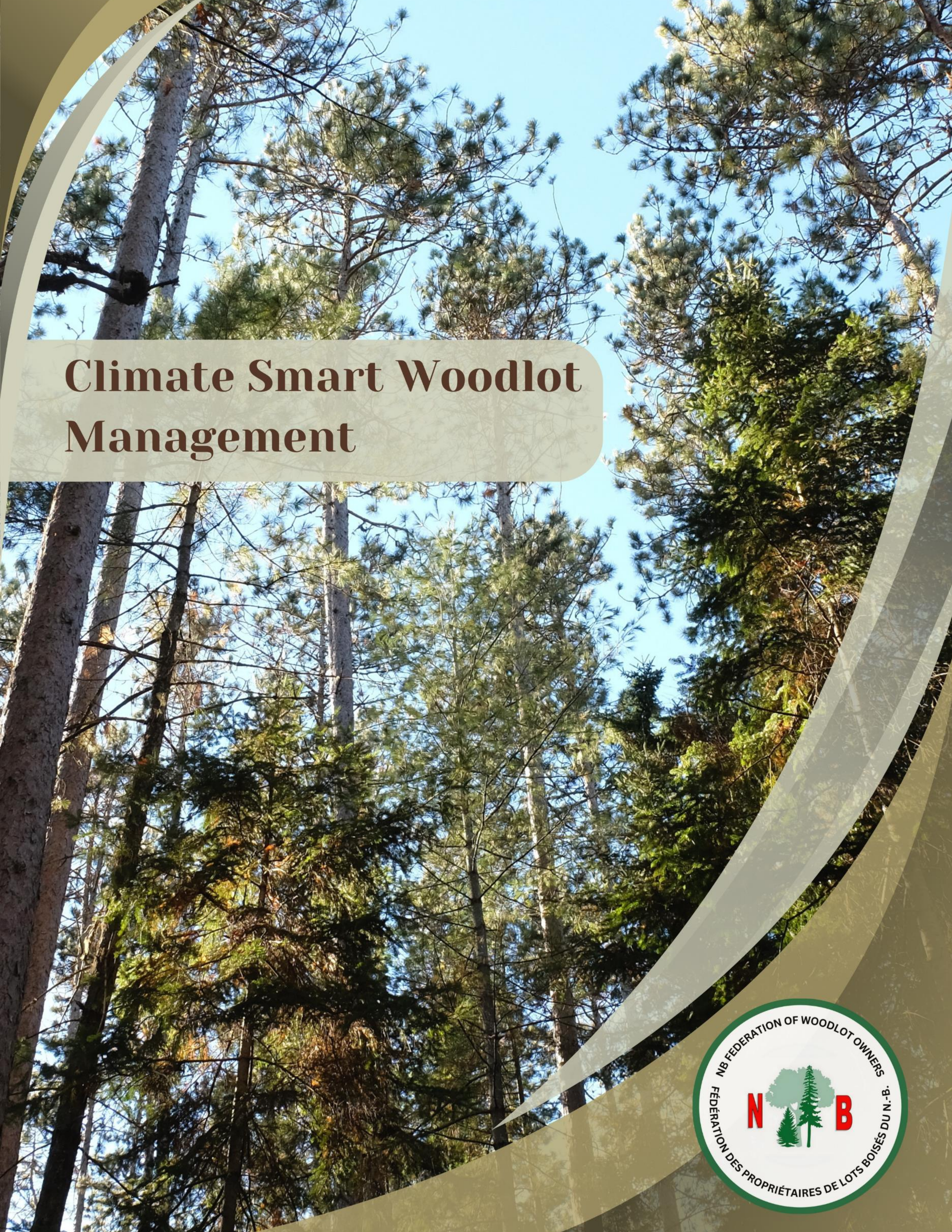


Climate Smart Woodlot Management

NB FEDERATION OF WOODLOT OWNERS
NB
FÉDÉRATION DES PROPRIÉTAIRES DE LOTS BOISÉS DU N.-B.

Preface

Our forests are on the frontline in our battle against climate change. While they act as carbon sponges helping us in this fight, they are also vulnerable to climate variations, which affect their superpowers. It is therefore urgent to take measures to improve their resilience and help them adapt better.

This guide has been developed to raise awareness among woodlot owners about climate challenges, and to provide them with information and advice to support them in implementing climate-smart management on their woodlot(s).

About the Federation

The New Brunswick Federation of Woodlot Owners (NBFWO) is a not-for-profit organization committed to advocating for the rights of woodlot owners in New Brunswick, and promoting their economic and social interests. It also organizes educational events to provide resources and tools for effective woodlot management. The NBFWO therefore supports woodlot owners in their efforts.

Acknowledgment

This guide was created as part of the "*Climate Smart Woodlot Management*" project funded by the Environmental Trust Fund (ETF). The NBFWO would like to thank the ETF for its support.

New Nouveau Brunswick
Your Environmental Trust Fund at Work
Votre Fonds en fiducie pour l'environnement

The NBFWO would also like to thank its collaborators, without whom this project would not have been possible, as well as the qualified professionals who took the time to review this guide and validate its content.

Table of content

Introduction

"Climate change"! Two words that have been echoing around the world for many years. Hurricanes of unprecedented intensity, extreme droughts, devastating wildfires and much more; the culprit: "climate change"; and when it comes to climate change, human activities are involved. Since the industrial revolution, humankind has been emitting large amounts of greenhouse gases into the atmosphere, increasing the Earth's global temperature. This global warming has a significant impact on all the ecosystems across the planet, especially forests, which act as carbon sinks and play a crucial role in regulating the climate.

Canada is home to forest ecosystems essential to maintaining climate balance, including the Wabanaki-Acadian forest, which covers the Maritimes. Rich and diverse, this forest holds a unique ecological heritage. However, it is vulnerable to climate variations. The impacts of global warming have already been observed. It is therefore important to take action to help the Wabanaki-Acadian forest adapt to the changing climate. With enhanced resilience, it will continue to provide ecological services that contribute, among others, to community well-being.

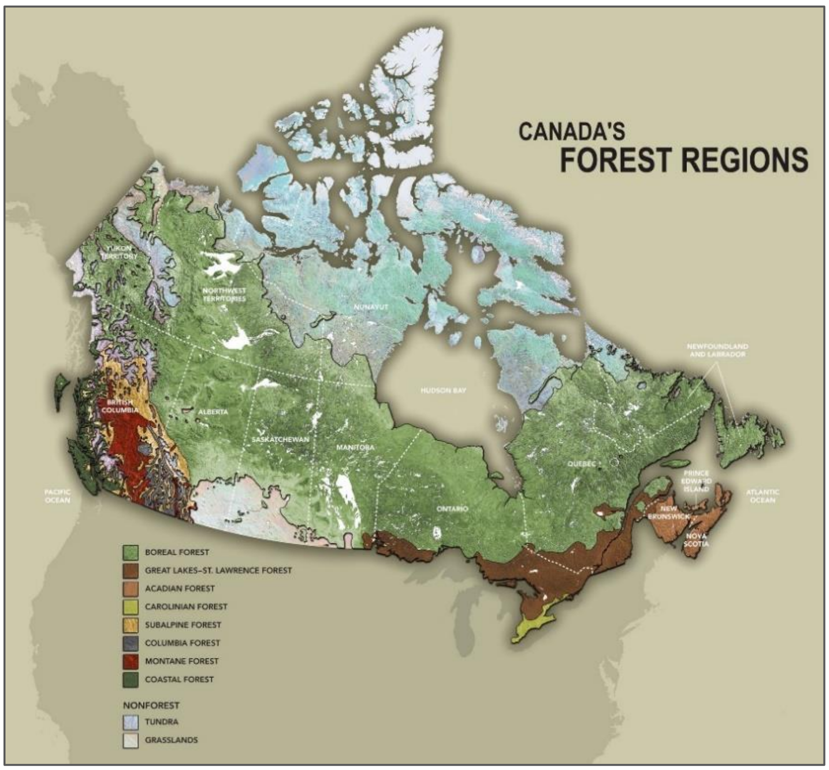
In New Brunswick, more than 40,000 woodlot owners collectively own approximately 1.74 million hectares of land. Given that the province covers around 7.344 million hectares, the management of these private lands has a significant impact on the resilience of the ecosystem. In this context, it is essential for private landowners to be well informed and have a deeper understanding of climate challenges.

This guide is a tool woodlot owners can use to better grasp these challenges and gradually transition to management practices that are more suited to a changing climate. The first part of this guide introduces the Wabanaki-Acadian forest, the ecosystem it represents, and its evolution. The second part focuses on climate change, while the final section covers climate-smart management.

The Wabanaki-Acadian forest

General information

The Acadian Forest is one of Canada's forest regions [1]. It is called “Acadian” to acknowledge the Acadians, descendants of the French colonists who settled in Acadia, and “Wabanaki” to honor the Wolastoqiyik and Mi'kmaw peoples [2,3]. It is also known as the New England Forest in the United States.



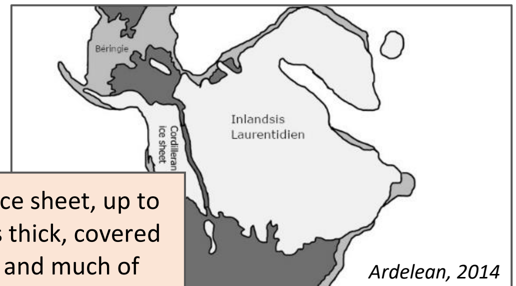
Canada forest regions [1]

The Wabanaki-Acadian Forest covers the Maritimes—Nova Scotia, Prince Edward Island, and most of New Brunswick—and extends to the northeastern United States. It lies between the boreal forest to the north and the deciduous forest to the south. The geographical, topographical, and geological characteristics of this region give it a wide range of ecological conditions. The Wabanaki-Acadian Forest is therefore a complex and rich ecosystem in terms of biodiversity, with over thirty tree species including boreal species at the southern limit of their range as well as temperate species at the northern limit of their range [2,3].

Evolution of the Wabanaki-Acadian forest

Before becoming the forest we know today, the Wabanaki-Acadian forest went through various stages since the last ice age.

Deglaciation



The Laurentide ice sheet, up to three kilometers thick, covered the Maritimes and much of Canada [4].

Vegetation took over and a tundra-type ecosystem was formed [5,6].

Temperature ↗

Vegetation flourished and trees colonized the area. Different species, including boreal species, successively dominated the ecosystem [5,6].

Temperature ↗

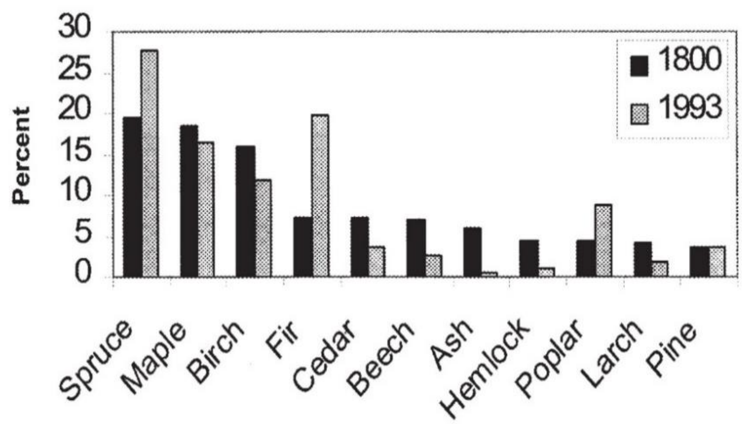
Temperate species settled, and the evolution of this ecosystem led to the Wabanaki-Acadian forest.

Humankind impact

Since the arrival of the first European settlers in the Maritimes, the evolution of the Wabanaki-Acadian forest has taken a new trajectory, marked by human activity. Wood, being an important resource for heating, construction and other commercial activities, and land, valuable for agriculture, the Wabanaki-Acadian forest has been extensively harvested to meet human needs. Therefore, the ecosystem we see today is not exactly the same as the one witnessed by the first settlers.

Historical records and scientific studies have provided insights on the pre-settlement Wabanaki-Acadian forest. It was dominated by temperate species such as red spruce, eastern hemlock, sugar maple, eastern white cedar, yellow birch and American beech [7]. Eastern white pine, white ash and red oak were also important species in this ecosystem [7].

Today, the composition of the Wabanaki-Acadian forest is no longer what it used to be. The same species can be found, but in different proportions. The chart to the right, from a study carried out in Kings County in southern New Brunswick, shows the estimated frequency of major trees around 1800 and in 1993.



Estimated frequency of major trees in Kings County around 1800 and in 1993 [6]

This chart shows a decline in the frequency of most species and a predominance of the spruce genus and balsam fir at the end of the 20th century. In 1993, spruce and balsam fir represented 50% of the forest, whereas they accounted for about 25% over 200 years ago [6]. Some scientists refer to this as the "borealization" of the Wabanaki-Acadian forest, a trend toward a more boreal character. Given climate change, such an evolution could weaken the ecosystem by the end of the 21st century.

Climate change

Definition

In the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)*, published between 2021 and 2023, climate change refers to:

"A change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/ or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic* changes in the composition of the atmosphere or in land use." [8]

* United Nations body responsible for assessing the science related to climate change.

* Anthropogenic: caused by human activities.

Earth's climate

For millions of years, Earth's climate has varied greatly, alternating between very warm periods and ice ages. These variations are caused by various natural factors, including:

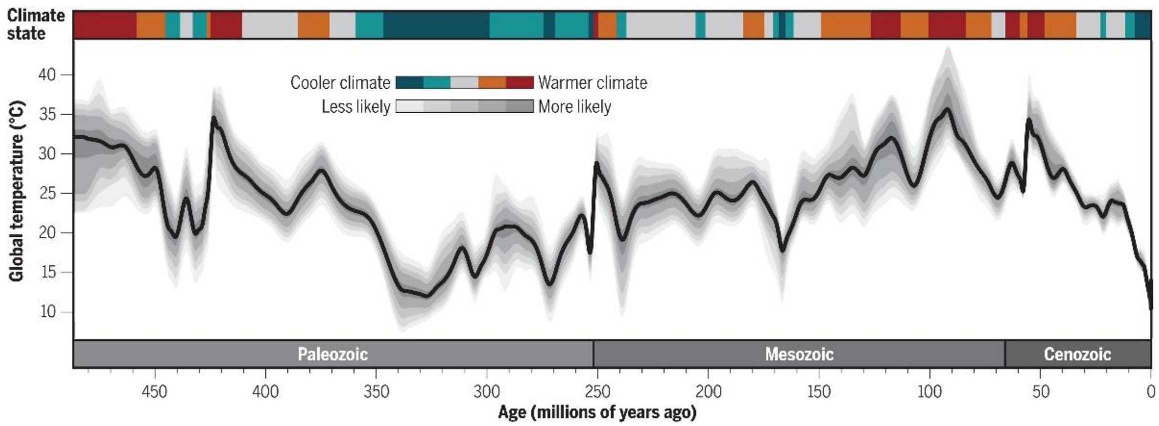
- Earth's orbit, Earth's axial tilt and the direction of Earth's axis of rotation [9-11]: known as the Milankovitch cycles, these parameters vary over the long term and have an impact on the solar energy the Earth receives, leading to variations in its climate.

- Solar activity [10-12]: the Sun produces energy that heats the Earth. The amount of energy it emits varies approximately every eleven years, which plays a role in the evolution of the Earth's climate.

- Volcanic activity [10,11]: volcanic eruptions release gases, such as carbon dioxide and sulfur dioxide, as well as particles. Depending on their magnitude, these emissions could have an impact on the Earth's climate.

Many scientists study Earth's climate history using climate indicators, known as proxies, such as sediments or ice cores, or tree rings [13]. This scientific discipline, known as paleoclimatology, allows us to trace the evolution of Earth's climate over the different geological eras, and to better understand current and future climatic dynamics.

The Smithsonian Institution and the University of Arizona co-led a study on the evolution of Earth's climate over the past 485 million years. The researchers recently published the chart below, which was obtained by combining geological data and computer simulations.



Global mean surface temperature over the past 485 million years [14]

This curve shows that global mean surface temperature has varied between 11°C and 36°C (52°F and 97°F) over the past 485 million years, with a predominance of warm-climate periods [14]. The results of the study also reveal that temperature is strongly correlated with the amount of carbon dioxide in the atmosphere. This gas, along with others such as methane, are called greenhouse gases (GHG) and are responsible for the phenomenon of the same name: the greenhouse effect.

Greenhouse effect

The greenhouse effect is a natural phenomenon that occurs in the Earth's atmosphere, where greenhouse gases “trap heat”; hence the name “greenhouse effect”, referring to the mechanism of a greenhouse.

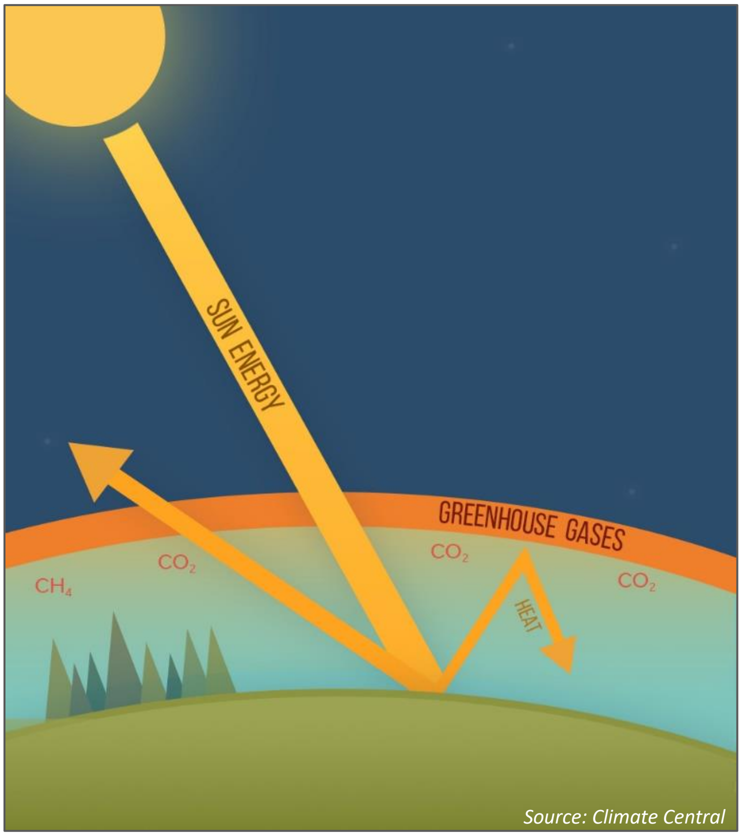


Diagram showing the greenhouse effect

The radiation the Earth receives from the Sun initiates the greenhouse effect. About 30% of this solar energy is reflected back into space by surfaces such as ice and clouds [15]. The remaining 70% is mainly absorbed by the Earth's surface. The surface then releases the absorbed energy in the form of thermal infrared radiation, which will be mostly absorbed by greenhouse gases and re-emitted in all directions. The energy that radiates back toward planet Earth will heat its surface as well as the lower atmosphere.

The greenhouse effect keeps the Earth’s average surface temperature at around 15°C [15,16]. Fortunately for us, without this natural phenomenon, the temperature would be -18°C!

Anthropogenic climate change

Since the 1950s, the Earth's average temperature has been following an upward trend. Although the natural factors mentioned above play a key role in the evolution of Earth's climate, they are not responsible for this recent global warming. Fossil fuel combustion, deforestation and other anthropogenic activities since the industrial era are the main cause. These activities release substantial amounts of carbon dioxide and other greenhouse gases, enhancing the greenhouse effect and thus leading to an increase in the temperature.

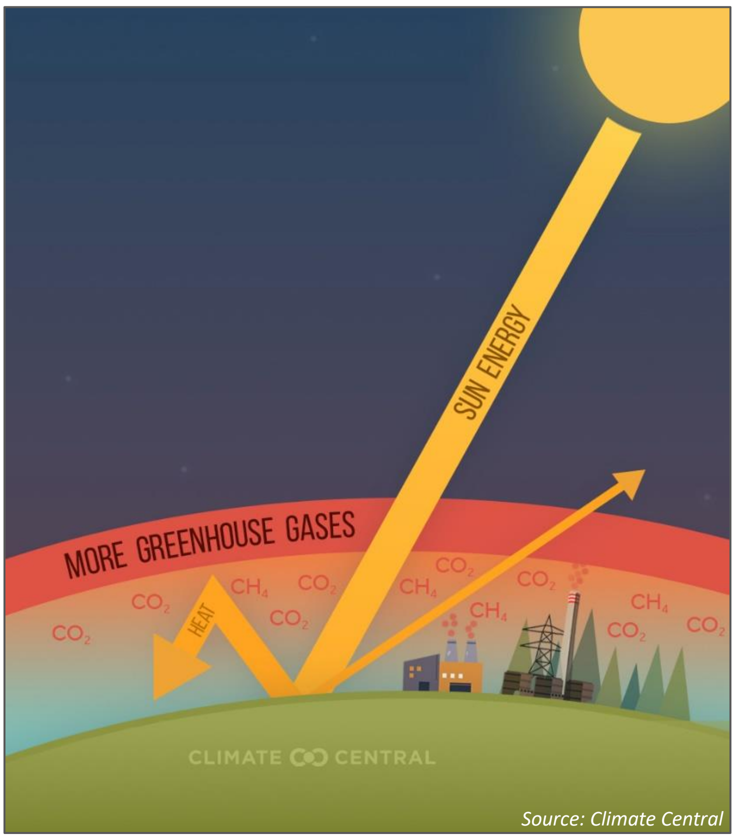
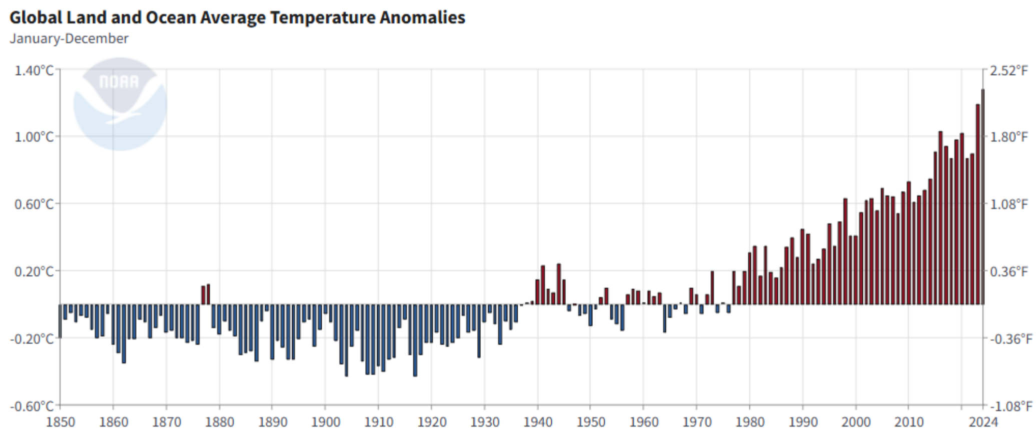


Diagram showing the greenhouse effect enhanced by human activities

The chart below illustrates the current global warming by showing the temperature anomalies since 1850. It compares the yearly average temperature with the 20th century average of 13.9°C (57.0°F).



Global land and ocean average temperature anomalies [17]

The Earth's temperature has risen by an average of 0.06°C (0.11°F) per decade since 1850 [17]. However, warming has accelerated over the past few decades: it is now three times faster (0.20°C / 0.36°F per decade). It is also worth noting that the ten warmest years since 1850 have been the last ten, with 2024 being the warmest year on record. The global surface temperature in 2024 was 1.29°C (2.32°F) above the 20th century average.

Future projections

As with previous reports, the Sixth Assessment Report (AR6) of the IPCC aims to assess and summarize scientific knowledge on climate change: its causes, impacts and future risks [18]. It also provides adaptation and mitigation strategies to reduce these risks, thereby guiding global actions in response to climate challenges. This report presents five new potential scenarios for the evolution of Earth's climate by the end of the 21st century (refer to the table on the next page).

SSPs, or "Shared Socio-economic Pathways", represent five potential socio-economic pathways in the absence of climate policy: SSP1 to SSP5 [19,20]. In other words, the SSPs describe how society might evolve based on factors such as population growth, education and economic development. SSP1 pathway, for example, takes the green road, prioritizing sustainable practices. This pathway thus presents low challenges to mitigation and adaptation. SSP4, on the other hand, adopts a divided road, presenting low challenges to mitigation due to significant technological advances, but high challenges to adaptation due to increasing inequalities.

The SSPs were developed to complement the Representative Concentration Pathways (RCPs), introduced in the previous report, which focus more on greenhouse gas concentrations and radiative forcing* [8]. This SSP-RCP combination is thus the core of the five scenarios in IPCC's AR6 mentioned above. It is important to note that the value on the right in the scenario designations represents the approximate level of radiative forcing.

* Radiative forcing: factor influencing the balance between the energy received and the energy emitted by the Earth.

The following table presents future global surface temperature projections for the different scenarios. More specifically, it shows the temperature differences relative to the average global surface temperature of the period 1850-1900. The results are given for three 20-year periods. For each period, the best estimate, as well as a very likely range, are reported.

	Near term, 2021-2040		Mid-term, 2041-2060		Long term, 2081-2100	
Scenario	**Best estimate (°C)**	***Very likely* range (°C)**	**Best estimate (°C)**	***Very likely* range (°C)**	**Best estimate (°C)**	***Very likely* range (°C)**
SSP1-1.9	1.5	1.2 to 1.7	1.6	1.2 to 2.0	1.4	1.0 to 1.8
SSP1-2.6	1.5	1.2 to 1.8	1.7	1.3 to 2.2	1.8	1.3 to 2.4
SSP2-4.5	1.5	1.2 to 1.8	2.0	1.6 to 2.5	2.7	2.1 to 3.5
SSP3-7.0	1.5	1.2 to 1.8	2.1	1.7 to 2.6	3.6	2.8 to 4.6
SSP5-8.5	1.6	1.3 to 1.9	2.4	1.9 to 3.0	4.4	3.3 to 5.7

Changes in global surface temperature by the end of the 21st century for different scenarios [8]

The report outlines that the "global surface temperature will continue to increase until at least mid-century under all emissions scenarios considered. Global warming of 1.5°C and 2°C will be exceeded during the 21st century unless deep reductions in CO_2 and other greenhouse gas emissions occur in the coming decades." [8]

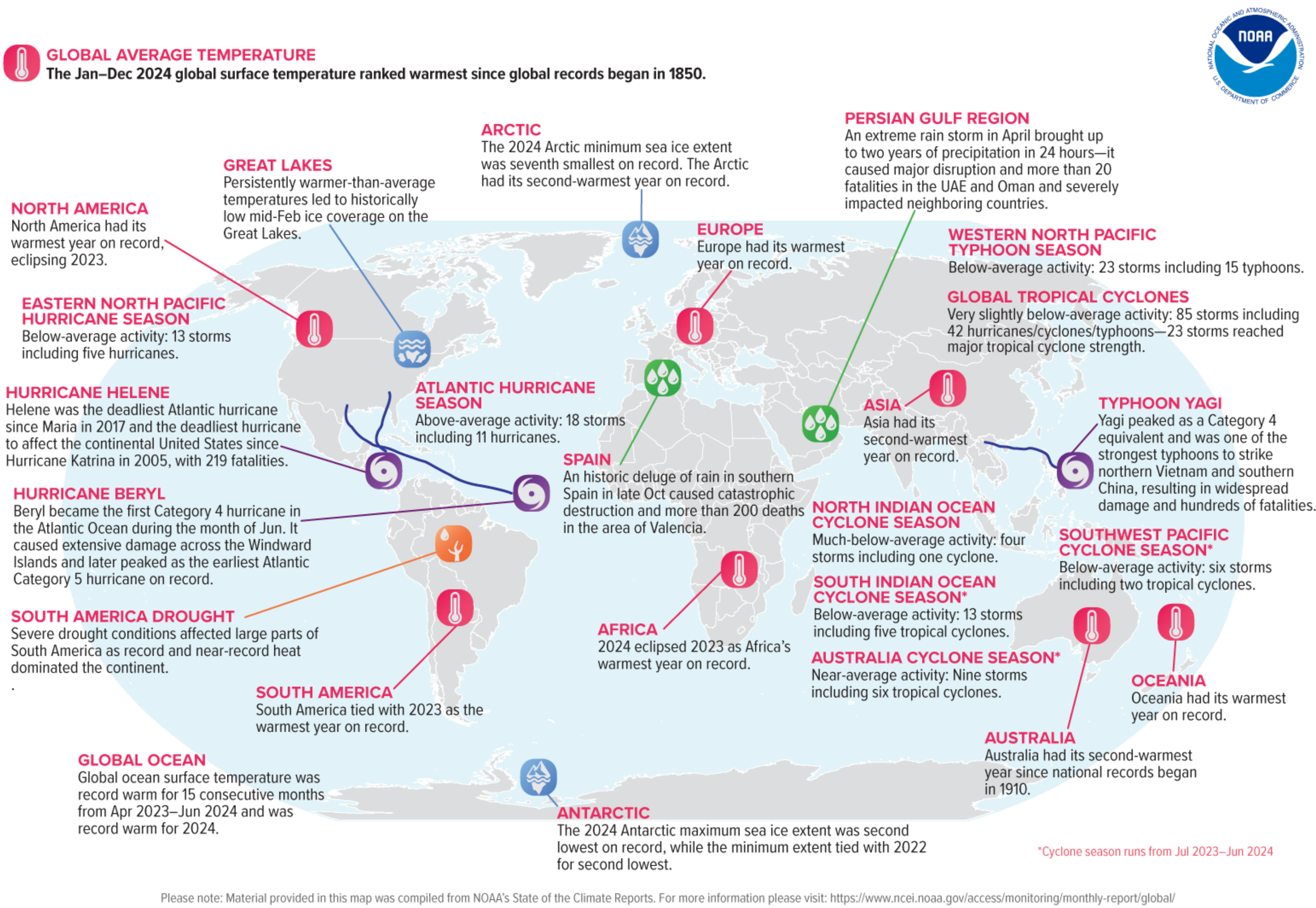
Moreover, a "global warming of 2°C, relative to 1850–1900, would be exceeded during the 21st century under the high and very high GHG emissions scenarios considered in this report (SSP3-7.0 and SSP5-8.5, respectively). Global warming of 2°C would extremely likely be exceeded in the intermediate GHG emissions scenario (SSP2-4.5). Under the very low and low GHG emissions scenarios, global warming of 2°C is extremely unlikely to be exceeded (SSP1-1.9) or unlikely to be exceeded (SSP1-2.6). Crossing the 2°C global warming level in the midterm period (2041–2060) is very likely to occur under the very high GHG emissions scenario (SSP5-8.5), likely to occur under the high GHG emissions scenario (SSP3-7.0), and more likely than not to occur in the intermediate GHG emissions scenario (SSP2-4.5)." [8]

Global warming impacts

The impacts of climate change take many forms, affecting not only the environment and ecosystems, but also human societies and the economy. These impacts are already being observed and are expected to intensify in the coming decades. Below is an overview of the main phenomena [21-23]:

- More frequent extreme temperatures (e.g. heatwaves)
- More intense and frequent droughts and wildfires
- More intense and frequent storms and hurricanes
- More frequent flooding due to increased precipitation
- Sea level rise due to ice melt
- Ocean acidification
- Biodiversity loss

Global warming impacts are unevenly distributed. Each region experiences the consequences differently, depending on its location and vulnerability, as illustrated in the image below.

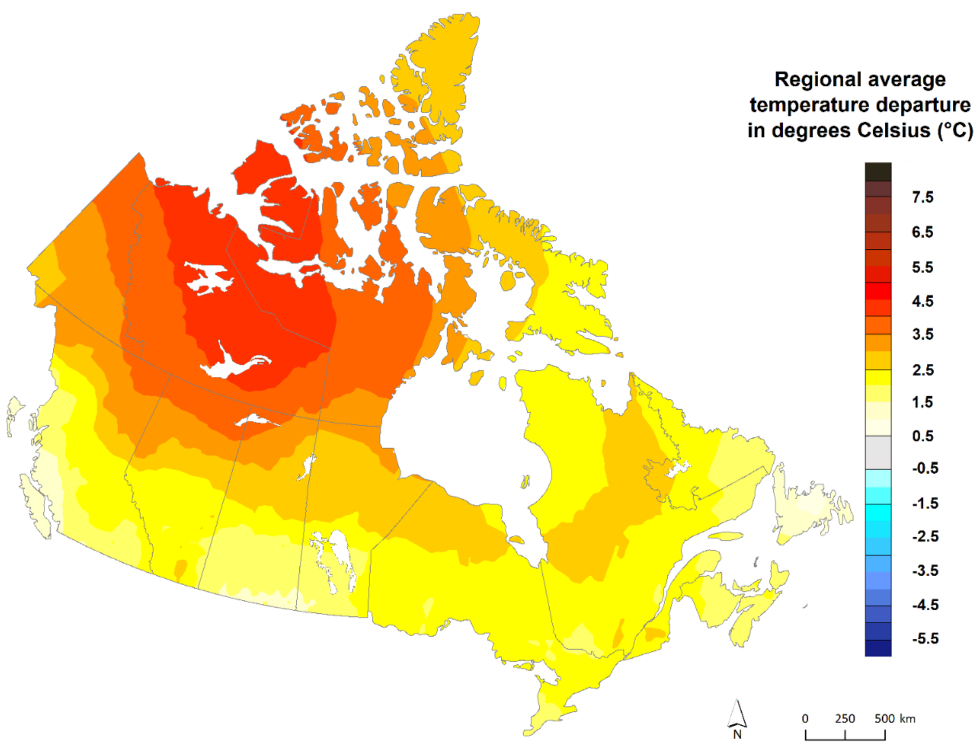


Significant climate anomalies and events in 2024 across the world [17]

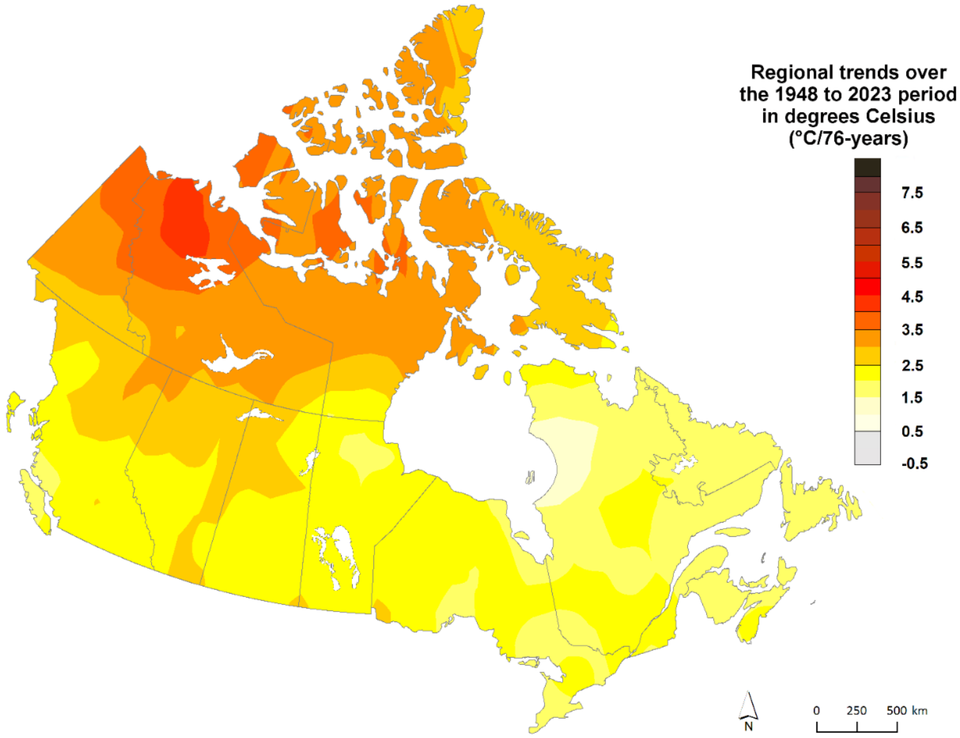
Climate change in Canada

As is happening worldwide, Canada’s climate is warming. Data shows that the country's average annual temperature has increased almost twice as fast as the global average [24]. This trend is likely to continue: forecasts suggest an increase of four to eight degrees Celsius by the end of the 21st century [25].

However, temperature variations differ from one region to another, with northern Canada being the most affected, as shown in the two maps below. The first map presents, at the regional level, the difference between temperatures recorded in 2023 and the reference value (1961-1990 period), while the second highlights regional trends in temperature change over a 76-year period (1948-2023). This second map clearly illustrates that almost all the Canadian territory has experienced a temperature increase of at least 1°C over the period from 1948 to 2023.



Regional average temperature departures from the 1961 to 1990 reference value, Canada, 2023 [24]



Regional temperature change trend, Canada, 1948 to 2023 [24]

Global warming also has an impact on precipitation, sea ice, and snow in Canada:

- An increase in the average annual precipitation was observed between 1948 and 2012, with Northern Canada experiencing the highest relative increase [26]. Flooding may become more frequent and more intense which could damage infrastructure and disrupt daily life.

- Sea ice* in the Canadian Arctic has decreased on average by nearly 7% per decade between 1968 and 2015 [27]. This loss exposes the coastline to more waves and storm surges*, increasing the risk of erosion and flooding. Indigenous peoples and northern communities are also impacted in terms of travel and livelihoods.

* Sea ice: ice found at the sea surface that has originated from the freezing of seawater (UNTERM).

* Storm surge: unusual rise in sea level, usually when strong winds push water into land (Government of Canada).

- In most parts of the country, the number of days per year with snow cover has been reduced by 5 to 10% per decade during most years between 1981 and 2015 [28]. This pattern has an impact on water availability as well as infrastructure. In northern Canada, travel and access to food sources could be disrupted.

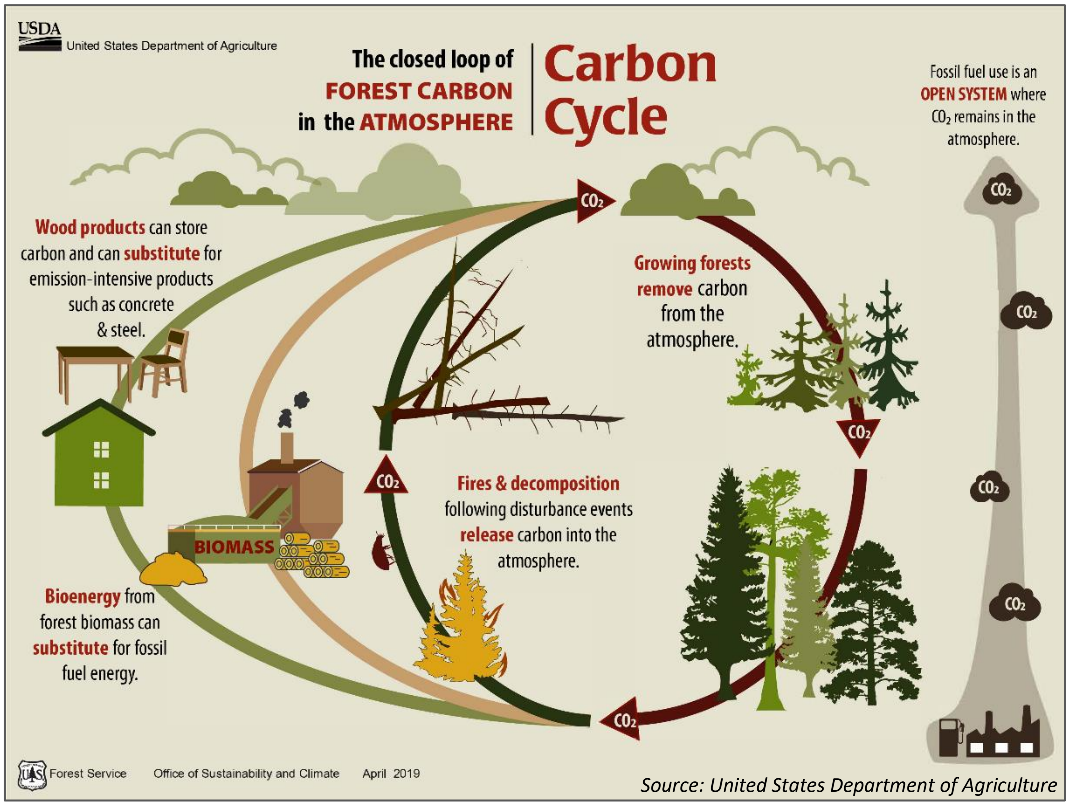
In terms of precipitation, future projections indicate both positive and negative variations, depending on the region and the season [26]. As for sea ice, it will continue to decrease in the Canadian Arctic [27], as will snow cover in most of Canada [28].

Forests in a changing climate

A forest is a highly complex ecosystem where numerous interactions between the species occur to maintain its balance and dynamics. With global warming, combined with human consumption of forest resources, this balance is being disturbed and weakened.

The impacts of climate change on natural disturbances such as storms, droughts, wildfires, and insect outbreaks are a growing threat to forest health [25,29,30]. Each of these disturbances acts as a stress factor that increases the ecosystem's vulnerability to additional challenges. Interactions between these stressors can amplify their effects, leading to greater risks [29,30]. Droughts, for example, can make forests more vulnerable to wildfires, which in turn can foster insect outbreaks that target wood weakened by flames.

Global warming has significant consequences on the many services provided by forests: carbon storage, soil conservation, water resource protection, habitat creation for biodiversity, contributions to both local and global economies, etc. Carbon storage is one of the most important services because trees absorb carbon dioxide and store it. However, the destabilization of forest ecosystems could compromise this function: instead of storing carbon, weakened forests could emit carbon dioxide [29,30].



Source: United States Department of Agriculture

Carbon cycle

Forests have the ability to adapt to climate change and demonstrate resilience. However, the pace of the human-induced climate change makes it uncertain whether forests will be able to keep up and transition to resilient ecosystems that can maintain their essential functions.

Climate Smart Woodlot Management

Definition

According to the European Forest Institute, “Climate-Smart Forestry is a targeted approach or strategy to increase the climate benefits from forests and the forest sector, in a way that creates synergies with other needs related to forests. The approach builds on three pillars:

- Reducing and/or removing greenhouse gas emissions to mitigate climate change
- Adapting forest management to build resilient forests
- Active forest management aiming to sustainably increase productivity and provide all benefits that forests can provide.” [31]

In other words, climate-smart forestry contributes to carbon storage, enhances the resilience of forest ecosystems and supports sustainable productivity:

Climate-smart forestry pillars

Diversity, the key factor

In a climate-adapted forestry approach, diversity must be at the heart of any strategy. A diverse forest, both in terms of species and age classes, is better equipped to withstand environmental stressors and adapt to change [32-34].

Diversity spreads the risks and protects the forest cover [32-34]. In the event of disturbances such as storms, diseases, or others, one part of the tree population will be potentially impacted, while the other will remain preserved. A variety of tree species thus offers the ecosystem a greater chance of survival, contributing to its resilience. In contrast, a forest lacking diversity is more vulnerable. The ecosystem will be substantially weakened if the dominant species is exposed to a specific stress factor, such as the spruce budworm, a defoliating insect that mainly targets balsam fir and white spruce, or the Dutch elm disease, which harms elm populations and causes the death of affected trees.

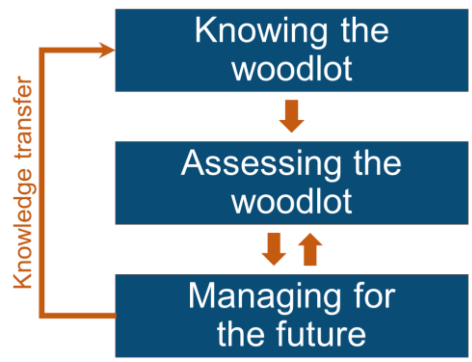
Diversity also plays a crucial role in enhancing biodiversity [32,33]. A diverse forest supports a variety of wildlife and a wider range of fungal species. This ecological richness is vital for maintaining the balance of the ecosystem.

As for carbon sequestration, recent studies suggest that diversity provides considerable advantages. A study published in 2023 states that “conserving and promoting functionally diverse forests could promote soil carbon and nitrogen storage, enhancing both carbon sink capacity and soil nitrogen fertility” [35]. Another study, also published in 2023, finds that diverse planted forests store more carbon than monocultures [36].

From an economic perspective, diversity reduces losses in the event of extreme weather occurrences [33]. It also offers some commercial flexibility, considering that species in demand today may no longer be so by the end of the century. Resilient species may be increasingly sought after, while vulnerable species may see their value decline as climatic conditions change.

In conclusion, diversity is a key factor that contributes to the resilience of forest ecosystems, both ecologically and economically.

Process



Knowing the woodlot is the first step in a climate-smart management process. It is important that a landowner take the time to identify the type of forest and site, as well as the species present in the woodlot, and to understand how it is changing in response to climate change. This phase of the process will guide the landowner in setting one or more management goals for the woodlot. Once identified, a site assessment can be conducted to evaluate the woodlot's potential and any associated risks. This step also helps establish appropriate management priorities. A climate-smart management plan can then be developed to manage the woodlot for the future, enhancing its resilience to climate change and promoting sustainable resource use.

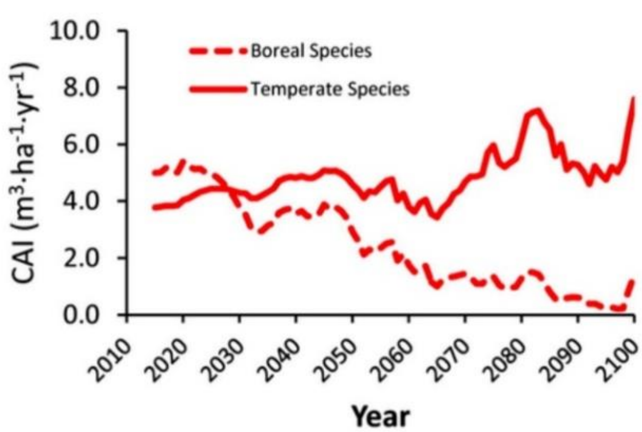
The last two steps of this process should be ongoing. After several years, a landowner should reassess his woodlot and adapt the management plan based on changes to the site, evolving management goals, and emerging environmental challenges.

When the time comes to pass on the woodlot to the next generation, it is crucial to transfer all the knowledge to ensure the continuity of the process and, consequently, the long-term sustainability of the woodlot.

Wabanaki-Acadian forest: understanding change

Although diversity is the key factor in climate-smart management, knowing which species to retain and which to remove is important since some will adapt better to climate change than others. Knowledge of tree species in the Wabanaki-Acadian forest and their ability to thrive in a changing climate is therefore essential in order to make informed decisions.

In general, boreal species that are adapted to cold climates, such as balsam fir, are expected to decline in competitiveness and abundance, unlike temperate species, such as red oak, which should benefit from rising temperatures. The graph below, illustrating the projected current annual increment* (growth) of both boreal and temperate species by the end of the 21st century, highlights this trend:



Current annual increment for boreal and temperate species for the period 2010-2100 and for the high-emissions scenario of the IPCC 5th Assessment Report [37]

* Current annual increment (CAI) is the increase in volume over the current year (Manitoba Government - Appendix VI Mean Annual Increment and rotation age tables used in the Wood Supply Analysis Report for Forest Management Unit 13 and 14, 2004).

According to a literature review providing a better understanding of potential impacts on the Wabanaki-Acadian forest, "results from three recent research projects into the resilience of this forest type, and its constituent tree species, to the effects of climate change have come to some consensus: that only nine species will likely persevere in the long-term (2011-2100): eastern hemlock, eastern white cedar, red maple, red oak, red spruce, sugar maple, white ash, white pine, and yellow birch. Of those species, only four are likely to increase in growth and distribution: red maple, red oak, white ash, and white pine." [38]

"Another fourteen species were identified by one or two (but not all three) of the research projects as having moderate to high resilience to climate change: American beech, American mountain ash, balsam poplar, black cherry, bur oak, butternut, ironwood, mountain maple, mountain paper birch, pin cherry, serviceberry, silver maple, striped maple, and white elm." [38]

It is important to note that the Wabanaki-Acadian forest covers over 100,000 km^2 in eastern Canada. As environmental conditions vary from one region to another, a species' potential to adapt to future climatic variations depends on its location. The impact of insects and pathogens impact is also worth mentioning. Species that are able to thrive in a changing climate may see their ability to do so reduced by pests and diseases, such as butternut, which is affected by butternut canker, or white ash, by the emerald ash borer. Finally, let us not forget the competition between species within an ecosystem. One of the studies suggests that a strong competition from American beech and red maple may explain the lower resilience of sugar maple [37].

Woodlot assessment

An in-depth woodlot assessment conducted by a forester is a critical step in a climate-smart management process. On the one hand, it will help to estimate the value of the woodlot, and, on the other hand, to anticipate its evolution in response to the upcoming environmental challenges. This assessment will guide the strategies to be adopted in order to enhance the ecosystem's resilience and minimize climate change-related risks, while maximizing its economic value.

When assessing a woodlot, surveying the stand composition is a priority. The species present must be listed and the wood volume estimated. This step will help determine the type of the forest stand and assess its potential to meet climate change challenges. For instance, a balsam fir dominated stand would present greater long-term challenges than a mixed hardwood stand.

It is then important to assess the forest soil as it sustains the ecosystem biological activity and is crucial to tree growth. Analyzing its attributes (e.g. texture, structure, depth) will provide information on its properties, such as fertility or water-holding capacity. Whether it is poor or rich in nutrients, clay or sandy, forest soil will reflect the forest ecosystem potential as well as its vulnerabilities, and give an indication of its productivity.

As a forest is exposed to various disturbances throughout its lifetime, a woodlot assessment must also include a risks assessment. These factors, both abiotic* (e.g. wind, wildfires) and biotic* (e.g. pests), play an important role in forest dynamics. However, in a global warming context, each presents an increasing risk that can significantly disrupt the ecosystem's balance. Assessing these risks is therefore crucial to understanding the woodlot vulnerability and developing an appropriate management plan.

* Abiotic: pertaining to an ecosystem where life is absent (UNTERM).

* Biotic: applied to the living components of the ecosystem, as distinct from the abiotic physical and chemical components (UNTERM).

Below are the main risks that have an impact on forest ecosystems:

- Extreme winds [39-42]

  As a tree grows, it adapts and builds resistance to withstand prevailing winds. However, this resistance is not without limits. When exposed to extreme winds, a tree can be uprooted or broken. This type of damage, known as blowdown, threatens the stability of forest ecosystems.

  Vulnerability to blowdowns is driven by several factors, including:

  - Geographical and topographical context: wind gusts vary according to the site's location and topography. Forests in mountainous or coastal areas are exposed to higher risks, as winds are generally stronger in these environments.

  - Forest soil: soil type, depth, and drainage have an impact on tree stability. For instance, a stand on waterlogged or sandy soil is more vulnerable to blowdowns.

  - Tree species: a species' root system plays a role in its ability to withstand winds. Species with shallow roots are more at risk than those with deep roots.

  - Thinning: any practice that creates openings in a woodlot temporarily weakens the stand, increasing the risk of damage in the event of high winds.

- Forest soil compaction [43-47]

When exposed to mechanical stress, from heavy equipment for example, forest soil experiences pressure that leads to porosity loss. This phenomenon, known as compaction, prevents good water and air penetration, hindering root development and reducing nutrient availability.

A soil's sensitivity to compaction depends on its characteristics. Sandy soils, for instance, are less prone to compaction than silty soils. Rocks and large particles also help absorb some of the pressure and reduce the risk. Soil moisture is another key factor. Wet soils deform more easily than dry ones, making them more vulnerable to compaction.


© Diane Fargialla, 2024

It is worth noting that natural recovery from soil compaction is a slow process, and remediation through human intervention can be costly. Therefore, preventing further damage through best management practices is a more effective approach.

- Wildfires [48-52]


Raging wildfire. Photo: SciJinks, NOAA

Although wildfires are essential to the regeneration of some forest ecosystems, they are increasingly becoming a threat due to global warming. Driven by rising temperatures and more severe droughts, wildfires are occurring more frequently, with greater intensity and across wider areas, and their season is longer. They are harder to control, and the resulting damage is escalating. A study published in

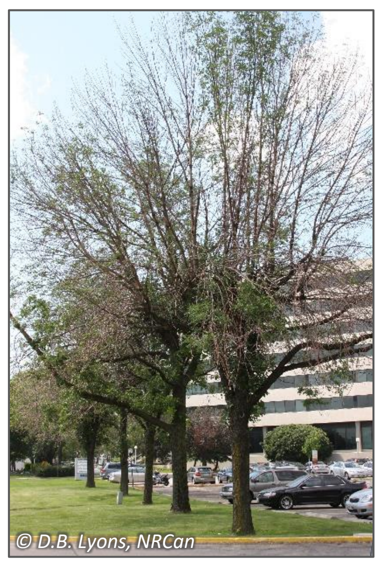
2024 reveals that the global frequency of extreme wildfires has more than doubled over a 21-year period (2003-2023) [49].

This trend is confirmed in Canada, where temperatures are rising twice as fast as the global average. The 2023 season was one of the most destructive on record, with over 7,000 fires burning more than 17 million hectares [50]. In New Brunswick, the area burned this year (854 hectares) was almost double the ten-year average of 454 hectares [50].

Some forest ecosystems are more vulnerable to wildfires than others, with the forest stand's composition being the key factor. Softwoods, or conifers, are in fact more sensitive to fires than hardwoods. They are more flammable due to their lower density wood and the presence of needles. As a result, they burn more quickly, which can lead to intense and more violent fires. Hardwoods, on the other hand, with higher density wood and moisture content in leaves, are more resistant to fires. They have a greater ability to slow fire spread.

- Pests and diseases [53-55]

Beech bark disease



Urban trees infested by emerald ash borer

Insects and pathogens play an important role in a forest ecosystem's balance, contributing, among others, to tree populations' dynamics and dead vegetation's decomposition. However, climate change is tipping this ecological balance, turning these organisms into significant disruptors. The situation is even more concerning if it involves non-native insects or pathogens. New climatic conditions could make Canada's forests more favorable to a greater number of invasive species.

Insects and diseases affect host species differently. The consequences can vary from a minor alteration in the tree's appearance to its death. Forest stands dominated by high-risk species that are likely to suffer serious and irreversible damage, are the most vulnerable.

The table below outlines the main pests and diseases present in the Wabanaki-Acadian forest.

Pest / Disease	Origin	Affected tree species
Spruce budworm	Native	Balsam fir and spruce species * Other conifers can be affected in case of severe outbreaks
Emerald ash borer	Non-native	Ash species
Hemlock woolly adelgid	Non-native	Eastern hemlock
Beech bark disease	Non-native	American beech
Butternut canker	Unknown	Butternut
Dutch elm disease	Non-native	White elm

In conclusion, assessing a woodlot requires a comprehensive approach that considers a range of factors. While it is a complex task, it is important for developing an appropriate management plan that includes a description of the stand as well as recommendations. In a climate-smart management process, these recommendations aim to preserve the long-term resilience of the forest ecosystem.

Long-term management

Once a management plan has been drawn up, a woodlot owner can assign the execution of on-the-ground actions to qualified contractors. These experts will carry out the necessary interventions while conforming to best forestry practices. After the work is completed, the landowner must regularly monitor the woodlot to ensure that the ecosystem's health is preserved. In the event of any concerning signs, it is advisable to contact a professional to identify the problem and determine the appropriate measures to be taken.

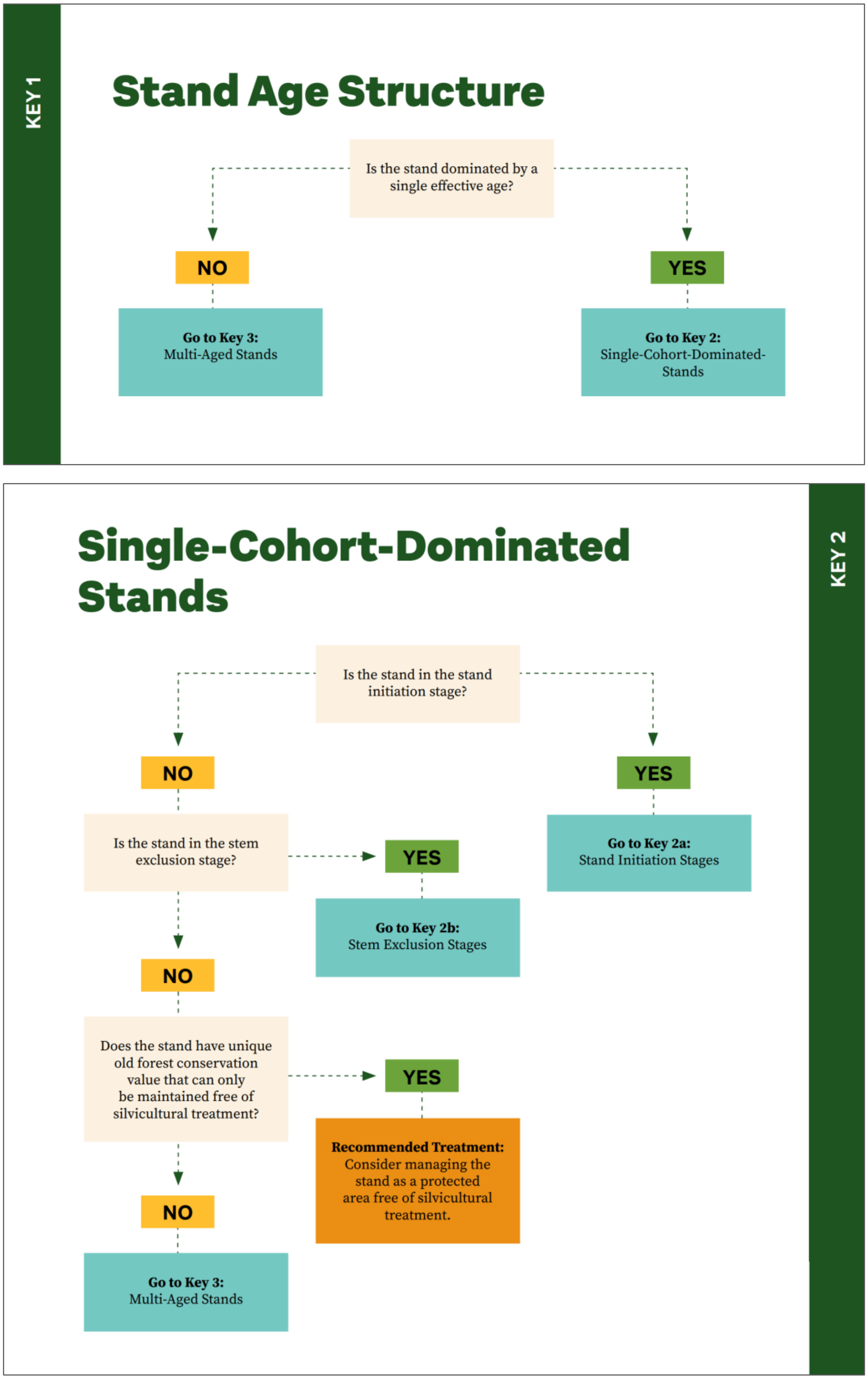
Reassessing the woodlot after a few years should be included in the management process. This step is required to assess the evolution of the woodlot and adapt the management plan in line with the new observations. This adaptation phase must also consider the owner's objectives, which may have changed, as well as the latest scientific information on climate-adapted forest management. It is highly recommended that an owner stay informed and up to date with the latest forest concerns.

In summary, maintaining a climate resilient woodlot relies on continuous monitoring and adaptability. Management must be both proactive and reactive to effectively address environmental challenges.

Climate Adaptive Silviculture Prescription Decision Tool

The Climate Adaptive Silviculture Prescription Decision Tool allows users to broadly assess a woodlot within the Wabanaki-Acadian forest and receive a silvicultural treatment suggestion aimed at promoting the resilience of the forest ecosystem to climate change as well as carbon storage. This tool was developed by Gareth Davies (FT, CLP, Forest Ecologist, Silviculturist) with input from Megan de Graaf (MScF, Community Forests International) as part of the *Your Forest in a Changing Climate* (BRACE) project led by the New Brunswick Federation of Woodlot Owners.

This tool is presented as a decision tree, a visual diagram that guides users through a series of choices. More specifically, it asks a set of questions to be answered with "yes" or "no". Based on the answer, it directs users to the next relevant question, and so on. At the end of the process, a silvicultural treatment is recommended.



Keys 1 and 2 of the Climate Adaptive Silviculture Prescription Decision Tool [56]

The Climate Adaptive Silviculture Prescription Decision Tool encourages users to observe a woodlot from different perspectives and gain a better understanding of specific factors to consider when developing a management plan. However, this tool does not replace an in-depth professional assessment. It was designed to guide woodlot owners and assist them in their climate-smart management approach.

Who to contact

You are not on your own! There are many professionals in the forestry sector who are ready to assist you. To find out who to contact, do not hesitate to contact the New Brunswick Federation of Woodlot Owners (NBFWO).

The NBFWO collaborates with government departments, forest products marketing boards, as well as other organizations. The Federation can therefore guide you. A phone call or an e-mail is all it takes to establish contact.

506-459-2990

info@nbwoodlotowners.ca

Conclusion

It is crucial to realize that Earth's climate is following a worrying trajectory. Global surface temperature is increasing and extreme weather events are becoming more frequent. This rapid shift towards a warmer climate represents a major threat to humanity, as well as biodiversity and the planet's ecosystems.

Forests are essential ecosystems that provide many services and play a vital role in the fight against climate change. However, their ability to fulfill these functions is being strongly compromised. The time they have to adapt naturally to this changing climate is very short, and it is uncertain whether they will be resilient enough to maintain their ecological balance in the years to come.

We must act. We have to minimize the negative impacts of global warming on forests, including the Wabanaki-Acadian forest in the Maritimes. This forest ecosystem, rich in biodiversity, is invaluable for the human communities that depend on it. It is therefore essential to anticipate and mitigate future risks. To do so, promoting a mixed ecosystem with various age classes is a priority. By implementing appropriate strategies, and using the knowledge and the tools at our disposal, we can enhance this ecosystem's resilience and ensure its ecological stability.

Climate change is a reality from which we cannot escape, but we hold the keys to help the Wabanaki-Acadian forest face environmental challenges. The watchword: diversity!

References

1. Forest classification. *Natural Resources Canada*.

2. What is the Wabanaki Forest?. *The Nashwaak Watershed Association*.

3. Amirault J., 2021. Wabanaki-Acadian Forest: History, Species, and Biodiversity. *Woodland Woman*.

4. Ardelean C., 2014. The Early Prehistory of the Americas and the Human Peopling of the Western Hemisphere. An Overview of Archaeological Data, Hypotheses and Models. En Studii de Preistorie, 11: 33-95.

5. R. J. Mott, 1975. Palynological Studies of Lake Sediment Profiles from Southwestern New Brunswick. Canadian Journal of Earth Sciences. 12(2): 273-288. https://doi.org/10.1139/e75-024

6. Loo J. and Ives N., 2003. The Acadian forest: historical condition and human impacts. For. Chron. 79(3): 462–474. https://doi.org/10.5558/tfc79462-3

7. Noseworthy J. and Beckley T.M., 2020. Borealization of the New England – Acadian Forest: a review of the evidence. Environmental Reviews. 28(3): 284-293. https://doi.org/10.1139/er-2019-0068

8. IPCC, 2021. Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2391 pp. DOI: 10.1017/9781009157896.

9. The Milankovitch Cycles. *Climate Change & Nature: New Zealand*.

10. What causes the Earth's climate to change?. *British Geological Survey*.

11. Causes of Climate Change. *U.S. Environmental Protection Agency*.

12. Vinós J., 2024. How we know that the sun changes the Climate. Part I: The past. *Climate Etc*.

13. What Are Proxy Data?. *National Oceanic and Atmospheric Administration*.

14. Judd E.J. and al., 2024. A 485-million-year history of Earth's surface temperature. Science 385, eadk3705. DOI: 10.1126/science.adk3705

15. Global warming. *NASA*.

16. L'effet de serre : un phénomène naturel. *Climat.be*.

17. Global Climate Report. *National Oceanic and Atmospheric Administration*.

18. About the IPCC. *IPCC*.

19. CMIP6 and Shared Socio-economic Pathways overview. *Government of Canada*.

20. Hausfather Z., 2018. Explainer: How 'Shared Socioeconomic Pathways' explore future climate change. *Carbon Brief*.

21. Climate change impacts. *National Oceanic and Atmospheric Administration*.

22. Causes and Effects of Climate Change . *United Nations*.

23. Consequences of climate change. *European Commission*.

24. Temperature change in Canada. *Government of Canada*.

25. Impacts of climate change on forests. *Natural Resources Canada*.

26. Changes in precipitation. *Government of Canada*.

27. Changes in sea ice. *Government of Canada*.

28. Changes in snow. *Government of Canada*.

29. Climate Change Impacts on Forests. *U.S. Environmental Protection Agency*.

30. Forest-Based Climate Solutions. *The Forest Center of Northwest Massachusetts*.

31. Climate-Smart Forestry. *European Forest Institute*.

32. Embracing Diversity: Four Ways Forests are Naturally Diverse. *Tree Canada*.

33. Creimer D., 2023. Encourager la diversité en forêt, c'est encourager sa résilience!. *Société pour la nature et les parcs*.

34. Call for a diverse national forest. *Auckland University of Technology*.

35. Chen X. L., Taylor A. R., Reich P. B., Hisano M., Chen H. Y. H. and Chang S. X., 2023. Tree diversity increases decadal forest soil carbon and nitrogen accrual. *Nature*, 618, 94–101. https://doi.org/10.1038/s41586-023-05941-9

36. Warner E., Cook-Patton S.C., Lewis O.T., Brown N., Koricheva J., Eisenhauer N., Ferlian O., Gravel D., Hall J.S., Jactel H., Mayoral C., Meredieu C., Messier C., Paquette A., Parker W.C., Potvin C., Reich P.B. and Hector A., 2023. Young mixed planted forests store more carbon than monocultures—a meta-analysis. Front. For. Glob. Change 6, 1226514. https://doi.org/10.3389/ffgc.2023.1226514

37. Taylor A.R., Boulanger Y., Price D.T., Cyr D., McGarrigle E., Rammer W. and Kershaw J.A., 2017. Rapid 21st century climate change projected to shift composition and growth of Canada's Acadian Forest Region. Forest Ecology & Management. 405: 284–294. DOI : 10.1016/j.foreco.2017.07.033

38. De Graaf M., 2018. Climate Change-Resilience in the Acadian Forest: A Review. *Community Forests International*.

39. Bunce A., 2017. Wind and Trees 101: To Touch a Tree. *University of Connecticut*.

40. Fiche technique N°140 : La forêt face au vent. *Centre Régional de la Propriété Forestière de Normandie*.

41. Windthrow. *Forest Research*.

42. Managing wind risk in forests. *Scion*.

43. Helgerson O.T. et Miller R.E., 2008. Keeping your forest soils healthy and productive. Washington State University Extension. EB2019. https://research.fs.usda.gov/treesearch/30437

44. Le sol forestier : élément clé pour le choix des essences et la gestion durable. *Centre National de la Propriété Forestière*.

45. Les sols forestiers : mieux les connaître pour mieux les préserver. *Zimmer : l'expertise forestière*.

46. Fiche technique N°141 : Le tassement des sols. *Centre Régional de la Propriété Forestière de Normandie*.

47. Préserver les sols forestiers lors des récoltes de bois. *Centre Régional de la Propriété Forestière Nord-Pas-de-Calais Picardie*.

48. Wildfires and Climate Change. *NASA*.

49. Cunningham C. X., Williamson G. J. and Bowman D. M. J. S., 2024. Increasing frequency and intensity of the most extreme wildfires on Earth. Nature Ecology & Evolution, 8(8), 1420–1425. https://www.nature.com/articles/s41559-024-02452-2

50. Canada Report: 2023 Fire Season. *Canadian Interagency Forest Fire Centre*.

51. Feux de forêt et biodiversité. *France Nature Environnement Bretagne*.

52. Effects of weather, topography and fuels on fire behavior. *Government of Nova Scotia*.

53. Forest Pests and Climate Change. *Climate Atlas of Canada*.

54. Forest ecosystem impacts. *Natural Resources Canada*.

55. Summary of Forest Pest Conditions 2023. *Government of New Brunswick*.

56. Davies G. with input from De Graaf M., 2022. Managing Forests for Climate Change. *New Brunswick Federation of Woodlot Owners*.