UNITED NATIONS ECONOMIC COMMISSION FOR EUROPE

Boreal Forests and Climate Change

From Impacts to Adaptation

Policy Brief

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Acknowledgements

This policy brief, compiled by the secretariat, outlines the main expected environmental and economic impacts of climate change on boreal forests, highlights ongoing research about the role of boreal forests in climate change mitigation and outlines possible adaptation pathways. It builds on research conducted by experts of the United Nations Economic Commission for Europe/The Food and Agriculture Organization of the United Nations (UNECE/FAO) Team of Specialists on Boreal Forests and the International Boreal Forest Research Association (IBFRA). It aims to provide policymakers, experts and the general public with information about boreal forests in the context of climate change.

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Abbreviations and Acronyms

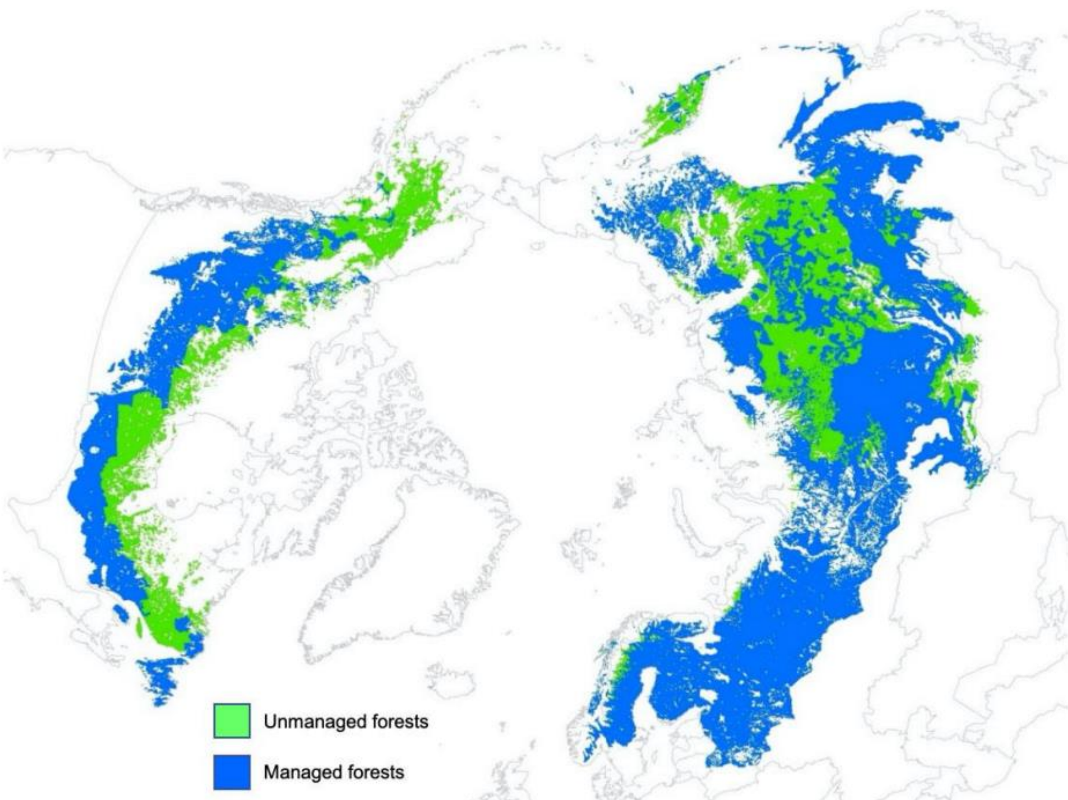
CSF	Climate Smart Forestry
FLR	Forest Landscape Restoration
FRA	Forest Resources Assessment
GHG	Greenhouse Gas
IBFRA	International Boreal Forest Research Association
IPCC	Intergovernmental Panel on Climate Change
RCP	Representative Concentration Pathway

1. Introduction

Boreal forests (also referred to as “taiga”) grow in the Northern Hemisphere, between latitudes of 50- and 70-degrees north (see Figure 1), where temperatures are generally very low, and precipitation falls primarily in the form of snow. Boreal forests consist mostly of cold-tolerant evergreen conifers with needle-like leaves, such as pine, fir and spruce. The boundaries of the boreal forest belt are usually marked by the July isotherms: the northern border is the 13° Centigrade July isotherm; the southern border is the 18° Centigrade July isotherm.[a]

As part of one of the world’s largest terrestrial carbon sinks[b] and covering about 27 per cent of the global forest area,[c] boreal forests have an essential role to play in addressing climate change. With globally increasing concentrations of atmospheric greenhouse gas (GHG) and longer growing seasons due to climate warming, circumpolar boreal forests may experience increased growth rates and thus increasing carbon sequestration. However, these forests are also subject to a substantial risk of decreased productivity and tree cover loss due to drought, wildfires, windstorms, diseases and insect outbreaks, which could result in large releases of carbon into the atmosphere.

Figure 1 Boreal forest extent (managed forests (in blue) and unmanaged forests (in green))



Source : The International Boreal Forest Research Association (IBFRA). Map © www.ibfra.org.

To date, the largest recent-increases in temperature resulting from climate change have been recorded in the Arctic region, and as a result, boreal forests are one of the first places where the complex effects of climate change can be observed. These effects, and the dynamic response of boreal forests to them, will have important implications for the world as a whole in terms of atmospheric carbon and a host of other values and outputs associated with this major biome.

The circumboreal zone has already been observed to be warming more than the world average.[d] This trend is likely to continue, [e] even if current targets for global emissions and climate warming are met. Published evidence so far suggests that fundamental long-term changes in some ecosystems are likely to be long-lasting. Boreal forests are one such ecosystem where climate-related biophysiological changes have already been observed.

This policy brief outlines the main expected environmental and economic impacts of climate change on boreal forests, highlights ongoing research about the role of boreal forests in climate change mitigation, and outlines possible adaptation pathways. It builds on research conducted by experts of the UNECE/FAO Team of Specialists on Boreal Forests and the International Boreal Forest Research Association (IBFRA) and aims to provide policymakers, environment practitioners and the public with relevant information.

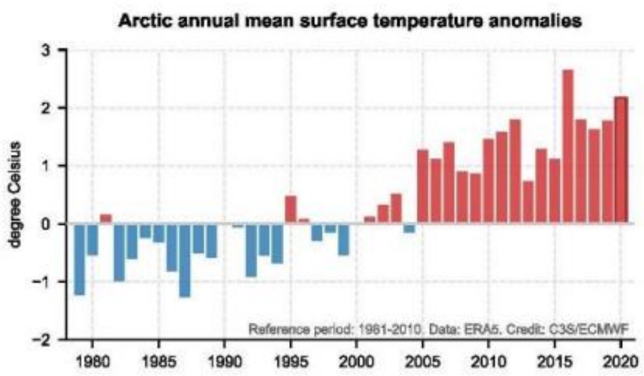
2. Biophysical and environmental impacts of climate change on boreal forests

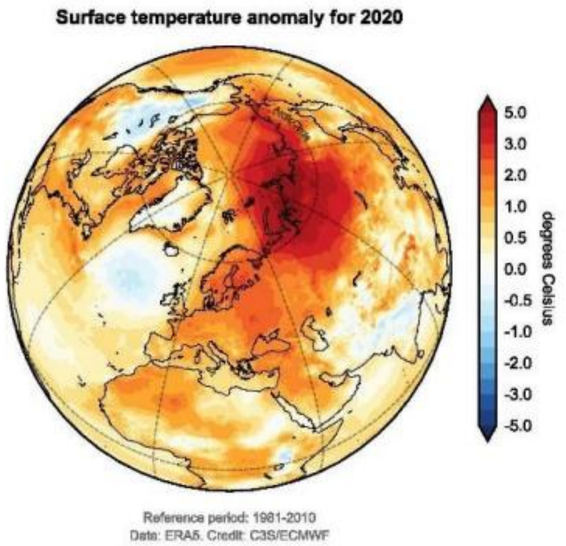
A. The Arctic is warming

In recent decades, the average temperature in the Arctic has increased two times faster than that for the rest of the planet. Different regions where boreal forests and Arctic ecosystems interact show past average annual temperature increases from 0.4 to 2 degrees C, as can be seen in Figure 2.

Figure 2

a. Left: **Time series of annual mean surface temperature anomalies from 1979 to 2020 averaged over the Arctic region (66.6°N–90°N).**
b. Right: **Map of the annual mean surface temperature anomaly in 2020. All anomalies are calculated relative to the 1981–2010 mean.**





Source: ERA5.©C3S/ECMWF.[f]

According to the latest draft report of the Intergovernmental Panel on Climate Change (IPCC), "it is virtually certain that the Arctic will continue to warm more than global surface temperature, with high confidence above two times the rate of global warming". [g] This has significant implications for the boreal region, where these high rates of warming will influence forested systems.

B. Impacts of warmer temperatures on boreal forests

The sensitivity of boreal forests to warming has significant implications for the climate system due to the effects on the exchange rates of water, carbon and energy between the biosphere and the atmosphere.

The immediate and most obvious response of boreal forests to global warming is drier conditions. This leads to physiological stress in trees resulting in an increase in the outbreak of pest insects and diseases, and an increase in the areas burned by wildfires. Each of these disturbances is interconnected: stressed trees, for example, are more susceptible to pests, and accumulated dead trees lead to more frequent and severe wildfires. According to the FAO Forest Resources Assessment (FRA), insects, diseases and severe weather events damaged about 40 million hectares of forests in 2015, mainly in temperate and boreal forests.[h]

Ecologically, the displacement of plant habitats and, ultimately, bioclimatic zones towards the north, is expected to have significant effects on the species composition of boreal forest ecosystems. Over the past few decades, boreal forests and plants have continuously shifted north. This has been accompanied by earlier blooming and leafing of plants, and poleward shifts in tree-feeding insects. According to modelling of different climate scenarios,[i] the impact of climate change on hardwood forests would be less significant than on conifers; at the same time, the recession of conifers would free up space for their replacement with small-leaved species.[1]

Many of the observed and expected effects of climate change on boreal forests are interrelated and synergistic. Some of them include:

- Changes in biological diversity;
- Change of hydrological regime and deterioration of moisture availability in the south of the boreal biome;
- Change in growth of growing stock;
- Changes in accessibility and quality of wood;
- Changes in the range and migration of certain animals;
- Change to animal habitats.

An increase in the length of the growing season or the growing degree-days[2] may have a positive effect on the annual average tree growth.[j] However, this positive effect on boreal forests could be offset by negative effects due to the specificity of climate change (e.g. warming and drought in summer with increased rainfall in winter), increased variability and extremes of weather conditions, and an increase in the area and intensity of natural disturbances.

[1] Small-leaved species include cold-resistant shrubs and trees (birch, poplar, willow and buckthorn). They often occur along rivers and creeks (see https://www.fao.org/3/i3299b/i3299b.pdf).

[2] Growing degree days' measure heat accumulation over the growing season. They are an important indicator of plant and pest development.

C. Outlook for boreal forests in a changing climate

By the end of the 21st century, the vegetation season is expected to increase in all bioclimatic zones. In the Representative Concentration Pathway (RCP) 4.5 scenario (see Box 1), the average vegetation period in the circumboreal zone could increase by 25 days compared to the base period. In the RCP8.5 scenario, this would increase by 41 days.[k] Global warming of even 2°C could shift the boreal forest boundary 500 km north over 100 years - meaning that, hypothetically, forests expansion to the north could occur at a rate of 5 km per year, while the currently observed natural rate of tree species displacement does not exceed an average of 200-300 m per year.[l]

BOX 1 What are Representative Concentration Pathways?

The Representative Concentration Pathways (RCPs) describe four different 21st century pathways of greenhouse gas (GHG) emissions and atmospheric concentrations, air pollutant emissions and land use. The pathways describe different climate futures, all of which are considered possible depending on the volume of GHG emitted in the years to come. They include a stringent mitigation scenario (RCP2.6), two intermediate scenarios (RCP4.5 and RCP6.0), and one scenario with very high GHG emissions (RCP8.5). Scenarios without additional efforts to constrain emissions ("baseline scenarios") lead to pathways ranging between RCP6.0 and RCP8.5 (for more information visit https://ar5-syr.ipcc.ch/topic_futurechanges.php).

As described above, the predicted climatic changes will increase the risk of forest fires and the duration of the fire season in boreal forests. One of the potential long-term consequences of forest fires is the formation of more homogeneous and hardwood-dominated forest landscapes.[m]

3. Economic impacts of climate change on boreal forests

Boreal forests provide important raw materials for the global forest products market. More than 33 per cent of lumber and 25 per cent of paper on the global export market originate from boreal forests.[n] According to FAO,[o] climate change will have economic impacts on the forest sector and consequently on forest management. A recently published UNECE/FAO study has modelled the impacts of projected changes in forest productivity on global forest products markets.[p] The modelling results suggest that climate change, in the scenario with the highest CO^2 concentrations, would generally increase forest productivity, reducing prices and increasing global forest product consumption and production. However, results also suggest that price declines brought about by higher global forest productivity will alter production and trade competitiveness of individual countries. [3]

In boreal and cold-winter temperate forests, harvesting has traditionally been undertaken in winter when frozen soils improve the operational efficiency of forest machinery and reduce soil damage. Wet and waterlogged soils are much more prone to damage, which may result in reduced productivity.[q] Damaged soils may also affect species compositions and forest functioning.[r] Rising winter temperatures may restrict harvesting operations by reducing the number of days when soils remain frozen.[s] Excessive off-season rainfall may have a similar impact, making it difficult to continue harvesting without damaging vulnerable soils, with potentially serious consequences for timber production.

The increased incidence of wildfires is also expected to affect the supply of forest products and ecosystem services, leading to higher costs for fire management and control. An increase in the incidence of pests and the frequency and intensity of extreme weather events could increase damage to financially valuable stands and disrupt industrial operations. This could reduce the period of favourable conditions for timber harvesting and transport. In addition, increased precipitation and storm events could damage road networks and transport infrastructure like bridges and culverts.

As a result, climate change may require modifications of long-standing timber harvesting schedules, upgrades of logging infrastructure, the use of adaptable harvesting and transportation equipment and techniques, and adjustments of silvicultural methods. Such changes could increase forest management costs and, in some cases, may require substantial capital investments in infrastructure, equipment and training.

[3] Modelling results are based on only a few parameters and selected countries. For more complete results and information on information on the methodology, consult the complementary discussion paper "The outlook for UNECE forest sector in a changing climate: a contribution to the Forest Sector Outlook Study 2020-2040".

4. Role of boreal forests in climate change mitigation

Boreal forests provide critical services locally, regionally and globally. Indigenous peoples and other communities depend on ecosystem services provided by boreal forests for fishing, hunting, gathering, recreation, spiritual activities, medicines and economic opportunities. Boreal Forests also host many species of flora and fauna, and unique wildlife. Globally, boreal forests help regulate the climate through the exchange of energy and water.[t]

Boreal forests also constitute a large reservoir of biogenic carbon on a level comparable to, if not greater than, that of tropical forests. According to various estimates, carbon reserves in the terrestrial biomass of boreal forests amount to 40.7,[u] 53.9,[v] or 57[w] billion tons of carbon. In addition, estimates suggest that the total carbon reserve in the circumboreal zone (including vegetation, soil and peatlands) ranges from 272[x] to 1715[y] billion tons. A review study[z] showed that mid-point estimates of total circumboreal carbon stores, including peatlands, are 1095 billion tons of carbon, which is larger than any previous mean estimates.

Temperature increases will likely have an impact on the carbon storage capacities of the circumboreal zone: as more permafrost areas thaw and more areas of boreal forests burn, large amounts of GHGs are likely to be released. The carbon storage potential of boreal forests continues to be a topic of debate, with ongoing research looking into the impacts of forest management on the carbon balance of boreal forests (see Box 2). Some scientists argue for instance that boreal forested peatlands may have been overlooked as unproductive ecosystems, due to their semi-open structure and low stem density. As a result, the carbon sequestration potential of forested peatlands is inaccurately evaluated and peatlands' role in climate mitigation therefore underestimated.

Carbon sequestration rates of boreal forests are also likely to be significantly influenced by a warming climate, although the net positive or negative effects are highly uncertain. As previously described, higher temperatures and atmospheric CO^2 concentrations combined with longer growing seasons are likely to promote higher growth and thereby sequestration rates. In turn, more severe fire seasons may offset those positive gains, but create younger forests across the boreal region, forests which tend to have higher sequestration rates than older forests. Combined with sustainable forestry activities and their potential to create areas of higher sequestration rates and lower fire risk, the overall sequestration picture for the boreal ecosystem is uncertain.

BOX 2 Sustainable boreal forest management – challenges and opportunities for climate change mitigation

Report from an Insight Process conducted by a team appointed by the International Boreal Forest Research Association (IBFRA), published in 2021 (available at https://www.skogsstyrelsen.se/globalassets/om-oss/rapporter/rapporter2021202020192018/rapport-2021-11-sustainable-boreal-forest-management-challenges-and-opportunities-for-climate-change-mitigation-002.pdf).

Research recently published by IBFRA has analysed the carbon storage potential of managed and unmanaged boreal forests. It highlights the fact that Nordic countries (Finland, Norway and Sweden) have the largest harvest removals in percentage of standing stock carbon, while showing significant and large increases in carbon stock in living biomass. This increase is not a result of forest area expansion or increases in stand age across landscapes, but rather the result of increased growth rates of managed forests. Countries where much less of the forests are managed for wood harvests, Canada, Russia and United States (Alaska), showed little or no increase in carbon stocks[4] in living biomass over the 1990 – 2017 time period. The authors nevertheless caution against strict comparisons between managed and unmanaged forests across the boreal biome due to the lack of comparable high-quality data from the larger countries and differences in national definitions of managed forests. Just like the effects on the GHG balance, the negative effects of forest management (e.g. on biodiversity) should not be seen in isolation, but rather should be compared to the impacts of the production and use of alternative products, with associated GHG emissions and other effects on the environment, e.g., climate impacts on biota, including effects on biodiversity. Political decisions must, of course, also value socioeconomic and cultural dimensions.

[4] Forest carbon stock is the amount of carbon that has been sequestered from the atmosphere and is now stored within the forest ecosystem, mainly within living biomass and soil, and to a lesser extent also in dead wood and litter.

5. Adapting boreal forests to a new climate reality

A. Forest management, landscape restoration and certification

In the face of the complex and diverse effects of climate change on boreal forests, the development and implementation of appropriate adaptation programmes becomes increasingly urgent. Such adaptation measures need to be rooted within national forest legislative frameworks, taking into account sustainable forest management principles such as "climate-smart forestry" approaches (see Box 3),[bb] forest landscape restoration principles (see Box 4), as well as both traditional and best silvicultural practices.

BOX 3 What is climate smart forestry?

The Climate Smart Forestry (CSF) concept considers the entire forest and wood products chain, encompassing energy and material effects that are not attributed to forestry (based on current accounting practices). CSF is about more than just the carbon storage potential of forest ecosystems: it includes adaptation measures and strives to achieve synergies with other forest functions such as ecosystem services and biodiversity. CSF is centred around the following three pillars:

1) reducing and/or removing greenhouse gas emissions to mitigation climate change
2) adapting forest management to enhance the resilience of forests
3) active forest management aiming to increase productivity and income and to sustainably provide all benefits that forests can provide.

Adaptation measures should predominantly focus on increasing the resilience of forests to possible climate change scenarios through changes in forest composition and structure; predicting forest composition based on up-to-date forest data, forest regulatory and technical frameworks, and other adaptation measures; and improving forest accounting and scientific support for key forest management activities to enhance the early detection of climate-related negative impacts in forest ecosystems and subsequentially facilitate a rapid response based on best practices. Adaptation measures should also take into account both the harmful and beneficial relationship between insects and other pathogens with their boreal forest hosts, responding to anticipated risks and opportunities related to climate change.

Another way to increase adaptation to climate change in forestry operations is through forest certification. Forest certification is a market-driven mechanism for ensuring responsible forest management through compliance by the relevant certificate holder to a set of stakeholder-developed standards that are verified by independent third-party auditors.[dd]

BOX 4 What is forest landscape restoration and how can it help to increase the capacity of forest ecosystems to absorb carbon?

Forest landscape restoration (FLR) aims to "restore a range of forest functions at the landscape level. It includes actions to strengthen the resilience and ecological integrity of landscapes with the participation of local communities. FLR is an integrating framework that can be applied across a range of land uses to ensure that key ecosystem goods and services are available for future generations and deal effectively with the uncertainties of climatic, economic, and social change".[cc] Healthier forests, with healthy biodiversity, yield benefits such as more fertile soils, bigger yields of timber and larger stores of greenhouse gases.

B. Wildfires

Boreal forests are adapted to burning. Less frequent fires help create habitat mosaics of various ages and stages of regeneration. With the increasing occurrence of wildfires in the circumboreal zone, forests are losing their resilience to recover from large fire events. Improving forest fire awareness and resilience can include limiting the occurrence and spread of forest fires to prevent possible carbon emissions, loss of forest biomass and negative impacts to boreal forest ecosystem services.

In some instances, however, fire suppression and the planting of non-native tree species in open habitats can lead to larger and hotter fires due to the risk of fuel accumulation. Solutions can include restoring natural fire regimes by integrating information on climate impacts in fire management responses[ee] and removing non-native species[ff] to decrease the vulnerability of people and ecosystems to the exacerbated fire risk that results from climatic changes (including temperature increases and changing rainfall patterns). Restoring peatlands and wetlands through strategic re-wetting, selective spruce tree removal and replanting with fire-resistant mosses have proven to mitigate carbon losses from wildfires in Canada.[gg]

In addition, it is often those communities that are directly impacted by wildfires that lack financial means to put in place preventative measures. Financial and technical support to, for example, thin forests surrounding settlements, encourage the construction of fire-proof homes and develop evacuation plans could enable such communities to become more fire resilient. Sustainable forest management in these communities can result in improved fire management, as well as fire resilience and awareness activities.

C. Forest workforce

The impacts of climate change, along with changing technology, changing requirements for sustainability (biodiversity, water and soil protection) and competition between different forest uses will continue to significantly alter job requirements in forestry at all levels.[hh] Forest training programmes will therefore need to be adapted to better incorporate knowledge about the influence of climate on forest conditions and dynamics, as well as new methods of climate change adaptation, including updated harvesting techniques.

6. Main take-aways

Climate change is likely to have numerous and potentially profound effects on boreal forests. These effects will be wide-ranging, multi-dimensional, and will have complex consequences.

Climate effects will alter ecosystem services in the boreal region, including carbon storage and capture, water and soil processes, and ecological processes that affect species range and biodiversity patterns.

In all predicted climate scenarios, the global boreal ecosystem will have a significant role to play in helping the planet regulate the long-term effects of climate change.

Adaptation strategies taken by boreal forest countries will be paramount to make boreal forests more resilient to climate change. Possible strategies will include the use of climate smart forestry practices, forest restoration activities and efforts to adapt forests to increasing wildfire risks.

The future of boreal forests under shifting climate conditions will have significant effects on local, regional and global forest markets and fibre supplies.

It will be necessary for the forest workforce to update skills and make adjustments in order to manage forests in this new environment.

National forest legislative frameworks and forest management principles will need to be adapted to climate effects; Indigenous and local forest-based communities, and all relevant parties in the circumboreal zone need to collaborate to mitigate the future effects of climate change and realize the full potential that boreal forests present.

In a rapidly changing environment, international bodies and organizations that foster circumboreal cooperation will play a greater role in coordinating these efforts.

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