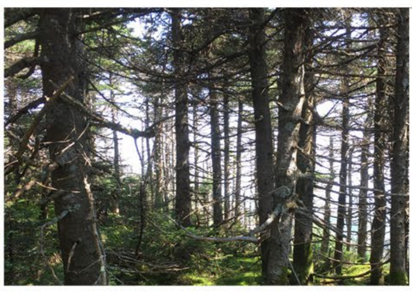
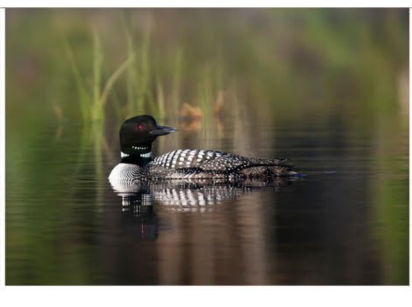
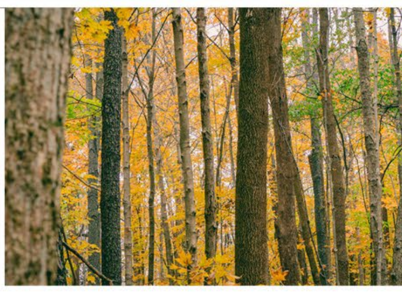
SUSTAINABLE FORESTRY INITIATIVE
REGIONAL CLIMATE CHANGE RISK SUMMARY:
NORTHEAST US AND LAKE STATES







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INTRODUCTION

Climate Smart Forestry (CSF) is defined as sustainable adaptive forest management to protect and enhance the potential of forests to adapt to and mitigate climate change (Bowditch et al. 2020, Cooper and MacFarlane 2024). The threats posed to these forests by climate change can be equally diverse, with variations across geographies and forest types in terms of risk level, frequency of occurrence, and severity of impacts. Therefore, implementation of CSF practices across the geographically diverse footprint of SFI-certified forests in North America necessitates regional approaches to promote climate change adaptation and mitigation.

Acting strategically on CSF requires strategic, science-backed approaches that address:

1. How climate change is affecting, or is expected to affect, forests, trees, and forestry operations across different regions
2. Forest vulnerability to climate change impacts
3. Principles and practices for adapting to and mitigating those risks, based on forest type group
4. Guidance to monitor and evaluate the effects of those practices to inform future decision-making

The rapid pace of climate change and the continuous emergence of new data also pose challenges in keeping strategies updated and relevant. Integrating evolving scientific knowledge into practical implementation remains a significant hurdle. Differing priorities and levels of interest can affect the cohesive implementation of CSF strategies. Overcoming these barriers will require continued innovation, investment, and cooperation among stakeholders involved in forest management.

The primary aim of this report is to advance a systematic approach for CSF across various geographies, utilizing diverse data sets and emerging research. This report is intended to reach other audiences interested in this topic including government agencies, users of forest products (e.g., those in building and construction), conservation groups, and interested members of the public including consumers.

The Sustainable Forestry Initiative (SFI) 2022 Forest Management Standard includes a Climate Smart Forestry objective that requires certified organizations to identify and address climate change risk by developing adaptation strategies and identifying opportunities to enhance mitigation. A key aspect of the CSF objective is a requirement to identify and prioritize climate risks based on the best available scientific information. In addition to adaptation, the CSF objective emphasizes identifying and addressing opportunities to mitigate climate change impacts associated with forest operations.

SFI STANDARDS AND ADVANCING CSF

SFI is an independent, non-profit organization advancing the value of forests as a critical component to our collective future. With over 150 million hectares certified to the SFI Forest Management Standard in North America, and tens of millions more positively influenced by SFI Fiber Sourcing, SFI and SFI-certified organizations have the scale to implement solutions across the landscape. During the 2022 standard revision process, SFI enhancements objectives adding two new objectives focused on Climate Smart Forestry and Fire Resiliency and enhanced requirements on the conservation of biological diversity. These require certified organizations to identify and address climate change and fire risks to forests and forest operations and develop adaptation objectives and strategies.

The SFI 2022 Forest Management Standard, through its Climate Smart Forestry (CSF) objective incorporates performance measures for climate change adaptation and mitigation strategies, enhancing forest resilience and carbon sequestration capacities and reducing emissions associated with forest operations on public and private lands. This includes activities like enhancing climate benefits of forest operations (via implementation of practices to improve forest health, productivity, and resilience), increasing the area and density of certified stands (via afforestation, prompt reforestation, and supplementation of understocked stands), and minimizing carbon losses during forest operations (via protection of advanced regeneration during harvest and retention of productive stems during partial harvest).

Interpreting Climate Impacts and CSF Practices

Because SFI-certified forests span broad geographies across North America, they include a wide array of ecological zones (i.e., distinct elevations, climates), tree species compositions, site conditions, age classes, management histories, productivity levels, and patch sizes. This report provides foundational context to support systematic evaluation of climate risks and appropriate CSF interventions to address those risks. This approach involved a high-level assessment of climate change-related impacts to forests in each region and vulnerabilities of local forest type groups to those impacts. The review used large, recognized sub-national regions, within which ecologically significant information regarding dominant forest type groups, key species, and site considerations was synthesized to tailor to species- and condition-specific threats and vulnerabilities.

Advancing CSF can be supported with hierarchical decision-making linking climate-driven forest threats and impacts from regional geographies (ecoregions), forest type groups, with site- or species-specific concerns. Critical evaluation of climate-driven impacts to local forest communities provides a foundation for which Climate Informed Principles and Practices (CLIPPs) can be applied.

Regional Considerations

Climate change will affect forests and trees differently across North American geographies. This analysis uses sub-national regions in both the US and Canada. Boundaries for US regions largely follow state groupings used by the US Forest Service (USFS), with ecoregions presented at 2 scales (Level II & III) based on definitions by the Commission for Environmental Cooperation (CEC Working Group 1997). The boundaries of the Forest Regions of Canada are based on Rowe (1972) and are characterized by ecological features, climatic conditions, and forest community types.

Forest community groupings align with definitions used by national natural resource agencies. For US regions, definitions of Forest Type follow USFS Forest Inventory and Analysis definitions of Forest Type Groups while for Canadian regions, the framework follows definitions of Species Group used by Canada's National Forest Inventory. Tailoring the design and structure of the decision support framework to account for regional considerations such as subregional delineations, forest type groups, climate impacts, and management practices will allow for consistent communication and advancement on Climate Smart Forestry.

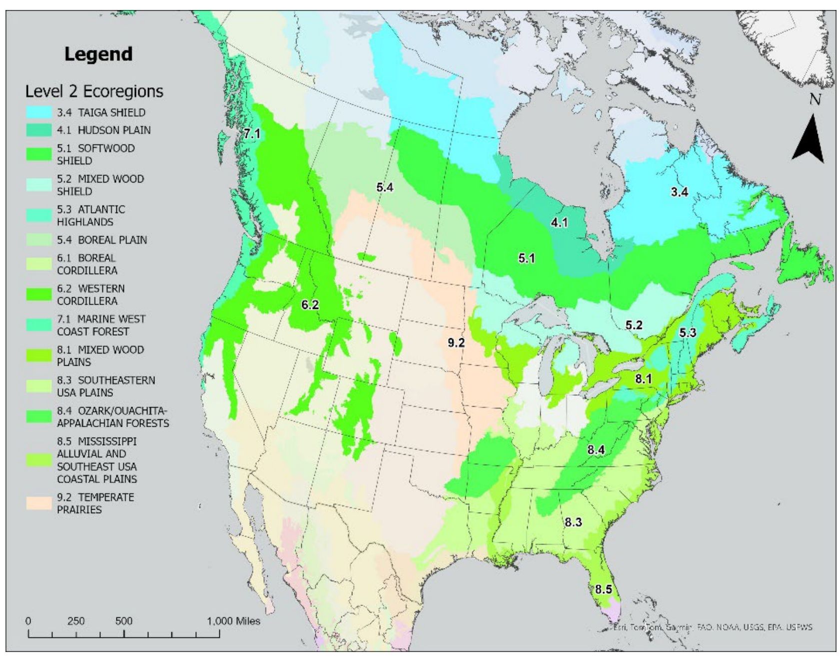


Figure 1. Map of Level II ecoregions (CEC Working Group 1997).

Data and information relating to regional climate change stressors to forests were also sourced differently for the US and Canada. For regions of both countries, data on climate change impacts were synthesized from a diversity of scientific resources. Some important resources for US regions included the US National Climate Assessments, Northern Institute of Applied Climate Science (NIACS) Vulnerability Assessments, the USFS Tree Atlas, and feedback from regional forest experts. For Canadian regions, important sources of this data included Natural Resources Canada's *Canada in a Changing Climate: Regional Perspectives Report*, The State of Canada's Forests Annual Reports, and Canada's Changing Climate Reports, among others.

Geographic distinctions were also considered regarding formulation and framing of climate smart forest interventions. For Canadian regions, the Canadian Forest Service Database of Adaptation Options served as a valuable resource and supported identification of adaptation options to address forest vulnerabilities based on peer-reviewed publications. For US regions, adaptation pathways were framed around concepts of strategies, approaches, and tactics published in Adaptation Menus developed by NIACS and the USFS (Ontl et al. 2020 and Swanston et al. 2016). These resources inform the categorization and framing to downscale adaptation responses from broader approaches to specific activities for regions in both the US and Canada.

For the purposes of this report, the Northeast and Lake States include the states of Connecticut, Delaware, Illinois, Indiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, Missouri, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, Vermont, and Wisconsin. With over 40% of the US population residing within its borders, this region represents one of the most highly populated areas of the country (Shifley et al. 2016). It's also one of the most forested regions in the nation, with more than 40% of its total land area classified as forestland (USDA Forest Service Northeastern Area 2005). The Lake States and Northeast US contains significant spatial variation in forest type coverage across its landscape (Shifley et al. 2016; USDA Forest Service Northeastern Area 2005).

Ecoregions of the Northeast and Lake States

The Northeast US and Lake States can be divided into the following forested Ecoregions: Mixed Wood Shield, Atlantic Highlands, Mixed Wood Plains, Central US Plains, Southeastern US Plains, Ozark/Ouachita-Appalachian Forests, Mississippi Alluvial and Southeast USA Coastal Plains, and Temperate Prairies (U.S. Environmental Protection Agency, 2013). These ecoregions consist of many level III ecoregions as depicted in Figure 2. A description of each ecoregions unique features, dominant forest cover groups, and climate change impacts is summarized in Table 2 (U.S. Environmental Protection Agency, 2013).

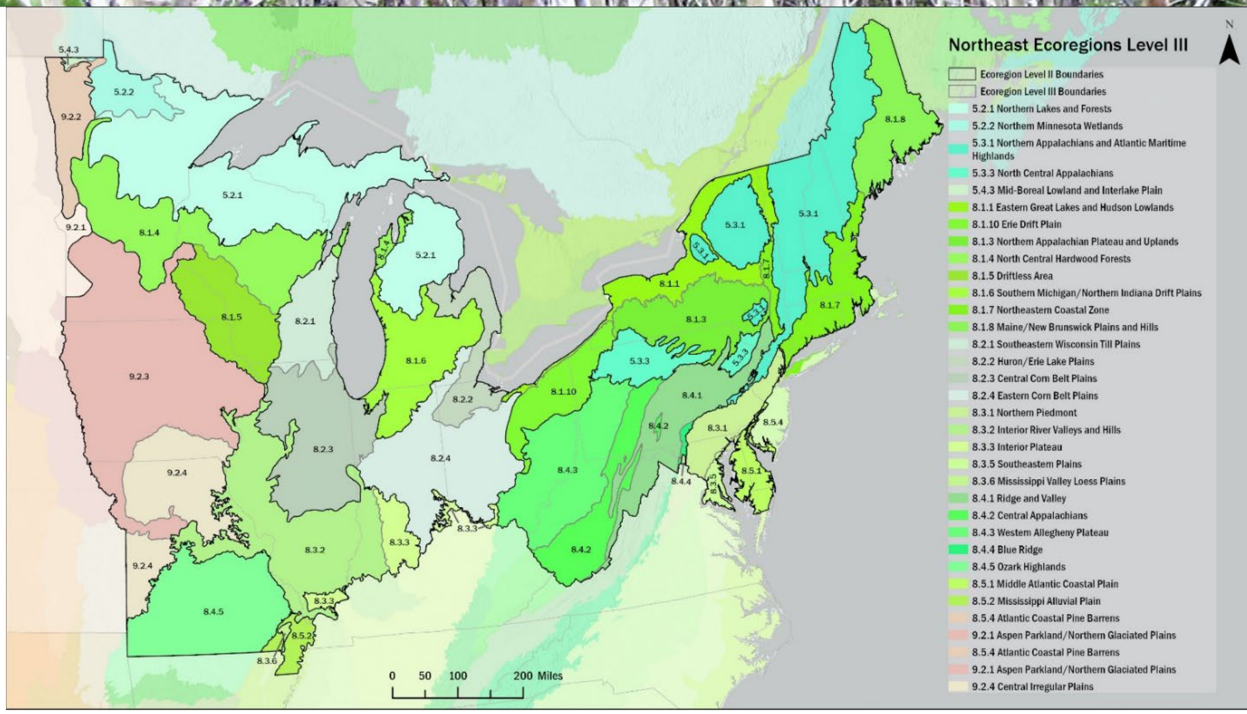


Figure 2. Ecoregions of the Lake States and Northeast (U.S. Environmental Protection Agency, 2013)

NORTHEAST AND LAKE STATES CLIMATE TRENDS AND IMPACTS ON FORESTS

In the Northeast and Lake States, climate change is having a range of impacts on the forested landscape. The forest impacts that are currently being observed, with anticipated increases, include droughts, changes in seasonality, wildfires, extreme storm events, droughts, and an increase in pests and pathogens including damage from insects. It should also be noted that these impacts can co-occur, and combinations of these impacts can drive stressors that ultimately cause tree mortality.

Temperatures in the region are projected to get warmer. Currently, the coolest areas with a mean annual temperature of ~32° F (1° C) are in northern Minnesota, White Mountains of New Hampshire and northwestern Maine. The warmest areas with annual temperatures of ~60° F (15° C) are present in southeastern Missouri and the Delmarva peninsula in Maryland and Delaware. In the 2000s, the Northeast and Lake States have experienced an observed increase in temperature with the greatest differences occurring during the winter across the northern tier of the region and an increase in summer temperature along the Atlantic seaboard (Avery et al. 2023).

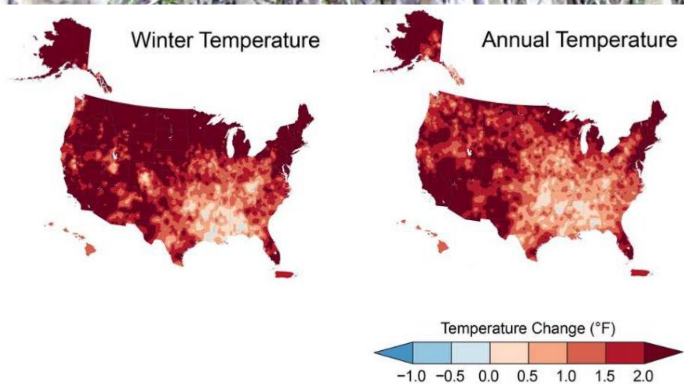


Figure 3. Observed Temperature Change 2002-2021 for the Winter, Annual Average, and Summer across the US based on 1901-1960 Averages (Marvel et al. 2023) (NOAA NCEI and CISESS NC).

Figure 4. The map shows the shift in the plant hardiness zones based on observed temperature changes between 2023 and 2012 (USDA 2023).

Increasing temperatures are changing the plant hardiness zones (USDA 2023). This trend results in changes to ecosystems that allows northward and altitudinal expansion by species that are adapted to warmer temperatures and potentially outcompete species that are competitive on a site due to their adaptation to colder temperatures.

Precipitation is variable across the region with topographic influence driving these patterns. Generally, average annual precipitation is expected to increase with the greatest increases occurring in the summer months. Since the 1900s there has been a general increase in precipitation across the Northeast and Lake States. New England and the southern Lake States have seen notable increases in precipitation especially during the summer. In the winter, there has been an increase in precipitation in Minnesota, Wisconsin, and Michigan.

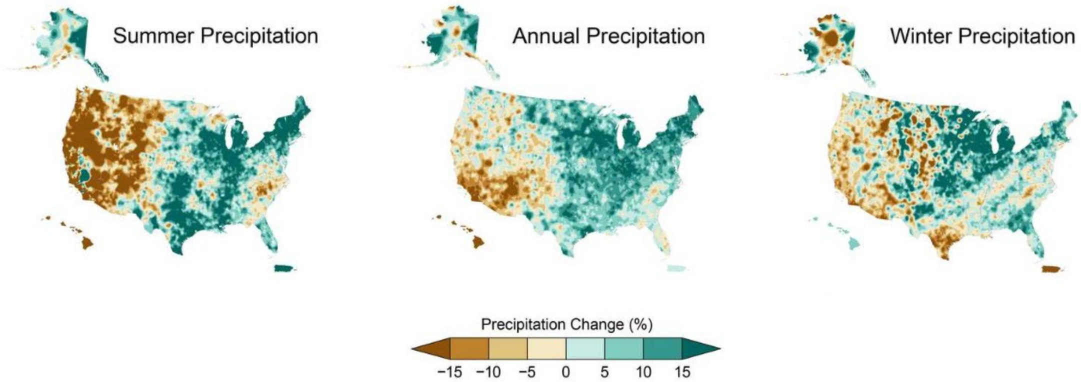


Figure 5. Observed change in Precipitation from 2002-2021 compared to 1901-1960 average for Summer, Annual, and Winter precipitation (Marvel et al. 2023).

Between 1958 and 2021, the total precipitation on the heaviest 1% of days has increased by 60% Northeast and by 45% in the Lake States (Marvel et al. 2023). When precipitation occurs with a large quantity over a short amount of time water will run off the landscape instead of infiltrating into the soil. Heavy precipitation events also can lead to soil erosion and streambank erosion during these peak flows. Forest types that are adapted to drier conditions and that cannot survive being inundated are at risk of being stressed or experiencing mortality during these extreme precipitation events. In addition, in riparian areas vegetation can be uprooted during flooding and regeneration wiped out.

Drought In between times of extreme precipitation extended periods of drought are expected to occur. Depending on the time of year this can greatly affect the productivity of forests. If drought occurs during the summer months, growth rates can be greatly reduced. The stress caused by the droughts can also make trees more susceptible to invasion by pests and pathogens which can lead to mortality. Drought can also result in wildfires.

Wildfire The projected changes in precipitation will affect the fuel conditions that can lead to wildfire. Figure 6 shows fire risk across the Northeast and Lake States, current increased risk can be found in northern Minnesota, Michigan, southern Missouri, southern New Jersey and southwestern West Virginia. Many of these areas are places where fire is a part of the ecological disturbance regime, but with a history of fire suppression and fragmentation of forests due to development the risk of severe wildfires that impact human populations can lead to catastrophic damage.

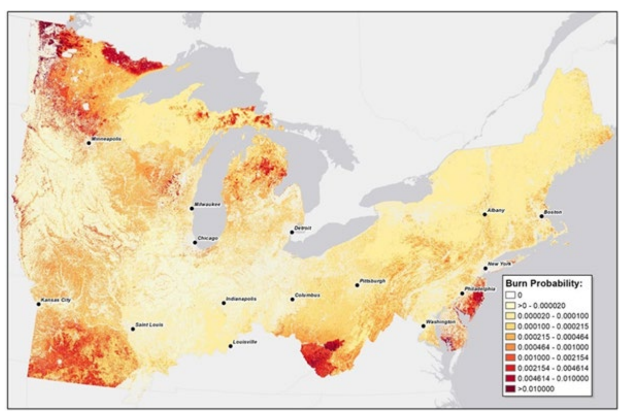


Figure 6. Map of integrated FSim burn probability results for the Eastern Region study area at 30-m resolution (Napoli et al. 2021)

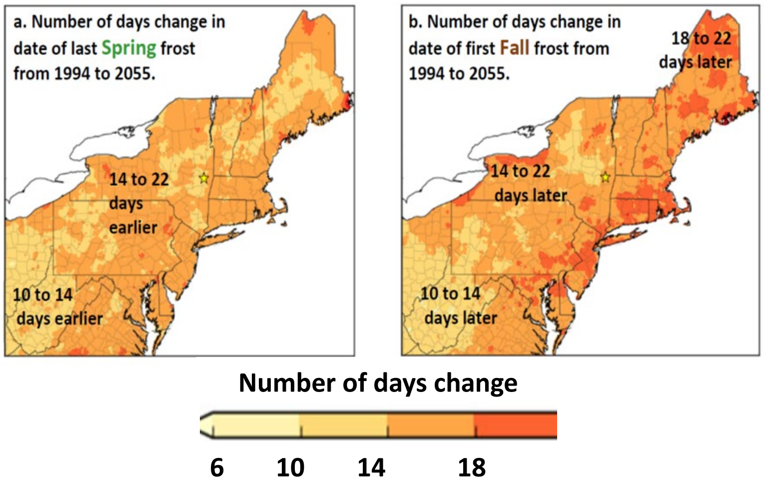


Figure 7. Projected change in final spring and first fall frost dates 1994-2055 (Wolfe et al. 2018 in Koehler 2018)

Seasonality In the Northeast, there has been an observed change in the growing season length. It is projected that across much of the region the date of the last spring frost will be 14-22 days earlier by 2055 compared to 1994. In addition, in Northern Maine, it is projected that the date of the first frost will be 18 to 22 days later by 2055 (Figure 7). This extended growing season can also come with a more unpredictable freeze that cycle that can damage plant tissues that may break bud early, only to be inflicted with another hard freeze. This can be especially damaging to conifers. These oscillations can also alter soil processes with increased respiration and earlier spring thaws. This overall trend will lead to increased growing season evapotranspiration as production increases in this region's forests.

Pests and Disease For some forest pests, winters act as a moderating factor that limits population spread. Hard freezes can kill eggs or overwintering adults. With warming winters and fewer hard freezes pests have opportunities to expand their ranges and have the potential for population explosions. As seen in Figure 8, Hemlock Woolly Adelgid, that parasitizes and kills eastern Hemlock, has expanded its extent since its discovery in 1951. Currently, the northern populations of hemlock remain unaffected largely due to the moderating effects of winter. Other compounding effects of anticipated climate change are increases in the number of broods or reproductive cycles of forest pests that comes with a longer growing season. In combination with other stressors such as drought, there comes a risk of mortality from pest outbreaks which could then lead to heavy fuel loading in forests and thus increased wildfire risk. Forests are most vulnerable when at the edge of the range of known forest pests with variable climatic controls which can allow unimpeded infestation.

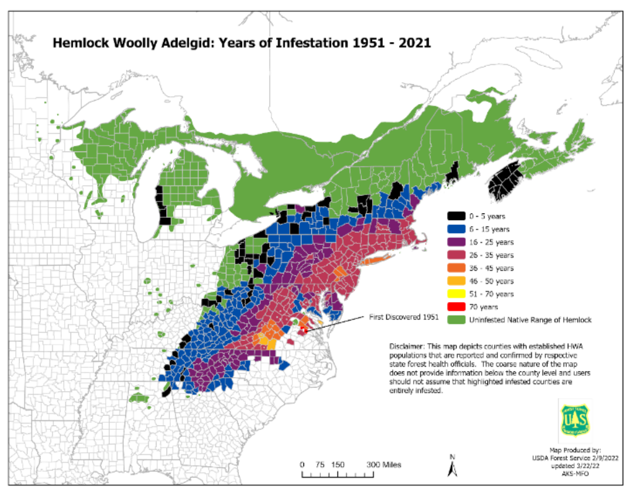


Figure 8. Years of Infestation by Hemlock Woolly Adelgid whose expansion is mediated by cold winters (USFS)

Cumulative Effects The interactions of these climate-driven impacts can increase the severity of a disturbance, resulting in increased mortality. For example, with increasing temperature, trees will increase their evapotranspiration thus using more water which can then exacerbate droughts increasing the severity of wildfires and susceptibility to insects and diseases. Another example is with especially true in northern areas of the southeast, where cold winters can act as a deterrent to the spread of insects. When winter temperatures increase, this deterrent no longer exists, and pests can have outbreaks in these forest types which can then lead to mortality and increased risk of severe wildfire through the additional fuel loading.

NORTHEAST AND LAKE STATES FORESTS

The Northeast and Lake States are dominated by six key forest cover groups: oak/hickory, maple/beech/birch, spruce/fir, aspen/birch, elm/ash/cottonwood, and white/red/jack pine. Figure 9 shows region-level data for the total forested area and total forest carbon for each of the major cover types (USDA FS FIA 2025). The maple/beech/birch and oak/hickory forest type groups are the most abundant forests of this region, with oak/hickory covering roughly 70 million acres and maple/beech/birch covering 45 million acres. However, the maple/beech/birch forest type group holds more carbon per unit area, 115 tons/acre, compared to the oak/hickory group, 104 tons of carbon per acre on average. The regional extent of spruce/fir is similar to that of the aspen/birch group, around 15 million acres; but spruce fir holds roughly 12 more tons per acre of carbon than aspen/birch.

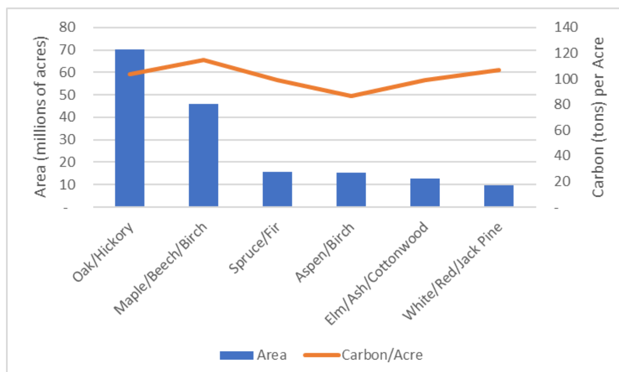


Figure 9. (Bars) Area of forest type groups across the Northeast and Lake States. (Line) Tons of Carbon per acre by Forest Type Group (USDA FS FIA 2025).

Forest Cover Group Climate Change Impacts

Some of the most significant threats to forests of the Northeast and Lake States US include pests and diseases, warming winters, barriers to regeneration (e.g. herbivory), and drought. Table 1 shows a comparison of major climate-related threats to regional forest cover types. Results presented in Table 1 were drawn from wide-ranging literature, see Brandt et al. 2014, Janowiak et al. 2014, Janowiak et al. 2018, Butler-Leopold et al. 2018, Butler et al. 2015, USDA FS FIA 2021, Handler et al. 2014, and Burrill et al. 2017.

Table 1. Climate-related threats of key concern to forest cover types of the Lake States + Northeast US.

FOREST COVER TYPE	DROUGHT	EXTREME STORMS	PESTS & DISEASE	REGENERATION ISSUES	WARMING TEMPERATURES	WILDFIRE
Oak/Hickory			x	x		
Maple/Beech/ Birch	x	x	x	x	x	x
Spruce/Fir	x	x	x	x	x	x
Aspen/Birch	x			x	x	
White/Red/Jack Pine	x		x	x	x	x
Elm/Ash/Cottonwood	x	x	x			x

Oak/Hickory

Figure 10. Oak/Hickory forest and distribution (inset) in the Northeast and Lake States US. Data: USFS FIA 2024

The oak-hickory forest type group covers more of the commercial forest land base in the eastern US than any other type. It comprises 70% of the total forest in the Central Appalachians with concentrations in West Virginia, Pennsylvania, southeast Missouri and southeast Ohio. Dominant species in this group include White Oak, Chestnut Oak, Northern Red Oak, Post Oak, Blackjack Oak, Scarlet Oak, Hickory, Yellow Poplar, and Sweet Gum (Eyre 1980). This forest type has relatively low vulnerability to climate change as many species within the group are adapted to warmer and drier conditions. The species in this group are also resilient to disturbance such as wind events and low-severity fire. With projected temperature and precipitation changes, suitable habitats for this group are expected to increase and generally expand northward across its range. This suitable habitat is where a species can or does occur and expansion of species into new areas will depend on its ability to disperse into these areas (McKenney-Easterling 2000). The Oak-hickory group has less carbon per unit area than other forest type groups (USDA FS FIA 2025). In this group, more carbon is stored in the aboveground carbon pools than the belowground pools. However, due to its low vulnerability and resilience to climate change impacts it is projected to have a stable carbon pool and because of its prevalence on the landscape it is one of the largest carbon pools with the possibility of expansion if it occupies suitable new habitat.

Maple/Beech/Birch

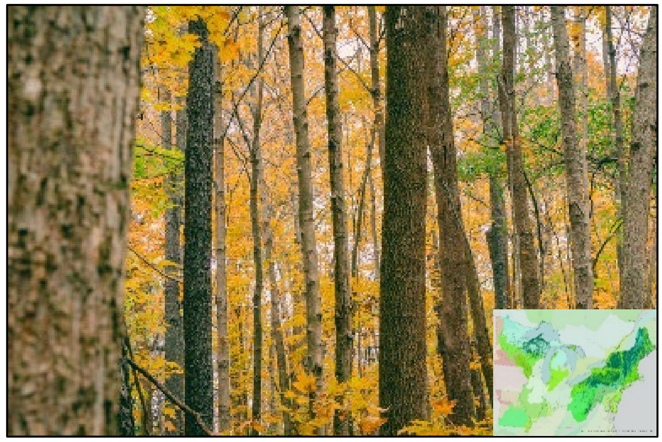


Figure 11. Maple/Beech/Birch forest and distribution (inset) in the Northeast and Lake States US. Data: USFS FIA 2024

Maple/Beech/Birch forests or Northern Hardwoods are abundant across New England and the Lake States. There are over 8 million acres in New England and New York alone. This forest type group is characterized by having a high amount of species diversity that supports high levels of biodiversity on the landscape. The dominant species in this group include Sugar Maple, American beech, Yellow Birch, Red Maple, Black Cherry, and Basswood (Eyre 1980). Northern Hardwoods are anticipated to have a range of vulnerability to climate change due to the diversity of sites the forest type group occurs on and the species composition that make up this group. Those forests that are the least vulnerable occur on cooler, moister sites and at high elevations particularly on northern aspects. The most vulnerable are at drier, low elevation sites that are low in species diversity (either due to past management or ecological type) (Janowiak et al. 2021). Future conditions that will drive the distribution and composition of this forest type group are climate change impacts that affect hydrology, soil moisture and nutrient availability. Altered disturbance dynamics can promote this forest type on the landscape (Rustad et al. 2012). Regeneration is a challenge for some species in this forest type group whether due to herbivory or pest and diseases (such as beech bark disease) that impact key species.

Spruce/Fir

Figure 12. Spruce/Fir forest and distribution (inset) in the Northeast and Lake States US. Data: USFS FIA 2024

The spruce/fir forest type group occurs at the most northern latitudes in the Northeast and Lake States. These forest types favor cooler sites with acidic soils and abundant precipitation. This forest type group includes northern white cedar, red spruce, black spruce, tamarack, and balsam fir. The dominant species are shade tolerant and require an overstory for successful regeneration (Eyre 1980). This forest type is considered highly vulnerable to climate change. The dominant species are cold-adapted and with warming and shorter winters they are losing suitable habitat. In areas where this forest occurs at high elevations the forests at the lower elevational edge create an ecotone with northern hardwoods and the northern hardwoods are able to expand its range into areas formerly dominated by spruce/fir, especially after disturbance (Rustad et al. 2012). This forest type is also susceptible to most disturbances, which are projected to increase in the region. Spruce/fir forests are susceptible to breakage from wind damage, they are intolerant of fire, and they are prone to defoliation and mortality from a range of pests (including spruce bud worm and balsam woolly adelgid). This forest type is especially important for carbon storage and stores more carbon per unit area than the other forest types in the region (USDA FS FIA 2025). This forest type sequesters more carbon

belowground than above ground. Due to projections this carbon pool is at risk under climate change scenarios.

Aspen/Birch

The Aspen/birch forest type occurs predominantly in the Lake States particularly in Michigan and northern Minnesota. This forest type can occur in single species stands or in a mixture with some other species. The dominant species in this forest type group are Aspen, Paper Birch, and Balsam Poplar. This forest type can occur as closed canopy stands, to open canopy woodlands to exposed shrublands. Aspen/birch forests are disturbance adapted and are shade intolerant and thus are able to regenerate after stand replacing disturbance (Eyre 1980). Aspen/birch stands are declining with the Lake States being the southern extent of its range. This decline is tied to current climate shifts as the climate becomes hotter and drier. Some projections estimate that aspen could lose more than 50% of its current suitable habitat by 2050 (Domke et al. 2008). This will have significant implications for forest carbon.

Figure 13. Aspen/Birch forest and distribution (inset) in the Northeast and Lake States US. Data: USFS FIA 2024

Elm/Ash/Cottonwood

The Elm/Ash/Cottonwood group occurs in floodplains and along rivers throughout the Northeast and Lake States. The dominant species in this group are Green Ash, Black Ash, American Elm, Red Maple, Sugar Berry, and Hackberry (Eyre 1980). Due to the rich nature of these riparian sites, this forest type group supports high biodiversity. This group is projected to have low-moderate vulnerability to climate change. These species are relatively tolerant of variable precipitation and the dominant species are highly competitive in these sites and are not likely to transition to other species. Altered flood timing and intensity can impair regeneration and the erosion of streambanks can uproot mature trees. This group is not limited to floodplains and thus is not anticipated to expand its range (Janowiak et al. 2014).

Figure 14. Elm/Ash/Cottonwood forest and distribution (inset) in the Northeast and Lake States US. Data: USFS FIA 2024

White/Red/Jack Pine

The White/Red/Jack Pine Forest Type Group occurs largely in Michigan and southern New Hampshire and Maine. Red and Jack Pine are more common in Michigan while White Pine is more common in New England. The primary species in this forest type group are Red Pine, Jack Pine, Eastern White Pine, and Eastern Hemlock (Eyre 1980). For Red Pine and Jack Pine fire is important with an occasional to frequent fire return interval. White pine is more shade tolerant and can develop under a closed canopy taking advantage of small disturbances to develop into the overstory. Red Pine is considered moderate to highly vulnerable to climate change, jack pine moderately vulnerable, and white pine has moderate to low vulnerability (Peters et al. 2020). These species experience impacts to regeneration from both herbivory and stress due to heat and drought. Pest and disease also affect this forest type group and with milder winters, pest outbreaks can increase in extent and magnitude. Red Pine and Jack Pine are near the southern extent of their range and thus are likely to lose suitable habitat within this region (Janowiak et al. 2014).

Figure 15. White/Red/Jack Pine forest and distribution (inset) in the Northeast and Lake States US. Data: USFS FIA 2024

ECOREGION IMPACTS WITH SPECIES-SPECIFIC INSIGHTS

This section presents a table with the climate risks by ecoregion and linking with the species-specific concerns presented in prior sections. Results in Table 2 show which major Forest Cover Type Groups are present in each Level II Ecoregion (column 1). A description of the forests at the Level III ecoregion scale are provided for context in column 2. Additionally, a summary of the climate change vulnerability of the forests in the ecoregion are summarized in column 3. These data are pulled from wide-ranging literature, expanded upon in prior sections.

Level II Ecoregion	Level III Ecoregion Description	Climate Change Impacts
Mixed wood Shield **Forest Cover Groups** • **Aspen/Birch** • **Maple/Beech/Birch** • **Spruce/Fir** • **White/Red/Jack Pine**	• **5.2.1: Northern Lakes and Forests**: Mostly coniferous and northern hardwood forests, with sugar maple, red maple, yellow birch, aspen, white spruce, balsam fir, hemlock, eastern white pine, jack pine, red pine. Cooler and wetter sites with black spruce, tamarack, northern white cedar. • **5.2.2: Northern Minnesota Wetlands**: Conifer/bog forest, mixed and boreal forest vegetation. White spruce, black spruce, balsam fir. Areas of maples and white pine. Successional areas with aspen, paper birch, and jack pine.	• Boreal species are most vulnerable • Temperate and southern species are least vulnerable
Atlantic Highlands **Forest Cover Groups** • **Maple/Beech/Birch** • **Spruce/Fir** • **Oak/Hickory** • **White/Red/Jack Pine**	• **5.3.1: Northern Appalachian** and Atlantic Maritime Forest: Mostly mixed hardwood and spruce-fir forests. Forest vegetation is somewhat transitional between the boreal regions to the north and the broadleaf deciduous forests to the south. Typical forests include mixed hardwoods of sugar maple, beech, and yellow birch; mixed forests with hardwoods and hemlock and white pine; and spruce-fir forests with balsam fir, red spruce, and birches. In swampy areas, black spruce, red maple, black ash, and tamarack. • **5.3.3: North Central Appalachians**: More forest covered than most adjacent ecoregions. Generally, northern hardwood forests of sugar maple, beech, and yellow birch, and Appalachian oak forests with white oak, red oak, and hickories. Some areas with hemlock, pitch pine, and white pine. Some bogs and marshes.	• Spruce/fir and conifer-dominated communities at both high and low elevations are most vulnerable • Hardwood and pine communities are least vulnerable
Mixed wood Plains **Forest Cover Groups** • **Maple/Beech/Birch** • **Oak/Hickory** • **Spruce/Fir** • **Aspen/Birch** • **White/Red/Jack Pine** • **Elm/Ash/Cottonwood**	• **8.1.1: Eastern Great Lakes and Hudson Lowlands**: Now mostly cropland, but once was heavily forested with mixed coniferous-deciduous forests. In remaining forests, sugar maple, yellow birch, eastern hemlock, basswood and eastern white pine form the most stable vegetation in the region; beech occurs on warmer sites. Dry sites are dominated by red oak and pine, and eastern white pine and cedar. Wetter sites support red maple, black ash, white spruce, tamarack, and eastern white cedar. • **8.1.3: Northern Appalachian Plateau and Uplands**: Large areas are in forests of Appalachian oak and northern hardwoods. White oak, black oak, hickories, some areas with white pine. Maple, beech, birch. • **8.1.4: North-Central Hardwood Forests:** Oak savanna, oak-hickory forests, maple-basswood forests, northern hardwoods of maple, beech, and birch. • **8.1.5: Driftless Area**: A mosaic of prairie with little bluestem, Indiangrass, and sideoats grama, and forests of bur oak and white oak. In more mesic areas, forests of sugar maple, basswood, and red oak, and riparian forests with elm, river birch, silver maple, and ash. • **8.1.6: Southern Michigan/Northern Indiana Drift Plains**: Oak-hickory forests, northern swamp forests, and beech forests were typical. White oak, red oak, black oak, bitternut hickory, shagbark hickory, sugar maple, beech are dominant tree species. • **8.1.7: Northeastern Coastal Zone**: Appalachian oak forest and Northeastern oak-pine forest are the natural vegetation types. These include white oak, red oak, hickories, white pine, and some maple, beech, birch and hemlock in cooler or more mesic areas. • **8.1.8: Maine/New Brunswick Plains and Hills**: Mixedwood forests composed of closed stands of sugar maple, beech, and yellow birch on upland sites, whereas eastern hemlock, balsam fir, eastern white pine, and white spruce prevail in valleys. In the drier, northern part of the region, white, red and jack pine along with spruce and fir are more common. • **8.1.10: Erie Drift Plain**: Once largely covered by beech-maple forests, mixed oak forests with red oak, white oak, and shagbark hickory, and mixed mesophytic forests with sugar maple, yellow birch, beech, and hemlock. Some elm-ash swamp forests.	• Mesic upland forests are most vulnerable • Fire-adapted communities are least vulnerable
Ozark/Ouachita-Appalachian Forests	• **8.4.1: Ridge and Valley**: Generally, Appalachian oak forest in the north, and oak-hickory-pine forest to the south.	• Fire may accelerate changes in forest composition

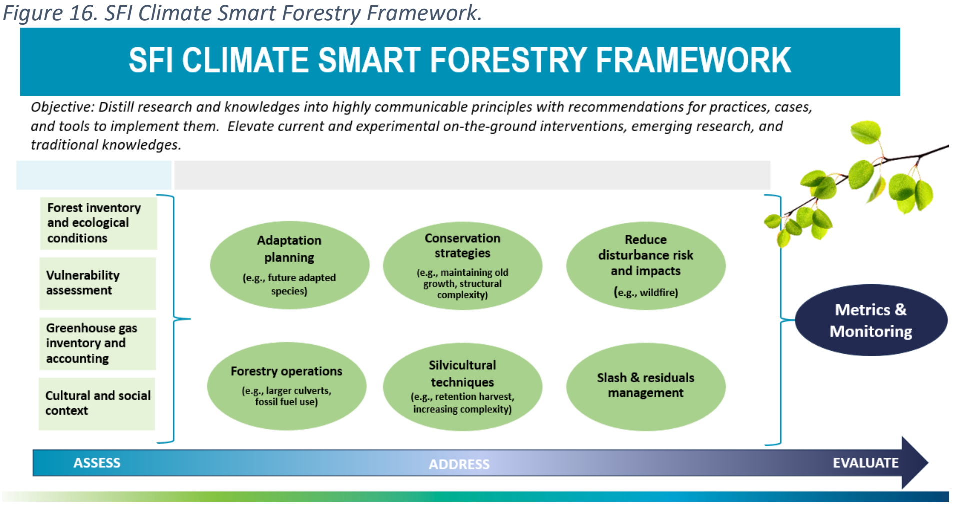
Level II Ecoregion	Level III Ecoregion Description	Climate Change Impacts
Forest Cover Groups • Oak/Hickory • Maple/Beech/Birch	• **8.4.2: Central Appalachians**: Mostly mixed mesophytic forest, once dominated by American chestnut, now with chestnut oak, red maple, white oak, black oak, beech, yellow-poplar, sugar maple, ash, basswood, buckeye, and hemlock. Some areas of Appalachian oak forest, and others with more northern hardwood forests of maple, beech, birch, and hemlock. Small areas of red spruce and hemlock at highest elevations in the north-central portion of the region. • **8.4.3: Western Allegheny Plateau**: The natural vegetation was mostly mixed mesophytic forest; in contrast with the oak–hickory forest of Ecoregion 8.3.3 to the southwest, and to the less diverse beech forest of Ecoregion 8.2.4 to the west. Chestnut oak, red maple, white oak, black oak, beech, yellow-poplar, sugar maple, ash, basswood, buckeye, and hemlock occur. Appalachian oak forests are also in the region. • **8.4.5: Ozark Highlands**: Oak-hickory and oak-hickory-pine forest are typical. Some savannas and tallgrass prairies were once common in the vegetation mosaic. Post oak, blackjack oak, black oak, white oak, hickories, shortleaf pine, little bluestem, Indiangrass, big bluestem, eastern red cedar glades.	• Changes to soil moisture expected to negatively impact regeneration and early growth
Southeastern US Plains Forest Cover Groups • Oak/Hickory • Elm/Ash/Cottonwood • Maple/Beech/Birch	• **8.3.1: Northern Piedmont**: Once was predominantly Appalachian oak forest as compared to the mostly oak-hickory-pine forests of the Piedmont ecoregion (8.3.4) to the southwest. Chestnut oak, white oak, red oak, hickories, ash, elm, and yellow-poplar occur. Eastern redcedar is common on abandoned farmland. Much of the natural vegetation has been removed. • **8.3.2: Interior River Valleys and Hills**: Bottomland deciduous forests and swamp forests were once extensive on poorly-drained, nearly level, lowland sites but most have been replaced by cropland and pastureland. Along the Mississippi, were silver maple, American elm, and green ash, with pin oak, pecan, bur oak, sycamore, honey locust, hickories, and black walnut. Bottomland forests had pin oak, bur oak, Shumard oak, cherrybark oak, overcup oak, swamp white oak, and swamp chestnut oak, and sweetgum. Some upland forests contain mixed oak forests of post oak, southern red oak, white oak, black oak, and shagbark hickory, while mesic sites include beech, yellow-poplar, sugar maple, and northern red oak.	• Mesic upland forests are most vulnerable • Fire-adapted communities are least vulnerable • In the absence of major disturbance, changes to forest composition are expected to occur at a gradual pace
Mississippi Alluvial and Southeast USA Coastal Plains Forest Cover Groups • Loblolly/Shortleaf • Oak/Hickory • Oak/Pine • Oak/Gum/Cypress	• **8.5.4: Atlantic Coastal Pine Barrens**: Mostly pine-oak forests with pitch pine, scarlet oak, black oak; also some shortleaf pine and chestnut oak. In inland areas, historically some mixed oak forests with white and black oaks, American beech, pignut and mockernut hickories, black walnut, tulip tree, and red maple. Most of this has been cleared. Some Atlantic white cedar swamps occur. Near the coast, some dune woodlands composed of American holly, black cherry, red cedar, red maple, pitch pine, hackberry, and sassafras. Some low, shrub thickets of bayberry, beach plum, shadbush, and highbush blueberry. On outer dunes, a sparse cover of dune grass, sea rocket, dusty miller, saltwort, and seaside spurge. The region represents the northern limit for many southern plant species.	• Coastal, lowland conifer, and montane forests are most vulnerable • Oak and pine dominated forests are least vulnerable • Threats to regeneration and recruitment • Forested wetlands, swamps, and marshes vulnerable to rising sea level

Table 2. Overview ecological forest types in the Lake States + Northeast US.

DECISION-MAKING FOR FORESTS AND CLIMATE

The threats posed from climate change to forests can be diverse, with variations across geographies and forest types in terms of risk level, frequency of occurrence, and severity of impacts. Implementation of climate-informed forestry practices across the geographically diverse footprint of SFI-certified forests in North America inherently needs regional approaches to promote climate change adaptation and mitigation, however, there are cross-cutting themes that can shape climate-informed forestry across the entire geography and at multiple scales. For example, managing forests for climate benefits requires key input information like a vulnerability assessment and greenhouse gas inventory. Drawing from this foundational information, forest managers can determine which practices to deploy (e.g., fuel treatments, adaptive management, or conservation strategies). The effects of such interventions can be monitored over time and inform future decisions. See the figure below for more details along with an accompanying table that includes descriptions in Appendix A.

Figure 16. SFI Climate Smart Forestry Framework.



SFI Climate Informed Principles (CLIPs)

In line with the2025-2030 SFI Strategic Direction, SFI has launched a Climate Smart Forestry Initiative that reaches across our Canadian and US landscapes. As part of this, SFI is developing Climate-Informed Principles (CLIPs), which aim to:

- Support systematic decision making for climate-informed interventions,
- Improve understanding of climate implications of different management options,
- Enhance the communicability of climate benefits of forestry interventions, and
- Support certified organizations in meeting the SFI Forest Management standard.

> **Principle**: The vision and direction for sustainable forest management as embodied in the principles of the SFI 2022 Standards.
>
> **Practice(s):** The actual application or use of an idea, belief, or method, as opposed to theories relating to it.
>
> *Source: SFI Standards, Section 14: Definitions (2022)*

Each CLIP will present a principle, its scientific rationale and a list of related practices, potential resources and tools, and case study examples. The SFI CLIPs will leverage and align with existing frameworks from partners like the United States Forest Service, the Adaptive Silviculture for Climate Change (ASCC) network, and Natural Resources Canada (Brandt et al. 2016, Ontl et al. 2020, NRCan 2025, Swanston et al. 2016).

Conclusion

Managing forests in a changing climate requires multiple temporal and spatial scales of information and decision-making. Like tree ring growth on a tree, climate interactions with forests and benefits of forestry interventions accrue over time. This creates immediate challenges for forest managers making decisions in forests with both observed and projected climate changes. These uncertainties mean strategies that work today may fail in the future, requiring that managers balance immediate needs with long-term resilience.

However, there are range of potential interventions and practices that can be applied to reduce uncertainty and pursue net positive outcomes. Practices to improve forest resilience and climate contributions depend on the site and the goals of the individuals managing it. Some actions will result in more stored carbon, others keep current levels steady, and some cause losses to ensure forest health and maintain carbon over time such as thinning forests to reduce wildfire risk or reintroducing fire. Ultimately, the best approach will likely be a mix of strategies that balance immediate outcomes with the forest's future health and resilience.

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Appendix A. Initial SFI Climate Smart Forestry Themes

	Climate Informed Principle	Climate Rational	SFI Standard
ASSESS	Access the best data on **Forest Inventory and Ecological Condition**	Forest inventory and ecological condition data provide critical insight into carbon storage, forest health, and biodiversity. In turn, this information supports efforts to enhance carbon sequestration and increase forest resilience, which are essential for climate change adaptation and mitigation.	SFI FM Objective 1, PM 1.1.4; Objective 4.1.7-8; Objective 9, PM 9.1.2.a-c
ASSESS	Complete a ***Vulnerability Assessment of climate change impacts on forests and forestry operations***	Vulnerability assessments identify regions, ecosystems, or communities most at risk from climate change impacts, enabling targeted adaptation and mitigation strategies. By understanding these vulnerabilities, mitigation efforts can focus on reducing climate-related risks to forests and forestry operations and enhancing resilience to future climate change.	SFI FM Objective 9, PM 9.1.1
ASSESS	Develop a robust **Greenhouse Gas Inventory**	Greenhouse gas inventory and accounting track emissions from forestry activities, providing a clear picture of the sources and quantities of greenhouse gases. These data help identify emission reduction opportunities, set targets, and measure progress toward mitigating climate change.	SFI FM Objective 9, PM 9.2.3
ASSESS	Determine relevant **Social and Cultural Context** including priorities and sources of knowledges	Ensuring management practices reflect the values, traditions, and needs of the people who depend on the forest. Integrating this knowledge helps build community support, protect culturally important species or landscapes, and create strategies that are both ecologically effective and socially acceptable.	SFI FM Objective 1, PM 1.1.6; Objective 5.4.1; Objective 6.1-2; Objective 8
ADDRESS	Develop and implement **Adaptation planning** for Forest Management (e.g. assisted migration, conversion to future adapted species)	Forest adaptation planning involves adjusting forest practices to anticipate and respond to changing climate conditions, such as introducing future-adapted species. This helps maintain carbon sequestration capacity, ecosystem health, and biodiversity and supports both adaptation and mitigation objectives.	SFI FM Objective1.2.2a; 2.5.1; 9.1.2.c

	Climate Informed Principle	Climate Rational	SFI Standard
ADDRESS	Implement climate mitigation and adaptation strategies in **Forestry operations**	Forestry operations contribute to climate change by using fossil fuels and disrupting stored carbon. Adjusting operations can help mitigate climate change and reduce greenhouse gas emissions by reducing fossil fuel use, increasing operational efficiency, and using forest biomass for renewable energy instead of fossil fuels. In addition, forestry operations can be adapted to be resilient to climate change impacts such as shorter winters, severe storms, and wildfire.	SFI FM Objective 9.2.1
	Implement **Conservation strategies** for climate and biodiversity	Forest conservation strategies protect and restore vital ecosystems, enhancing forests' ability to sequester carbon and maintain biodiversity. By reducing deforestation and degradation, these strategies help prevent the release of stored carbon and strengthen the forest's role in climate change mitigation.	SFI FM Objective 4.1.2,4-8; 4.2.2
	Modify **Silvicultural techniques** for adaptation and mitigation outcomes	Forest silvicultural techniques, like retention harvesting, can help maintain forest structure and health, allowing forests to continue sequestering carbon and supporting biodiversity, contributing to climate change mitigation. Maintaining or increasing forest complexity, such as promoting diverse tree species and varied age structures, enhances ecosystem resilience and carbon storage. This approach strengthens forest ability to adapt to climate change, supports biodiversity, and boosts long-term carbon sequestration, aiding in climate change mitigation (Messier 2019).	SFI FM Objective PM 1.1.1.i; PM 2.3.4; PM 2.4.2; PM 9.2.2.a-d
	Taking action to **address and reduce the impacts of climate-driven disturbance** (e.g. catastrophic wildfire)	Activities that reduce the risk of disturbance and impacts from disturbance (such as wildfires) prevent the release of large amounts of carbon stored in forests. Implementing strategies like controlled burns and creating firebreaks, help maintain forest health, resilience, and carbon sequestration capacity, thus supporting climate change mitigation. (Beverly et al. 2021). Post-disturbance forest restoration helps mitigate climate change by enhancing carbon	SFI FM Objective 2.4.1-3; SFI FM Objective 10.1.1-2

	Climate Informed Principle	Climate Rational	SFI Standard
		sequestration and storage, reducing soil erosion, further supporting ecosystem resilience in the face of climate impacts.	
	Minimize waste and ensure efficient utilization in **Slash & Residuals management**	Changes to slash management can mitigate climate change by reducing emissions from slash burning, increasing carbon stored on the landscape, or reducing wildfire risk. Residuals management can mitigate climate change by reducing waste and preventing the release of greenhouse gases from woody waste materials. Repurposing waste materials for energy production, new final products, or recycling decreases fossil fuel use and promotes a circular bioeconomy.	SFI FM Objective 2.3.3; Objective 7.1.1
EVALUTATE	Utilize appropriate **Metrics and Monitoring** to measure impacts of adaptation and mitigation strategies over time	A program that measures and monitors the impact of any action that addresses climate change risk can assess change over time. With these measurements, metrics can be established. Information gathered through a monitoring program can then be used to guide future steps to Assess and Adress climate change impacts.	SFI FM Objective 4.4.2; SFI FM Objective 4.4.1; Objective 9.1.4; 9.2.4

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