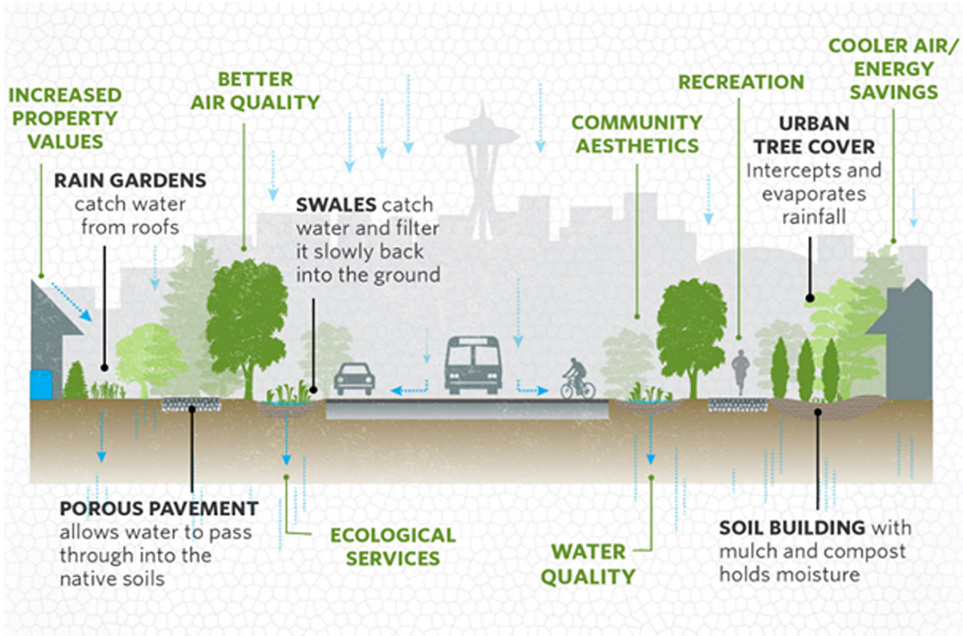
To make these initiatives possible, varying partner collaborations are necessary. These partners include:

- **Federal:** National Capital Commission and Agriculture Canada,
- **Provincial:** Ontario Ministry of Agriculture, Food, and Rural Affairs and Ministry of Natural Resources and Forestry,
- **Institutions;** Carleton University, University of Ottawa, and local conservation authorities (The City of Ottawa, 2019).

6.2 Stormwater Management

With climate change, there is an increased risk of heavier rainfall. After such weather events, the precipitation that builds up on the ground (stormwater) accumulates and cannot be absorbed by soil due to roads, pavement, or other grey infrastructure that is covering the ground. While on the ground, the accumulated stormwater becomes contaminated by waste that it encounters (such as cigarette butts, pet waste, oils, and other fluids that have leaked from vehicles). Both the loss of permeable surfaces in urbanized areas and heavier rainfall can increase the amount of stormwater on the ground after such weather events. Excess stormwater can cause flooding and severe damage to existing infrastructure and have negative impacts on human and environmental health.

Figure 13: Green & grey stormwater infrastructure (Sloniker, 2016).



Systems put in place to manage stormwater must consider how stormwater can affect communities. The excess water can cause sewer system overflows, threaten clean drinking water, and carry pollutants. Both naturalized and engineered green infrastructure can be incorporated effectively to complement or replace grey infrastructure. **Bioswales**, permeable pavement, rain barrels, green roofs, and stormwater ponds are just some of the components that can be used to create a system that can intercept, absorb, and retain stormwater. (Green Infrastructure Ontario, 2020). These green infrastructure solutions manage stormwater on site and treat the water, removing pollutants as it is reabsorbed. By managing stormwater where it falls, green infrastructure also takes pressure off existing sewer systems, reducing overflow events and prolonging the life of the infrastructure.

The 2006 Clean Water Act (CWA) in Ontario requires organizations that protect drinking water to develop plants for reducing the threat of stormwater runoff (Ministry of Environment, Conservation, and Parks, 2019). Policies such as this can inform decision making and planning in municipalities on how to ensure that stormwater management is considered in new developments, and how to retrofit green infrastructure solutions into existing communities to impart the same benefits.

DISCUSSION QUESTIONS

Q1. Are there ways your community, town, or city incorporates nature-based solutions through the design or protection of land that aids in mitigating climate change? Are there ways that improvements could be made?

Q2. Look at a map of your community to see your local urban forest. Where are the most trees? The least? Collect what information you can on their species, size, and whether or not they were planted as part of an urban plan.

Q3. How does your community, town, or city manage runoff from storms? Is there any green infrastructure used? How could the existing system be retrofitted to be more efficient?

7.0 Economic Impacts

The economy and the environment are innately intertwined, with humans acting as drivers of change and influence. Environmental integrity has often been a trade-off to short-term profit, but in a **sustainable economy** the two are one in the same.

A sustainable economy provides for future generations without the environmental degradation or social inequity experienced today. This is accomplished by investing in sustainable practices and climate change solutions rather than prioritizing profit over all else. By quantifying ecosystem services, the benefits of natural systems can be translated to the common language of monetary value and costs.

Ecosystem services is a general term used to categorize a wide range of natural benefits that ecosystems can contribute to people. The valuation of ecosystem services gives estimates that show policymakers the need to consider environmental variables. This section will describe the use of ecosystem services for promoting a sustainable economy and how decision-makers today are embracing these concepts.

7.1 Sustainable Economy

A sustainable economy relies on stable and prosperous industry to provide the necessary goods and services for society through practices that promote a healthy environment. It recognizes the value of protecting natural capital not only for resources, but for the ecological processes and holistic uses to society. Along with environmental sustainability, it also focuses on reaching socio-economic sustainability and sets out to meet the Sustainable Development Goals (United Nations, n.d.).

The current global economy is based largely on unsustainable practices and proceeds are distributed unevenly between countries and social classes. Consumerism and carbon-intensive livelihoods of developed nations has driven the present economy to rely heavily on planetary and human exploitation. This occurs because the **external costs** to society and the environment are not considered in the pricing of goods and services. When policymakers try to adjust for these costs, the fees fall on businesses, industries, and individuals. The resulting fear of financial loss and job insecurity is the largest obstacle environmentalists face today.

By continuing with a business-as-usual economy, the effects of climate change will become more extreme and increasingly threaten the economy, the environment, and human lives. As it stands, the world economy produces tremendous GHG emissions from production and consumption, population growth, and income growth. To decarbonize these activities, meeting human needs must be a higher priority than consumer preferences (Gough, 2017) Studies have shown that investing in more carbon-friendly alternatives can lead to greater profits and job creation (Gouldson et al., 2015).

While there is a clear need to change how the economy functions, there is no clear way for businesses to accomplish it practically. Researchers and academics are being urged to provide better education to manufacturing on design and engineering that is sustainable and adoptable (De los Rios & Charnley, 2017). To carry society to a sustainable economy, multiple stakeholders need to be involved, new processes developed, and education and financial support provided. Any major system change will require significant inputs, leading to loss of capital and high associated costs. New solutions are necessary for creating industry that is reliable and equitable for generations to come.

Nature-based solutions are tools used for climate change mitigation and adaptation; they also aid the shift towards sustainable development. Natural systems are renewable, self-regulating, and circular. Initial costs for implementing these solutions are inevitable, but the characteristics of natural systems require lower maintenance cost and have longer lifetimes.

One example of a nature-based solution which has been shown to lower GHG emissions, provide sustainable sanitation, and increase overall profits are constructed wetlands. In Winnipeg, conventional stormwater basins have been shown to produce methane emissions from aesthetic vegetation removal and cyanobacterial blooms. Compared to constructed wetlands for stormwater regulation, stormwater basins produce double the CO_2 emissions and involve greater upkeep costs from herbicide and harvesting (Badiou et al., 2019). Constructed wetlands also provide a more circular system for wastewater management than conventional sanitation practices (Masi et al., 2018). By capitalizing on nature's beneficial processes, alternatives to current systems can be designed by looking at what nature does right.

7.2 Ecosystem Services

Ecosystem services are aspects of ecosystems that provide benefits to human well-being, either through passive or active means (Fisher, Turner & Morling, 2007). They are a way to acknowledge the link between the environment and human welfare and account for the externalities currently unpaid by society. By understanding ecosystem services and using them to have a more holistic perspective of their benefits the value of protecting ecosystems come to light.

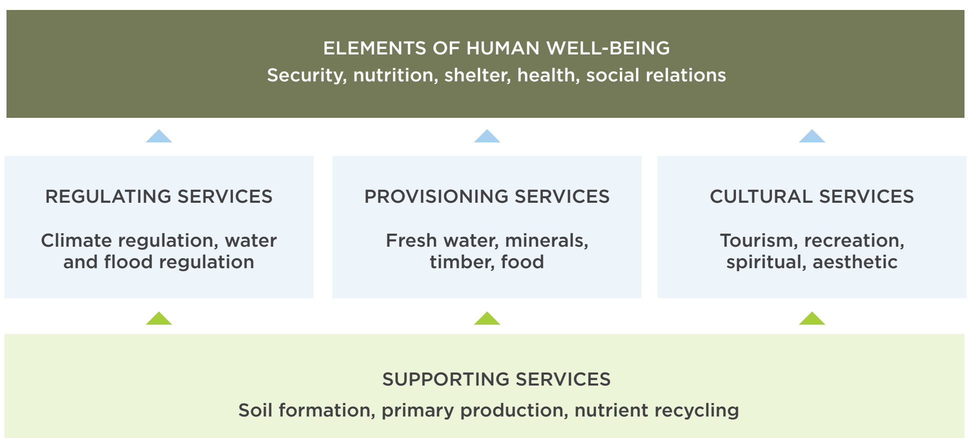
The healthier the ecosystems are, the less intense climate change impacts are to humans. This is known as ecosystem-based adaptation (EbA) which utilizes an ecosystem services approach to implement climate change adaptation and mitigation strategies for issues such as storm surges, droughts, floods, desertification, and food security (Chong, 2014). EbA can be considered a nature-based solution for climate change. Researchers have also presented nature-based solutions to support healthy ecosystems and the enhancement of their services (Keesstra et al., 2018). Through these interpretations, ecosystem services, nature-based solutions, and climate change adaptation, create a unique positive feedback loop where if one variable is improved, the others are improved as well.

The concept of ecosystem services has been around for decades, creating a robust field of research. There are generally four classifications of ecosystem services. Although many have pointed out the limitations of these classifications, they are still widely used today (Wilson, 2014; Fisher et al., 2007; Majewski, 2018).

- Provisioning services are the natural resources that ecosystems provide such as food, timber, and fuel.
- Cultural services are the intangible interests to humans.
- Regulating services are the natural processes that control ecosystem functions and provide humans with direct use. These have gained a lot of attention in ecosystem evaluations as they include services such as carbon storage, water filtration and erosion control.
- Supporting services describe the production and maintenance of basic ecosystem components that allow for all other services to function.

Services can also be examined as intermediate or final services that are linked to ultimate benefits enjoyed by humans (Fisher et al., 2007). This classification considers the complex interactions between ecosystem services and other forms of capital that are necessary for human welfare. Identifying and classifying ecosystem services provides a better understanding of the ways and extent humans rely on their environment and quantifies the toll of these actions.

Figure 14: The four categories used to differentiate ecosystem service types (Atlus Impact, 2017).

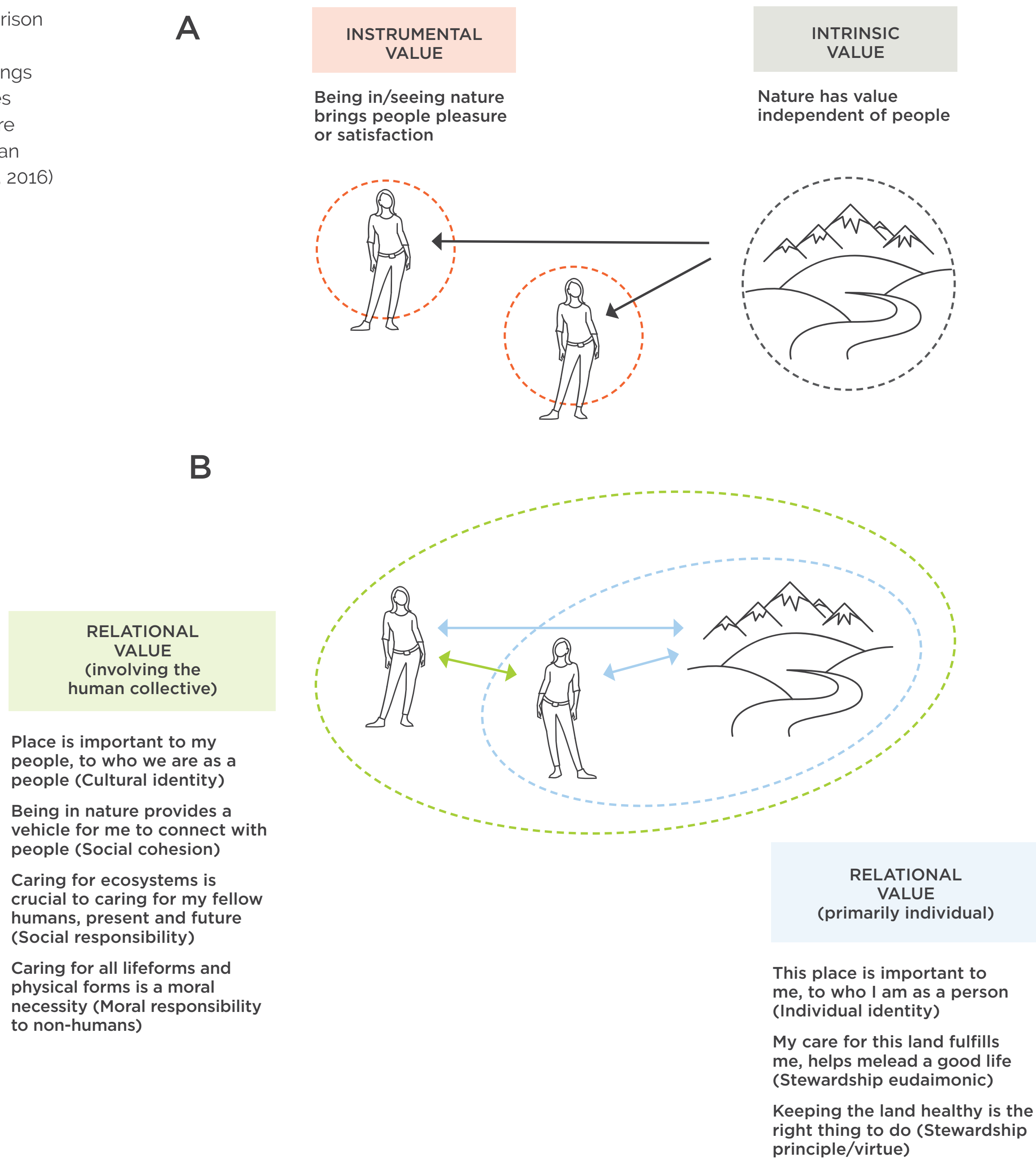


ECOSYSTEM VALUATION: RELATIONAL VALUES

Some services are easier to evaluate than others because they have already been included within the economy. Others are more abstract and are determinant on individual perspectives. Some services are inherent to the system as a whole and will have much more complex evaluations as they are more multifaceted and interconnected. There are many who argue an ecosystem services approach will never fully account for all ecological complexities and assigning a price to natural capital is not only impractical, but immoral. These limitations are widely acknowledged, and professionals are looking to include novel forms of worth to address these issues.

Relational values are cited as an alternative measure of value to instrumental or intrinsic values (Chan et al., 2016). This valuation system is based on the relationship humans have with nature and the actions necessary to lead an altruistic life. This is often thought of with regards to human relationships; we do not think solely on the benefits received or provided, but act on what is believed appropriate for the relationship. This allows society to appreciate the social and cultural interactions humans have more fully with nature and support community stewardship. Relational values are more expressive of local knowledge and ways of knowing that land that is innate to Indigenous peoples and other place based communities.

Figure 15: A comparison of instrumental and intrinsic value framings and relational values to assess how nature connects with human welfare (Chan et al., 2016)



Case Study: B.C.'s Peace River Watershed

A group of researchers from the David Suzuki Foundation undertook an immense project which identified and quantified the ecosystem services of a 5,611,799 ha watershed in the northeast corner of B.C. The region comprised of ten different land types, eight of which were included in the assessment with 64.4% being forest (Wilson, 2014). The use and non-use value of 12 ecosystem services was calculated for each land cover. A variety of valuation methods were employed, including market-based profits of goods (e.g., food and recreation) and associated costs such as **avoided cost**, **replacement cost**, and the cost of mitigation/restoration. Furthermore, the study considered valuations based on revealed preference from indirect market-based evaluations and stated preferences from survey-based information. Table 1 shows how these valuation methods operated in the context of different ecosystem services.

Table 1: Ecosystem services valued for the B.C. Peace River Watershed. Source: Wilson, 2014

ECOSYSTEM SERVICES ASSIGNED VALUE	VALUATION APPROACH	TYPE OF VALUE	VALUATION METHOD USED
Water supply	Average global value	Direct use	Transfer value per hectare from global average study (38 original studies)
Air filtration (gas regulation)	Avoided cost value	Indirect use	Transfer value from Lower Mainland study adjusted by population (original analysis based on average removal rates of pollutants by tree canopy cover and avoided costs)
Carbon storage (climate regulation)	Avoided cost value	Indirect use	Quantified carbon storage using forest age/ carbon analysis; annualized social carbon cost value based on average of U.S. and Canadian government social cost of carbon (SCC) (marginal SCC values from climate models)
Carbon sequestration (climate regulation)	Avoided cost value	Indirect use	Quantified forest carbon sequestration based on forest age/carbon analysis. Social carbon cost value based on average of U.S. and Canadian government SCC (marginal SCC values from climate models)
Flood control/ water regulation (disturbance prevention: wetlands)	Meta regression analysis value for Canada	Indirect use	Average value for Canada: from study that evaluated the value of wetlands in agricultural landscapes using a meta regression analysis reported by country
Erosion control (soil retention: perennial cropland/ pasture)	Avoided cost value	Indirect use	Value based on avoided water treatment costs to remove sediment provided by conservation of natural cover or conversion of annual cropland to permanent cropland/pasture cover

Waste treatment	Replacement cost value	Indirect use	Average removal rates of excess nutrients per wetland hectare from academic literature and average excess runoff from agricultural statistics and cropland area; average value based on cost to treat/remove excess nutrients from water system
Water filtration (forests)	Avoided cost value	Direct use	Avoided cost of water treatment costs based on current forest cover in PRW and local cost of water treatment in PRW.
Pollination	Market-based value	Indirect use	Estimated as 30% of reported pollinator value for B.C. crops
Habitat and biodiversity	Market-based value/average meta-analysis value	Indirect use / non-use	Estimated net value for increased wildlife viewing on conserved land or cropland restored to natural cover (grassland/ pasture); average habitat value from wetland values meta-analysis
Recreation	Survey-based value/travel cost	Direct use	Estimated economic value of outdoor recreation from several recreational surveys
Cultural/aesthetic	Survey-based	Indirect use / non-use	1) Willingness to pay to maintain rural scenic views 2) Willingness to pay to protect wilderness/ biodiversity

The final assessment reported all values as 2012 Canadian dollars. Carbon storage alone was valued between $6.7 billion to $7.4 billion per year, while all other ecosystem services provided a central value of $1.2 billion dollars of economic benefits (Wilson, 2014). Habitat, flood control/water supply/nutrient cycling and recreation were the following three ecosystem service groups with the highest values at $206,744,044, $133,157,316, and $119,738,498 respectively. The study also evaluated annual values based on land cover types and it was found wetlands with trees or shrubs had the highest worth.

The results of this evaluation, though incomplete, give decision-makers an idea of the immense costs associated with degrading natural capital. For example, the clearing of one hectare of a 10-20-year-old forest would result in 14.3 tonnes of carbon released which is translated to a total cost of $1,641.23 (Wilson, 2014). If the forest cleared is an old growth forest (>250 years old), these values would greatly increase to 263.3 tonnes of carbon and $30,334.53 (Wilson, 2014). The impacts can be translated to **marginal costs** for local communities. With a 10% forest cover decrease in the Peace River Watershed, local communities would incur higher water treatment rates resulting in a marginal value of $4.83/year per ha of forest cleared (Wilson, 2014). These evaluations provide a platform to argue for the protection of ecosystems by putting the costs into economic perspectives.

DISCUSSION QUESTIONS

Q1: What are the different valuation methods used? Do you think these methods fully capture the worth of Peace River Watershed?

Q2: What is the difference in economic value between old growth and young forests? Why do you think there is such a difference in these numbers?

8.0 Partners in Action: Leadership, Stakeholders and Collaboration

To work towards combating climate change with the help of nature-based solutions, partnerships are needed across disciplines and stakeholders. Collaboration between all levels of government, the public, private businesses, and non-profits is necessary for whole system changes. It is also important to acknowledge and empower individuals of different backgrounds and status such as youth, women, and Indigenous communities. With varying perspectives and participation from different disciplines, we can enhance the strategies, methods, and power of our solutions to adapt and mitigate climate change impacts.

8.1 Indigenous Knowledge

Indigenous Knowledge (IK), also known as Traditional Ecological Knowledge (TEK), refers to the evolving knowledge of Indigenous peoples over hundreds to thousands of years through direct contact with the environment.

IK is specific to different nations and locations but includes many aspects of the natural world such as the relationship between plants, animals, landscapes, and weather. It also involves hunting, fishing, trapping, forestry, and agriculture practices. IK is passed down through generations of Indigenous peoples and communities and encompasses ecology, spirituality, landscape relationships and more (Fish & Wildlife Service, 2011).

Indigenous peoples across the planet are increasingly advocating for incorporation of IK into a range of environmental decision-making contexts, including natural resource and wildlife management, pollution standards, environmental and social planning, environmental impact assessment, and adaptation to climate change (Swanson et al., 2019).

Three of the areas in which the input and participation of Indigenous peoples should be particularly sought, acknowledged, and supported include:

- Providing direct knowledge and insights relating to weather, environments, species, and habitats
- Contributing to development of models for accommodating and adapting to ongoing and imminent climate change
- Presenting alternative pathways and approaches to sustainable living for future generations.

IK greatly benefits scientists while addressing climate change on a regional level as Indigenous communities have the potential to identify environmental changes that signify climate change at local levels. Combining all forms of knowledge provides a greater understanding of the natural world and should influence how legislation is passed to address the climate crisis.

8.2 Climate Justice

Climate justice recognizes that the impacts of climate change are not distributed equitability and often vulnerable and underserved populations are disproportionally impacted. Furthermore, those bearing the brunt of negative climate change impacts are typically not significant contributors of GHG emissions. Gender, race, ethnicity, age, and income are all factors which influence how impacts of climate change are experienced.

Through the climate justice lens, plans to mitigate and adapt to climate change must include active consultation and engagement with vulnerable groups to ensure equitable solutions are developed which move society forward as a whole.

Figure 16: Protestors advocating for female rights for climate change (Centre Virchow-Villermé, 2015)

8.3 Nature-based Solutions in Policy

To create change and increase resilience in urban and rural environments, policy needs to be framed to implement nature-based solutions. Stakeholders from different policy areas and sectors (private sector, local communities, local/regional governments), scientists, non-government organizations, and Indigenous peoples should come together to develop holistic approaches to managing natural assets (geology, soil, air, water and all living things). Unfortunately, it can often be difficult to facilitate this collaboration due to a lack of communication and cooperation (van Ham & Klimmek, 2017).

There are instruments that could make implementing nature-based solutions in policy more plausible. Figure 17 demonstrates 4 areas that are needed to make this happen: providing information, fostering cooperation, making greening plans, and setting incentives (van Ham & Klimmek, 2017).

Figure 17: Instruments for implementing nature-based solutions (van Ham & Klimmek, 2017)

POLICY INSTRUMENTS FOR URBAN NATURE-BASED SOLUTIONS (NBS)

PROVIDING INFORMATION	FOSTERING COOPERATION	GREENING PLANS	SETTING INCENTIVES
• monitoring systems • accounting systems	• intra-municipal cross department NBS strategies • intra-municipal exchange platforms • public-private partnerships	• regional planning • urban planning • zoning	• pricing (municipal fees) • quantity-control (municipal fees) • municipal ecological fiscal transfers

8.4 Collaboration

To successfully implement nature-based solutions to respond to climate change, **transdisciplinary** and inclusive partnership approaches are needed. Through a collaborative approach, action using nature-based solutions for climate change adaptation and mitigation can be achieved to produce benefits for society and key priorities for policy and practice (van Ham & Klimmek, 2017). Partnerships can create and enhance relationships between different parts of society by bringing together resources, skills, knowledge and both institutional and governance capacities. In addition, partnerships can be versatile and flexible in the roles they adopt as the partners match their capacities to undertake a task to achieve a common target (Frantzeskaki et al., 2014).

Collaboration needs to occur between public, private, and non-profit sectors, all levels of government, businesses, Indigenous and local communities. The Climate Action Fund provides funding for innovative ideas that raise awareness of climate change and work towards Canada's clean growth and climate change plan (Environment and Climate Change Canada, 2019b). They have provided $3 million per year since 2018 to projects that are delivered by students, youth, Indigenous peoples and organizations, non-profits, businesses of various sizes, education, and research institutions (Kawartha Now, 2019). One of the projects that the Climate Action Fund supports is the launch of Random Acts of Green's mobile app that encourages Canadians to reduce their production of greenhouse gas emissions by making green choices (Kawartha Now, 2019). This example demonstrates how the federal government and a local business work together to create a platform for individuals and organizations of all types to participate in making sustainable choices to fight climate change.

8.4.1 Ethical Space

When Indigenous communities are brought together to share their worldviews on ecosystem management and conservation with practitioners of western science, it should be done in an ethical space in which all parties enjoy mutual respect. When non-Indigenous people seek to create these spaces to answer research questions, they should understand the space in which they are working as well as the limits of the participants (including themselves), as some of the questions asked could be perceived to infringe upon participants' boundaries, spaces, or rights.

The creation of ethical space does not need to be limited to formal consultation processes. This can also be a part of the dialogue between a gathering of individuals to share cross cultural knowledge in order to jointly achieve a goal of better resource management.

8.4.2 Two-eyed Seeing & Co-governance

First introduced by the Mi'kmaw people, the term 'two-eyed seeing' captures the intersection of two separate knowledge systems: one eye looks at Indigenous ways of knowing and oral traditions, while the other eye looks to Western science. By using both eyes together, a management strategy can be created with blended Indigenous and Western science knowledge systems to create a holistic beneficial environmental resource system. When practitioners used both knowledge systems together, they are striving towards a system of co-governance.

The earliest Indigenous teachings of treaty obligations outlined that Indigenous Peoples continuously offered to share the land with settler communities. This agreement to the sharing of resources is a form of co-governance. Through generations, Indigenous Peoples have developed patterns of resource use and management that reflect intimate local knowledge of the geography in which they inhabit, as well as the desire to leave enough resources for the survival of future generations. Indigenous Peoples are not preservationists, as their approach to resource management falls under the Western science definition of conservation.

Systems of co-governance may take different shapes depending on the needs and interests of the parties involved, but they will all fundamentally consist of the following themes:

- Understanding the values and protocols of the rights holders to the area,
- Use of Indigenous knowledge systems to strengthen Western science,
- Co-creation of a mutual understanding and sharing agreements (including Indigenous harvesting rights at the forefront of stake holder rights), and
- Formation of a relationship that is positive, long-lasting, economically beneficial, and sustainable for all parties involved.

DISCUSSION QUESTIONS:

Q1. What are some cultural considerations you should think of when planning an event?

Q2. How can a structure of co-governance be useful in modern environmental conservation measures?

9.0 Conclusion

As demonstrated throughout this guide, environmental issues are complex and can have wide reaching impacts. Further, each system experiences different imbalances and stressors, from climate change, to human development pressures, to overexploitation, and beyond. As a result, management approaches must be multi-faceted and tailored. Nature-based solutions can play an important role, as they can be as varied as the locations in which they are implemented, addressing a host of issues and providing a variety of goods and services based off location, design, and project goals.

As an important tool in responding to climate change and helping communities and ecosystems adapt to better handle the rapid pace of change we are currently experiencing, nature-based solutions represent a way forward. A relatively new field of comprehensive study, the true effectiveness of nature-based solutions continue to be assessed through the collection and analysis of long-term data.

In addition to ecological goods and services, the intrinsic value of natural systems cannot be overlooked. As we move forward, we must find ways to green urban areas and adapt our current built systems and structures to be more resilient and beneficial to both human health and the environment. Change at a local level is possible: look to your communities and see what you can do to make them more sustainable.

10.0 Glossary

A

Avoided cost: the expense not incurred due to the exclusion of a certain activity

B

Bioswales: linear channels that are designed to gather stormwater runoff while removing any debris and pollution.

Biome: a specific geographic area notable for the species living there. A biome can be made up of many ecosystems.

C

Carbon Sink: a natural reservoir that absorbs more carbon than it releases.

Conference of the Parties (COP): the formal meeting of the UNFCCC Parties to address and assess progress in dealing with climate change.

E

External Cost or Externality: the monetary value of a negative effect incurred by a third party in the process of producing or consuming a good or service

G

Gross Domestic Product (GDP): the combined market value of the goods and services produced within a specified time frame; it is used as a standard measurement of an economy

I

Indigenous Knowledge: knowledge acquired by Indigenous peoples and communities over hundreds of years based on direct experiences with the environment. Historically, this has also been referred to as 'Traditional Ecological Knowledge'.

Infrastructure: the physical and organizational structures and facilities needed for the operation of a society.

> **Green Infrastructure:** natural systems that have been incorporated into urban, suburban, or rural landscapes (ex stormwater management, urban forests)
>
> **Grey Infrastructure:** engineered structures and systems found in urban, suburban, and rural environments (ie buildings, roads, sewers). Also known as 'hard infrastructure'.

Intergovernmental Panel on Climate Change (IPCC): created in 1988 by the World Meteorological Organization (WMO) and the United Nations Environment Program (UNEP) to provide all levels of government with scientific information to help develop climate policies.

International Union for Conservation of Nature (IUCN): a membership Union composed of government and civil society organizations

K

Kyoto Protocol: the first agreement between nations to establish country-by-country reductions in GHG emissions and emerged from the United Nations Framework Convention on Climate Change.

L

Ladder fuels: live or dead vegetation that allows a fire to climb up from the forest floor into the canopy. Common ladder fuels include tall grasses, tree branches, and dead standing trees.

M

Marginalized: excluded from mainstream social, economic, cultural, or political life. Examples of marginalized populations include, but are by no means limited to, groups excluded due to race, religion, political or cultural group, age, gender, or financial status

Marginal Cost: the incremental change in monetary value that occurs when an additional item is produced

Montreal Protocol: an international agreement that ensures the protection of the earth's ozone layer by phasing out ozone-depleting substances.

P

Paris Agreement: adopted by consensus in 2015 at the 21st Conference of the Parties (COP) and signed in 2016, builds upon the United Nations Framework Convention on Climate Change and its central aim is to strengthen the global response to climate change by managing the global temperature rise to remain below 2 degrees Celsius.

Peatlands: a unique type of wetland ecosystem with organic soil, called peat. Peat is partly decomposed plant material that forms in poorly drained, low oxygen, acidic environments. Peat is primarily made up of a specific type of moss, called Sphagnum moss. By the Canadian definition, peatlands have a minimum of 40cm of peat (Government of Manitoba, n.d.).

Permafrost: any ground that remains completely frozen for at least two continuous years.

Phenology: the study of life cycle events and how they are influenced by seasonal variations in climate.

Positive Feedback Loop: a cyclical process which accelerates the effects of a disturbance imposed on a system. Regarding climate change, it speeds up the warming of the planet and other climatic changes.

R

Relational Values: a measure of value based on the relationship humans have with nature, among other things, and the notion of valuing altruistic behaviour

Replacement Cost: monetary value required for replacing one asset with another; the cost of a substitute.

S

Sequestration (carbon): the long-term storage of carbon dioxide (or other forms of carbon) to mitigate or defer global warming and climate change.

Soil Organic Carbon: is the carbon component of soil organic matter which is composed of carbon, hydrogen, and oxygen, and has small amounts of other elements, contained in organic residues.

Sustainable Economy: an economic model that is built on stable and prosperous industry which provides goods and services for society indefinitely through practices that promote a healthy environment

T

Transdisciplinary: relating to more than one branch of knowledge

U

United Nations Environmental Program (UNEP): an international organization established in 1972 to coordinate activities to increase the scientific understanding of environmental change and to develop environmental management tools.

United Nations Framework Convention on Climate Change (UNFCCC): the goal of the Convention is to stabilize greenhouse gas concentrations at a level that will prevent dangerous anthropogenic interference with the climate system.

11.0 References

Abedi, M. (2020). Severe weather in Canada cost $1.3 billion in insured damages in 2019: IBC. Global News. Retrieved from https://globalnews.ca/news/6441170/canada-severe-weather-costs-2019/

Abbas, F., Hammad, H.M., Fahad, S., Cerda, A., Rizwan, M., Farhad, W., Ehsan, S., & Bakhat, H.F. (2017). Agroforestry: a sustainable environmental practice for carbon sequestration under climate change scenarios - a review. *Environmental Science and Pollution Research,* 24(12): 11177-11191. DOI: 10.1007/s11356-017-8687-0

Adem Esmail B & Geneletti D. (2018). Multi-criteria decision analysis for nature conservation: A review of 20 years of application. *Methods Ecol* Evol, 9:42-53. https://doi.org/10.1111/2041-210X.12899

Alderville Black Oak Savanna. (2019). Alderville Black Oak Savanna. Retrieved from: http://aldervillesavanna.ca/

Alderville First Nation. (2016). Alderville Black Oak Savanna. Retrieved from https://alderville.ca/our-offices-services/alderville-black-oak-savanna/

Andrachuk, M. & Smit, B. (2012). Community-based vulnerability assessment of Tuktoyaktuk, NWT, Canada to environmental and socio-economic changes. *Regional Environmental Change,* 12:867-885. DOI: 10.1007/s10113-012-0299-0

Atlus Impact. (2017). *Natural Capital: Preparing your business to account for nature's value in your supply chain*. Retrieved from: https://altusimpact.com/altus-impact-work/themes/natural-capital/

Baah-Acheamfour, M., Chang, S.X., Bork, E.W., & Carlyle, C.N. (2017). The potential of agroforestry to reduce atmospheric greenhouse gases in Canada: Insight from pairwise comparisons with traditional agriculture, data gaps, and future research. *The Forestry Chronicle,* 93(2): 180-189. DOI: https://doi.org/10.5558/tfc2017-024.

Baidou, P., Page, B. & Ross, L. (2019). A comparison of water quality and greenhouse gas emissions in constructed wetlands and conventional retention basins with and without submerged macrophyte management for storm water regulation. *Ecological Engineering* 127:292-301. DOI: https://doi.org/10.1016/j.ecoleng.2018.11.028.

BBC News. (2013). A brief history of climate change. Retrieved from: https://www.bbc.com/news/science-environment-15874560

Bellard, C., Bertelsmeier, C., Leadley, P., Thuiller, W. & Courchamp, F. (2012). Impacts of climate change on the future of biodiversity. *Ecology Letters,* 15: 365-377. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3880584/pdf/emss-54918.pdf

Belleville, G., Ouellet, M.C. & Morin, C.M. (2019). Post-traumatic stress among evacuees from the 2016 Fort McMurray wildfires: exploration of psychological and sleep symptoms three months after the evacuation. *International journal of environmental research and public health*, 16(9), 1604.

Birds Canada. (2020). Climate crisis and Canada's birds. Retrieved from: https://www.birdscanada.org/conserve-birds/climate-crisis-and-canadas-birds/

Bittel, J. (2019). In the Fight Against Climate Change, Humans and Wildlife Are Allies. Retrieved from: https://www.nrdc.org/onearth/fight-against-climate-change-humans-and-wildlife-are-allies

Bouchard, C., Dibernardo, A., Koffi, J., Wood, H., Leighton, P.A. & Lindsay, L.R. (2019). Increased risk of tick-borne diseases with climate and environmental changes. *Canada Communicable Disease Report,* 45: 81-89. DOI: 10.14745/ccdr.v45i04a02

Burns Bog Conservation Society. (2019). Peatlands and Climate Change. Retrieved from: https://burnsbog.org/

Byun, E., Finkelstein, S.A., Cowling, S.A. & Baidou, P. (2018). Potential carbon loss associated with post-settlement wetland conservation in southern Ontario, Canada. *Carbon Balance Manage*, 13, 6. DOI: https://doi.org/10.1186/s13021-018-0094-4

Byrd, R. & DeMates, L. (2014). 5 Reasons Why Climate Change Is a Social Issue, Not Just an Environmental One. Huffpost. Retrieved from: https://bit.ly/2J8uL6E

Canadian Parks and Wilderness Society Manitoba Chapter. (n.d). Speak up for Woodland Caribou. Retrieved from: https://cpawsmb.org/what-we-do/woodland-caribou/

Canadian Wildlife Federation. (n.d.). Peatlands. Retrieved from https://www.hww.ca/en/wild-spaces/peatlands.html

Centre Virchow-Villermé. (2015). CVV contribution: "Women as actors in addressing climate change" [digital image]. Retrieved from: https://virchowvillerme.eu/newsletter-2/cvv-contribution-women-climate-change/

Chan, K.M., Balvanera, P., Benessaiah, K., Chapman, M., Díaz, S., Gómez-Baggethun, E., Gould, R., Hannahs, N., Jax, K., Klain, S. & Luck, G.W. (2016). Opinion: Why protect nature? Rethinking values and the environment. Proceedings of the national academy of sciences, 113(6), 1462-1465.

Cherry, N. & Haynes, W. (2017). Effects of the Fort McMurray wildfires on the health of evacuated workers: follow-up of 2 cohorts. *CMAJ open*, *5*(3): E638.

Chong, J. (2014). Ecosystem-based approaches to climate change adaptation: progress and challenges. International Environmental Agreements: Politics, Law and Economics, 14(4), 391-405.

Chong, C, Huang, E., Chen, L. (2017). Effects of climate change on Canadian forest fires. STEM Fellowship Journal, 3(2), 1-6.

Climate-ADAPT (n.d). The Adaptation Support Tool: 2. Assessing climate change risks and vulnerabilities. Retrieved from: https://climate-adapt.eea.europa.eu/knowledge/tools/adaptation-support-tool/step-2#:~:text=Vulnerability%20assessment%20is%20more%20than,starting%20point%20for%20any%20adaptation.

Cohen-Shacham, E., Walters, G., Janzen, C., Maginnis, S. (2016) Nature-based Solutions to address global societal challenges. Gland, Switzerland: IUCN. DOI: https://doi.org/10.2305/IUCN.CH.2016.13.en

Cohen, J., Lajeunesse, M., Rorh, J. (2018) A global synthesis of animal phenological responses to climate change. Nature Climate Change 8:224-228. DOI: https://doi.org/10.1038/s41558-018-0067-

Council of Canadian Academies. (2019). Canada's Top Climate Change Risks, Ottawa (ON): The Expert Panel on Climate Change Risks and Adaptation Potential. Council of Canadian Academies. Retrieved from: https://cca-reports.ca/wp-content/uploads/2019/07/Report-Canada-top-climate-change-risks.pdf

D'Acunha, B., Morillas, L., Black, T.A., Christen, A., & Johnson, M.S. (2019). Net Ecosystem Carbon Balance of a Peat Bog Undergoing Restoration: Integrating CO_2 and CH4 Fluxes from Eddy Covariance and Aquatic Evasion with DOC Drainage Fluxes. *Journal of Geophysical Research: Biogeosciences,* 124: 1-18. DOI: https://doi.org/10.1029/2019JG005123

de Azevedo, S.C., Singh, R.P., & da Silva Sr, E.A. (2016). Warm Dry Weather Conditions Cause of 2016 Fort McMurray Wild Forest Fire and Associated Air Quality. In *AGU Fall Meeting Abstracts*.

de los Rio, I.C., & Charnley F.J.S. (2017). Skills and capabilities for a sustainable and circular economy: The changing role of design. *Journal of Cleaner Production* 160:109-122. DOI: https://doi.org/10.1016/j.jclepro.2016.10.130.

Dilley, L. (2014). Restoration of Burns Bog: cumulative moisture deficit as an indicator of vegetation recovery and peat growth. Royal Roads University, British Columbia. Retrieved from: https://viurrspace.ca/bitstream/handle/10170/718/dilley_laura.pdf?sequence=1

Page, B., Aminian, P. & Steele, O. (2020). Determining the Nutrient Retention Capacity of Newly Restored Wetlands in Southwestern Ontario. Retrieved from: https://www.ducks.ca/assets/2020/02/Ontario-Small-Wetlands_FINAL-Report_Feb-7-2020.pdf

Egan, M., Logan, P. & DuWors, E. (1995). Benefits of Wildlife. Retrieved from: https://www.hww.ca/en/issues-and-topics/benefits-of-wildlife.html

Environment and Climate Change Canada. (2019a). Ozone layer depletion: Montreal Protocol. Retrieved from: https://www.canada.ca/en/environment-climate-change/corporate/international-affairs/partnerships-organizations/ozone-layer-depletion-montreal-convention.html

Environment and Climate Change Canada. (2019b). Climate Action Fund. Retrieved from: https://www.canada.ca/en/environment-climate-change/services/climate-change/climate-action-fund.html

Environmental Protection Agency. (n.d). Overview of Greenhouse Gases. Retrieved from, https:// www.epa.gov/ghgemissions/overview-greenhouse-gases

Fisheries and Oceans Canada. (2018). Understanding aquatic climate change risks. Retrieved from https://www.dfo-mpo.gc.ca/science/oceanography-oceanographie/accasp-psaccma/risks-risques/index-eng.html

Fisher, B., Turner, R.K. & Morling, P. (2007). Defining and classifying ecosystem services for decision making. *Ecological Economics*, 68(3), 643-653.

Fish & Wildlife Service. (2011). Traditional Ecological Knowledge for Application by Service Scientists. USA Government. Retrieved from: https://www.fws.gov/nativeamerican/pdf/tek-fact-sheet.pdf

Forest Gene Conservation Association. (2019). Managing Forests under Climate Change The Role of Assisted Migration in Southern Ontario. Retrieved from: https://fgca.net/wp-content/uploads/FGCA-CC-AM-June-2019.pdf'

Forests Ontario. (2015). Aquatics Module. Retrieved from https://www.forestsontario.ca/wp-content/uploads/2016/01/Aquatics_2016_FINAL.pdf

Forests Ontario. (n.d.,a). 50 Million Tree Program. Retrieved from: https://www.forestsontario.ca/planting/programs/50-million-tree-program/

Forests Ontario. (n.d.,b). What Lies Beneath…Your Feet! Retrieved from: https://www.forestsontario.ca/wp-content/uploads/2016/05/Canadian-Soil-Science-Society.pdf

Forests Ontario (2018). 2018 Climate Change Study Guide. Retrieved from https://www.forestsontario.ca/wp-content/uploads/2019/07/2018-OE-Climate-Change.pdf

Franson, J. (Photographer). (2016). Workers put out markers around a devastated area of Timberlea in Fort McMurray Alta, on Thursday, June 2, 2016 [digital image]. Retrieved from: https://globalnews.ca/news/2808805/fort-mcmurray-wildfire-cost-of-damage-from-alberta-disaster-to-be-released/

Friends of the Greenbelt Foundation (2018). Greenbelt Farmers: Sustaining Soil Health. Prepared by Headlands Ag-Enviro Solutions. Retrieved from: https://bit.ly/2WCHem7

Frantzeskaki, N., Wittmayer, J. & Loorbach, D. (2014). The role of partnerships in 'realizing' urban sustainability in Rotterdam's City Ports Area, the Netherlands. *J Clean Prod*, 65:406–417.

Friends of the Greenbelt Foundation (2016). Ontario's Good Fortune: Appreciating the Greenbelt's Natural Capital. Retrieved from https://www.greenbelt.ca/ontarios_good_fortune_greenbelt_natural_capital

Gale, N., Trant, H., Schiks, T., L'Ecuyer, J., Jackson, C., Thevathsan, N. & Gordon, A. (2013). An economic analysis of afforestation as a carbon sequestration strategy in southwestern Ontario, Canada. *Studies by Undergraduate Researchers at Guelph* 6(2): 55-65. DOI: https://doi.org/10.21083/surg.v6i2.2003

Global Climate Strike. (2019) About. Retrieved from: https://globalclimatestrike.net/about/

Gough, I. (2017) Heat, Greed and Human Need: Climate Change, Capitalism and Sustainable Wellbeing. London School of Economics, UK.

Gouldson, A., Colenbrander, S., Sudmant, A., McAnulla, F., Kerr, N., Sakai, P., Hall, S., Papargyropoulou, E. & Kuylenstierna, J. (2015). Exploring the economic case for climate action in cities. Global Environmental Change, 35, 93-105.

Government of Manitoba. (n.d.). Peatlands Management. Retrieved from https://www.gov.mb.ca/sd/forests_and_lands/land-management/peatlands/index.html

Government of Ontario (2017). Greenbelt Plan (2017). Retrieved from https://files.ontario.ca/greenbelt-plan-2017-en.pdf

Greenbelt Foundation (2020). Cooling Corridors: The Role of Green Infrastructure in Building Resilience to Extreme Heat. Retrieved from https://www.greenbelt.ca/cooling_corridors

Green Infrastructure Ontario (2016). "Ontario's Urban Forests: Call to Action". Retrieved from https://greeninfrastructureontario.org/app/uploads/2016/06/GIO_Urban_Forest_Call_to_Action_Sept15Print.pdf

Green Infrastructure Ontario (2019). State of Large Parks in Ontario's Golden Horseshoe. Retrieved from : https://greeninfrastructureontario.org/app/uploads/2019/06/StateofParks_Report-Final.pdf

Green Infrastructure Ontario (2020). An Economic Impact Assessment of the Green Infrastructure Sector in Ontario. Retrieved from https://greeninfrastructureontario.org/app/uploads/2020/04/Economic-Impact-Assessment-of-GI-Sector-in-Ontario_Online.pdf

Hamidov, A., Helming, K., Bellocchi, G., *et al.* (2018). Impacts of climate change adaptation options on soil functions: A review of European case-studies. *Land Degradation and Development,* 29: 2378-2378. DOI:10.1002/ldr.3006

Horton KG, La Sorte FA, Sheldon D *et al.* Phenology of nocturnal avian migration has shifted at the continental scale. *Nat. Clim. Chang.* **10,** 63–68 (2020). https://doi.org/10.1038/s41558-019-0648-9

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services [IPBES] (n.d). Scenarios and Models. Retrieved from: https://ipbes.net/scenarios-models

Intergovernmental Panel on Climate Change [IPCC]. (n.d). About the IPCC. Retrieved from https://www.ipcc.ch/about/

IUCN France. (2016). Nature-based solutions to address climate change. Paris, France: IUCN French Committee. Retrieved from: https://portals.iucn.org/library/sites/library/files/documents/2016-062.pdf

IUCN. (2017a). IUCN Issues Brief: Forests and Climate Change. Gland, Switzerland: IUCN. Retrieved from: https://www.iucn.org/sites/dev/files/forests_and_climate_change_issues_brief.pdf

Jackson, P. (2007). From Stockholm to Kyoto: A Brief History of Climate Change. Retrieved from: https://www.un.org/en/chronicle/article/stockholm-kyoto-brief-history-climate-change

Kawartha Now. (2019). Peterborough's Random Acts of Green receives $200,000 from federal government's Climate Action Fund. Retrieved from: https://bit.ly/2KiMKb9

Keesstra, S., Nunes, J., Novara, A., Finger, D., Alvelar, D., Kalantari, Z. & Cerdá, A. (2018). The superior effect of nature based solutions in land management for enhancing ecosystem services. *Sci Total Environ.* 611:997-1009. DOI: 10.1016/j.scitotenv.2017.08.077

Kovács, Z., Farkas, Z.J., Egedy, T., Kondor, A.C., Szabó, B., Lennert, J., Baka, D., Kohán, B. (2019). Urban sprawl and land conversion in post-socialist cities: The case of metropolitan Budapest. *Cities*, 92:71–81. DOI: https://doi.org/10.1016/j.cities.2019.03.018

Knox, S.H., Sturtevant, C., Matthes, J.H., Koteen, L., Verfaillie, J., Baldochhi, D. (2014). Agricultural peatland restoration: effects of land-use change on greenhouse gas (CO_2 and CH4) fluxes in the Sacramento-San Joaquin Delta. (2014). *Global Change Biology,* 21: 750-765. DOI: https://doi.org/10.1111/gcb.12745

Majewski, J. (2018). Pollination value as an ecosystem service. *Economics and Environment*, 1(64): 208-219.

Masi, F. Rizzo, A., Regelsberger, M. (2018). The role of constructed wetlands in a new circular economy, resource oriented, and ecosystem services paradigm. *J Environ Manage* 216:275-284. DOI: 10.1016/j.jenvman.2017.11.086.

Minayeva, T. & Sirin, A. (2012). Peatland Biodiversity and Climate Change. *Biology Bulletin Reviews,* 2(2): 164-175. DOI: 10.1134/S207908641202003X.

Ministry of Environment, Conservation, and Parks. (2019) Policy review of Municipal Stormwater Management in light of Climate Change. Retrieved from: https://www.ontario.ca/page/policy-review-municipal-stormwater-management-light-climate-change

Murray, W. (Photographer). (2019). 'They're trying to rush us': Tuktoyaktuk relocating homes too soon, says resident. Retrieved from: https://www.cbc.ca/news/canada/north/tuktoyaktuk-relocating-homes-erosion-1.5239765

NASA. (2020). Climate Change: How Do We Know? Retrieved from: https://climate.nasa.gov/evidence/

Natural Resources Canada. (2020b). Climate Change Impacts on Forests. Retrieved from: https://www.nrcan.gc.ca/climate-change/impacts-adaptations/climate-change-impacts-forests/impacts/13095

Natural Resources Canada. (2020c). Conservation and Protection of Canada's Forests. Retrieved from: https://www.nrcan.gc.ca/our-natural-resources/forests-forestry/sustainable-forest-management/conservation-and-protection-canadas-forests/17501

North American Waterfowl Management Plan (NAWMP). (2012). North American Waterfowl Management Plan – People Conserving Waterfowl and Wetlands. Retrieved from https://nawmp.org/sites/default/files/2017-12/NAWMP-Plan-EN-may23_0.pdf

NOAA. (2019). Is sea level rising? Retrieved from: https://oceanservice.noaa.gov/facts/sealevel.html

NOAA. (2020). Climate Change: Atmospheric Carbon Dioxide. Retrieved from: https://www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide

Odolczyk, R. (2019). Restoring Relationships: The Alderville Black Oak Savanna. Ontario Association of Landscape Architects. Retrieved from: https://www.oala.ca/ground_articles/restoring-relationships/

Ontario Federation of Agriculture, Environmental Defense. 2015. Farmland at risk: Why land-use planning needs improvements for a healthy agricultural future in the Greater Golden Horseshoe. Retrieved from: https://www.greenbelt.ca/farmland_at_risk

Ontario Ministry of Natural Resources and Forestry. 2017. A Wetland Conservation Strategy for Ontario 2017–2030. Queen's Printer for Ontario. Toronto, ON. 52 pp.

Ontario Nature. (2020). Pollinators. Retrieved from: https://ontarionature.org/campaigns/pollinators/

Rae L. (2020). Waterfowl at Your Service: How Ducks and Geese Help Our Environment. Retrieved from: https://www.ducks.ca/stories/conservator/waterfowl-at-your-service-how-ducks-and-geese-help-our-environment/

Raymond, C.M., Frantzeskaki, N., Kabisch, N., Berry, P., Breil, M., Nita, M.R., Geneletti, D. & Calfapietra. C. (2017a). A framework for assessing and implementing the co-benefits of nature-based solutions in urban areas. *Environmental Science and Policy*, 77:15–24. Retrieved from: https://www.sciencedirect.com/science/article/pii/S1462901117306317

Raymond, C.M., Frantzeskaki, N., Kabisch, N., et al. (2017b). An impact evaluation framework to support planning and evaluation of nature-based solutions projects. EKLIPSE Expert Working Group report. Retrieved from: http://www.eklipse-mechanism.eu/apps/Eklipse_data/website/EKLIPSE_Report1-NBS_FINAL_Complete-08022017_LowRes_4Web.pdf

Ripple, W.J., Wolf, C., Newsome, T.M., Galetti, M., Alamgir, M., Crist, E., ... & 15,364 scientist signatories from 184 countries. (2017). World scientists' warning to humanity: A second notice. *BioScience*, 67(12), 1026-1028.

Sloniker, E.S. (2016) Infographic. *Washington Nature*. Retrieved from https://www.washingtonnature.org/cities/stormwater/green-infrastructure-infographic

Smithsonian Magazine (2016) This Suffrage-Supporting Scientist Defined the Greenhouse Effect But Didn't Get the Credit, Because Sexism. Retrieved from: https://www.smithsonianmag.com/science-nature/lady-scientist-helped-revolutionize-climate-science-didnt-get-credit-180961291/

Society for Ecological Restoration. (n.d). Ecohydrological restoration of Burns Bog, British Columbia, Canada. Retrieved from: https://www.ser-rrc.org/project/ecohydrological-restoration-of-burns-bog-british-columbia-canada/

Stirling, M. (2017). Fort McMurray wildfire 2016: Conflating human-caused wildfires with human-caused global warming. *Available at SSRN 2929576*.

Swanson, G., Degawan, M., Hodgson-Smith, K., Moffa, A. (2019). *The Environmental Law Reporter,* 49(4). Retrieved from https://heinonline.org/HOL/LandingPage?handle=hein.journals/elrna49&div=37&id=&page=

Tarnocai, C. (2009). The Impact of Climate Change on Canadian Peatlands. *Canadian Water Resources Journal*, 34: 453-466. Retrieved from: https://www.tandfonline.com/doi/pdf/10.4296/cwrj3404453

The City of Ottawa. (2019). Climate Change Master Plan. Retrieved from: https://documents.ottawa.ca/sites/documents/files/climate_change_mplan_en.pdf

The Climate Reality Project. (2017). An Inconvenient Truth Then and Now: What›s Changed for our Climate Since 2006? Retrieved from: https://climaterealityproject.org/blog/inconvenient-truth-then-and-now

Tozer, D.C., Steele, O., Gloutney, M. (2018). Multispecies benefits of wetland conservation for marsh birds, frogs, and species at risk. *J Environ Manage* 212:160-168. DOI: 10.1016/j.jenvman.2018.01.055. Epub 2018 Feb 8. PMID: 29428650.

United Nations. (n.d.). *About the Sustainable Development Goals*. Retrieved from: https://www.un.org/sustainabledevelopment/sustainable-development-goals/

UNFCCC. (n.d.,a). What is the United Nations Framework Convention on Climate Change? Retrieved from: https://unfccc.int/process-and-meetings/the-convention/what-is-the-united-nations-framework-convention-on-climate-change

UNFCCC. (n.d.,b). What is the Kyoto Protocol? Retrieved from: https://unfccc.int/kyoto_protocol

UNFCCC. (n.d.,c). The Paris Agreement. Retrieved from: https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement

van Ham, C., Klimmek, H. (2017). Partnerships for Nature-Based Solutions in Urban Areas - Showcasing successful Examples. In Kabisch N, Korn H, Stadler J, Bonn A (Eds.), *Nature-Based Solutions to Climate Change Adaptation in Urban Areas. Theory and Practice of Urban Sustainability Transitions.* Springer. Retrieved from: https://link.springer.com/content/pdf/10.1007%2F978-3-319-56091-5.pdf

Walsh, J.M., & Servison M.S.V. (2017). State of the Birds 2017: Massachusetts Birds and Our Changing Climate. Massachusetts Audobon Society. Lincoln, Massachusetts. Retrieved from: https://www.massaudubon.org/content/download/21633/304821/file/mass-audubon_state-of-the-birds-2017-report.pdf

Westhaver, A. (2017). *Why some homes survived: Learning from the Fort McMurray wildland/urban interface fire disaster*. Toronto, ON: Institute for Catastrophic Loss Reduction.

Whelan, C.J., Wenny, D., Marquis, R.J. (2008). Ecosystem Services Provided by Birds. *Annals of the New York Academy of Sciences,* 1134(1): 25-60. DOI: 10.1196/annals.1439.003

Wilson, S.J. (2014). *The Peace dividend: assessing the economic value of ecosystems in BC's Peace River watershed*. Vancouver: David Suzuki Foundation. Retrieved from: https://davidsuzuki.org/wp-content/uploads/2017/09/peace-dividend-assessing-economic-value-ecosystems-bc-peace-river-watershed.pdf

Wood-Bohm, S. (2018). Agricultural soils as a solution provider to climate change. The Canadian Agri-food Policy Institute. Ottawa, ON. Retrieved from: https://capi-icpa.ca/wp-content/uploads/2018/10/2018-1012-CAPI-paper-AG-SOILS-SOLUTION-PROVIDER-CLIMATE-CHANGE.pdf

World O Meter. (2020). Current World Population. Retrieved from: https://www.worldometers.info/world-population/

Zhang, Y., Wang, X., Fraser, R., Olthof, I., Chen, W., Mclennan, D. & Wu, W. (2012). Modelling and mapping climate change impacts on permafrost at high spatial resolution for a region with complex terrain. Cryosphere Discussions, 6(6), 4599-4636. doi:10.5194/tcd-6-4599-2012