REGIONAL CLIMATE CHANGE IMPACTS AND VULNERABILITIES:
NEW ENGLAND AND NORTHERN NEW YORK

The following list of climate change impacts and vulnerabilities is summarized from the *Forest Ecosystem Vulnerability Assessment and Synthesis for New England and Northern New York* (www.nrs.fs.fed.us/pubs/55635).

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ALL FORESTS

Temperatures in New England are projected to increase 3.5 to 8.5 °F by the end of the century, with the greatest warming expected to occur during winter (robust evidence, high agreement).

All global climate models project that temperatures will increase over the next century as a result of continued increases in atmospheric greenhouse gas concentrations.

The growing season in New England is generally expected to increase by 20 days or more by the end of the century, due to fewer days with a minimum temperatures below 32°F (robust evidence, high agreement).

Evidence at both global and local scales indicates that growing seasons have been getting longer, and this trend is projected to become even more pronounced over the next century. Warmer temperatures will result in fewer days with minimum temperatures below 32°F and a shorter freeze-free season.

The winter season will be shorter and milder winters, generally leading to less precipitation falling as snow and reduced snow cover and depth (robust evidence, high agreement).

A variety of models project that winters will become more mild across the Northeast as temperatures increase. Warmer temperatures will cause more winter precipitation to be delivered as rain. Snowfall, snow depth, and snow pack are all expected to be reduced.

Sea levels along the Northeast Atlantic coast are expected to rise by 7 to 23 inches by the end of the century. All global climate models agree that sea level will rise (robust evidence, high agreement).

Sea levels have increased over the past century, and this trend is expected to continue. At the current rate of increase, seal levels could rise nearly 6 inches by the end of the century across the Northeast, which is a conservative estimate. Additional warming is expected to increase sea levels in the Northeast by 7 to 23 inches by the end of the century.

Precipitation patterns will be altered, with projected increases in annual precipitation and potential for reduced growing season precipitation (robust evidence, high agreement).

All global climate models agree that there will be changes in precipitation patterns across the assessment area, but there is large variability among projections of future precipitation. Most climate models project increases in annual preciptation. Seasonally, winter and spring are also generally projected to have increases in precipitation during the next century. Projections of summer and fall precipitation vary more widely, with many models projecting decreased precipitation or only very slight increases.

Intense precipitation events will continue to become more frequent in the Northeast (robust evidence, high agreement).

Heavy precipitation events have increased substantially in number and severity in the across the Northeast over the last century, and many models agree that this trend will continue over the next century. Extreme precipitation events could lead to more frequent or severe flooding and an increase in soil erosion.

Warmer temperatures and altered precipitation will interact to change soil moisture patterns throughout the year, with the potential for both wetter and drier conditions depending on the location and season (medium evidence, high agreement).

Soil moisture is expected to change in response to warmer temperatures and seasonal changes in precipitation. Changes are likely to vary seasonally as well as geographically. More intense and prolonged precipitation events would be expected to create wetter soil conditions, while increased temperatures and less frequent rainfall events would lead to drier soils . Wetter conditions may become for frequent during much of the year, but increased evapotranspiration associated with warmer temperatures and longer rain-free periods between large precipitation events may lead to drier soils during the growing season. Locations where soils and landforms cannot retain the water from intense precipitation events may be more likely to have drier conditions during the growing season.

Forest vegetation may face increased risk of moisture deficit and drought during the growing season (medium evidence, medium agreement)

The uncertainty of future precipitation patterns makes it difficult to determine whether conditions may become dry enough to increase moisture stress for plants in the Northeast. Forests that are affected by moisture deficits and drought are more likely to experience reduced tree vigor or increased mortality, both of which can affect forest composition and structure. Further, warmer temperatures can drive or enhance drought-induced mortality by disrupting plant physiology . This “hotter drought” can also interact with other forest stressors to cause tree death and forest die-off .

Certain insect pests and pathogens will increase in occurrence or become more damaging (medium evidence, high agreement).

The loss of a traditionally cold climate and short growing season in the region may allow some insect pests and pathogens to expand their ranges northward such as hemlock woolly adelgid and southern pine beetle. Forest impacts from insect pests and pathogens are generally more severe in ecosystems that are stressed by drought and other stressors. Basic information is often lacking on the climatic thresholds that trigger increased populations of many forest pests, and our ability to predict the mechanisms of infection, dispersal, and transmission for disease agents remains low. Further, it is not possible to predict which new pests or pathogens will enter the region during the 21st century.

Many invasive plants will increase in extent or abundance (medium evidence, high agreement).

Many invasive species that currently threaten regional forests may benefit directly from projected climate change or benefit from the relatively slower adaptation response of native species. Increases in carbon dioxide increase growth for many plant species, andcChanges in climate may have allowed some invasive plant species to expand their ranges northward, including bush honeysuckle, privet, and kudzu. Some invasive species are tolerant of drought, fire, flooding, and other disturbances and may be at an even greater advantage under future climate conditions. A lack of information regarding the climatic thresholds for many invasive plants limits the ability to predict future spread. Additionally, it is not possible to predict all future nonnative plant species that may enter the assessment area during the 21st century.

Many northern and boreal tree species will face increasing stress across much of the region (medium evidence, high agreement).

Across northern latitudes, warmer temperatures are expected to be more favorable to individuals near the northern extent of their species' range and less favorable to those near the southern extent.Results from climate impact models project a decline in suitable habitat and landscape-level biomass for northern species such as black spruce, red spruce, tamarack, and paper birch, as well as spruce-fir forest communities. These northern species may persist in the region throughout the 21st century, although with declining vigor. Boreal species may remain in areas with favorable soils, management, or landscape features. For example, climate refugia at high elevations or in other favorable microclimates may be buffered from some changes.

Habitat will become more suitable for southern species (medium evidence, high agreement).

Model results project that species currently near their northern range limits in the region may become more abundant and more widespread under a range of climate futures.Results from forest impact models suggest that species such as black cherry, chestnut oak, and yellow-poplar may have increases in both suitable habitat and biomass, and some deciduous forest types have the potential for productivity increases across the assessment area. It is important to note that forest communities will not be influenced only by shifts in habitat ranges, but also by species' ability to actually migrate and establish in new areas. Additionally, warmer climates are also likely to allow for range expansions and increased impacts from a variety of biological stressors, including insect pests, forest diseases, and invasive plant species.

Forest composition will change across the landscape (medium evidence, high agreement).

Changes in distribution for individual species is expected to lead to shifts in forest assemblages and tree species may rearrange into novel communities.Major shifts in overstory species composition may not be observable until well into the 21st century because of the long timeframes associated with many ecosystem processes and responses to climate change. These shifts, however, may become more apparent along ecotonal boundaries where boreal species reach the southern edge of their range . Major stand-replacing disturbance events, forest management, and human activities all have the potential to strongly influence how forests change in response to changing climatic conditions. Additionally, non-native species may also be to take advantage of shifting forest communities and unoccupied niches if native forest species are limited.

Shifts in forest composition will take at least several decades to occur in the absence of major disturbance (medium evidence, medium agreement).

Model projections that show future changes in habitat for many tree species do not account for migration constraints, longevity of current species, or differences among age classes. Because mature trees are expected to remain on the landscape, and recruitment of new species is expected to be limited, major shifts in species composition will not likely be observed by the middle of the century, except along ecotonal boundaries and in areas that undergo major stand-replacing disturbance events. However, climate change is may increase the intensity, scope, or frequency of some stand-replacing events such as windstorms, ice storms, and insect outbreaks, possibly promoting rapid shifts in species composition where these events occur.

Conditions affecting tree regeneration and recruitment will change (medium evidence, high agreement).

limate change impacts are more likely to be observed in seedlings and early growth than in mature trees. Temperature and moisture requirements for seed dormancy and germination are often much more critical than habitat requirements of an adult tree. Predicted changes in temperature, precipitation, growing season onset, and soil moisture may alter the duration or manifestation of germination conditions, and individual species will be uniquely affected. For species with high dispersal capabilities, these changes may result in redistribution on the landscape as seeds germinate only where conditions are met. Other species may fail to regenerate under altered future conditions, or may germinate without having optimal conditions for development. After establishment, saplings are still more sensitive than mature trees to disturbances such as drought, heat stress, fire, flooding, and herbivory. Changes in tree regeneration and recruitment will have long-term effects on forest composition and structure.

Forest productivity will increase during the next several decades in the absence of significant stressors (medium evidence, medium agreement).

Continued forest recovery and succession following historical disturbance is generally expected to be the dominant driver of forest growth for the next several decades. Changes in forest productivity due to climate change are likely to spatially variable. Projections point to increased tree growth and ecosystem carbon sequestration under warmer temperatures and longer growing seasons where soil moisture is not limiting. Many studies also point to the beneficial effects of carbon dioxide fertilization on forest productivity, although this effect can be dampened by nutrient and water limitations, ozone exposure, and tree age. Increasing disturbance, such as fires, windstorms, and pest outbreaks, and changes in land use could substantially reduce forest productivity, but are beyond the scope of most modeling efforts.

Low-diversity systems are at greater risk from climate change (medium evidence, high agreement).

Studies have consistently shown that diverse systems have exhibited greater resilience to extreme environmental conditions and greater potential to recover from disturbance than less diverse communities. This relationship makes less diverse communities inherently more susceptible to future changes and stressors. The diversity of potential responses of a system to environmental change (response diversity), is a critical component of ecosystem resilience. Response diversity is generally reduced in less diverse ecological systems. Genetic diversity within species is also critical for the ability of populations to adapt to climate change, because species with high genetic variation have better odds of producing individuals that can withstand extreme events and adapt to changes over time.

Species in fragmented landscapes will have less opportunity to migrate in response to climate change (limited evidence, high agreement).

Habitat fragmentation can hinder the ability of tree species to migrate to more suitable habitat on the landscape, especially if the surrounding area is nonforested. Modeling results indicate that mean centers of suitable habitat for tree species will migrate between 60 and 350 miles by the year 2100 under a high emissions scenario and between 30 and 250 miles under milder climate change scenarios. Based on data gathered for seedling distributions, it has been estimated that many northern tree species could possibly migrate northward at a rate of 60 miles per century. Fragmentation makes this disparity even more challenging, because the landscape is essentially less permeable to migration.

Systems that are limited to particular environments will have less opportunity to migrate in response to climate change (limited evidence, high agreement).

Some species and forest types are confined to particular habitats on the landscape, whether through requirements for hydrologic regimes, soil types, or other reasons. Similar to species occurring in fragmented landscapes, isolated species and systems face additional barriers to migration. Widespread species may also have particular habitat requirements. For example, sugar maple is often limited to soils that are rich in nutrients like calcium, so this species may actually have less available suitable habitat than might be projected solely from temperature and precipitation patterns. Riparian forests are not expected to be able to migrate to upland areas because many species depend on seasonal flood dynamics for regeneration and a competitive advantage. Similarly, lowland conifer swamps contain a unique mix of species that are adapted to low pH values, peat soils, and particular water table regimes. These species face additional challenges in migration compared to more-widespread species with broad ecological tolerances.

Systems that are more tolerant of disturbance have less risk of declining on the landscape (medium evidence, high agreement).

Disturbances such as wildfire, flooding, and pest outbreaks are expected to increase in the future. Forests that are adapted to gap-phase disturbances, with stand-replacing events occurring over hundreds or thousands of years, may be less tolerant of more frequent widespread disturbances. Mesic hardwood forests can create conditions that could buffer against fire and drought to some extent, but these systems are not expected to do well if soil moisture declines significantly. Forest systems that are more tolerant of drought, flooding, or fire are expected to be better able to withstand climate-driven disturbances. This principle holds true only to a given point, because it is also possible for disturbance-adapted systems to experience too much disruption. For example, dry pine forests and woodlands might benefit from drier conditions with more frequent fire, but these systems might also convert to savannas or open grasslands if fire becomes too frequent or drought becomes too severe.

MONTANE SPRUCE-FIR

Montane spruce-fir forests may lose suitable habitat to other forest types as temperatures and growing seasons increase.

his type is strongly associated with the coldest and most extreme climates. Reductions in snowpack may reduce soil moisture availability in the spring or increase the probability of root damage during freeze-thaw events. Increases in extreme storm events may lead to enhanced tree mortality from disturbance. At the same time, this type does have some adaptive capacity due to its ability to out-compete many other species, its capacity to persist on cold and nutrient-poor sites, and its recent signs of recovering from past stressors such as acid rain and logging that previously reduced its extent.

Many of the dominant tree species are expected to decline by the end of the century, including red spruce and balsam fir.

These are northern species near their southern range limits in New England and northern New York. Multiple forest impact models tend to agree that these species are more likely to decline in suitable habitat and biomass across a range of climate scenarios by the end of the century.

Montane spruce-fir forests are especially vulnerable at lower elevations or more southern latitudes.

The presence of this forest at high latitudes and elevations presents little opportunity for the community to move to new habitats. This is particularly true in southern New England, where this community is highly fragmented and exists primarily on isolated mountaintops. A temperature increase of 5 °F could eliminate all habitat from Massachusetts. Less substantial impacts are projected to be less in the northern part of the assessment area, such as in Maine, where the dominant species are expected to persist in some areas.

Warmer temperatures may allow balsam woolly adelgid to increase, while dampening the effects of the eastern spruce budworm in the northern New England and New York.

Many insect species are limited by extremely cold temperatures, and evidence suggests that several insect species may increase in a warmer climate, including the balsam woolly adelgid. At the same time, the native spruce budworm may be reduced under the warmer conditions expected in the future as its range shifts farther northward into Canada.

Changes in herbivore populations may also have substantial effects on forest growth and composition.

Changes in snowfall amount and duration throughout the assessment area may change the wintertime foraging behavior for herbivores such as moose, white-tailed deer, and snowshoe hare. Moose are expected to be negatively affected by numerous changes in the future, including heat stress and increased parasitism from winter ticks. In contrast, deer may benefit in many parts of the region as warmer winter temperatures and reduced snow depth increase access to winter forage. Where deer populations expand into areas currently dominated by moose, deer may spread the brainworm parasite, which does not affect deer but causes mortality in moose.

LOW-ELEVATION SPRUCE-FIR

Climate change may lead to decreased habitat or altered species composition in low-elevation spruce-fir forests.

This forest type is strongly associated with cold climates and is widespread across northern New England and New York. These forests may be particularly susceptible to warmer temperatures and longer growing seasons. The future climate is expected to be less suitable for the northern and boreal conifer species, while more favorable for many hardwood species that are a component of these forests. Enhanced stress and changes in competitive relationships among tree species are likely to alter forest composition. Forest vulnerability is expected to vary widely across the assessment area, with forests in some locations undergoing substantial changes.

Many of the dominant tree species are expected to decline by the end of the century, including red spruce and balsam fir.

These are northern species near their southern range limits in New England and northern New York. Multiple forest impact models tend to agree that these species are more likely to decline in suitable habitat and biomass across a range of climate scenarios by the end of the century. Impacts from climate change are projected to be less severe in the northern part of the assessment area, such as in Maine, allowing the dominant species to persist in some areas.

Some tree species may be more likley to persist or become more competative through the end of the century , including white pine, red maple, and some northern hardwood species.

These species all tolerate a fairly wide range of conditions. Multiple forest impact models tend to agree that these species are more likely to increase or remain stable in suitable habitat and biomass under a mild climate scenario, but these species may fare worse under a hotter, drier future climate scenario.

Warmer temperatures may allow balsam woolly adelgid to increase, while dampening the effects of the eastern spruce budworm in the northern New England and New York.

Many insect species are limited by extremely cold temperatures, and evidence suggests that several insect species may increase in a warmer climate, including the balsam woolly adelgid. At the same time, the native spruce budworm may be reduced under the warmer conditions expected in the future as its range shifts farther northward into Canada.

Changes in herbivore populations may also have substantial effects on forest growth and composition.

Changes in snowfall amount and duration throughout the assessment area may change the wintertime foraging behavior for herbivores such as moose, white-tailed deer, and snowshoe hare. Moose are expected to be negatively affected by numerous changes in the future, including heat stress and increased parasitism from winter ticks. In contrast, deer may benefit in many parts of the region as warmer winter temperatures and reduced snow depth increase access to winter forage. Where deer populations expand into areas currently dominated by moose, deer may spread the brainworm parasite, which does not affect deer but causes mortality in moose.

Low species diversity may reduce the ability of forests to adapt to climate change.

These forests tend to have relatively low diversity and be dominated by a relatively small number of northern and boreal species. Forests with lower species diversity may be more vulnerable. Further, management often favors the hardwood component in these forests, and additional stress or disturbance may continue to shift forest composition toward hardwood species.

Low-elevation spruce-fir forests are widely distributed across a variety of sites, increasing adaptive capacity.

These forests are also prevalent across the region on a wide variety of soils and landforms. Not all areas are expected to be affected equally, and in general, areas that are north-facing, at higher elevations, or are farther north in the region are expected to undergo less change and may continue to support spruce-fir forest in the future. At the same time, spruce-fir forests that are farther south may have a reduced capacity to cope with future conditions, particularly where past land use or management has already impaired the system.

LOWLAND MIXED CONIFER

Lowland conifer forests may have limited tolerance to changes in precipitation and water tables.

Lowland conifer forests function in a relatively narrow window of hydrologic and soil conditions. These conditions are expected to be perturbed in a variety of ways, including through increased severe precipitation events and flooding, increased risk of drought, and changes in the water table or relative influence of precipitation versus groundwater. In general, drier conditions would be expected to have a greater negative impact than excess moisture. Organic soils could decompose more quickly under warmer and drier conditions. Drier conditions in peatland systems could also impair tree regeneration or alter tree species composition toward the few hardwood species found in these areas. Wetland communities may be affected by increased storm events because shallow-rooted trees on saturated soils may be more prone to windthrow.

Organic soils may be more vulnerable to change in lowland mixed conifer forests.

Sphagnum moss, the primary source of peat in these systems, may be susceptible to warmer conditions. Warmer growing seasons may increase evapotranspiration rates and reduce the rate of peat accumulation in these forests, and peat layers may begin to erode as decomposition rates increase.

Many of the dominant tree species are expected to decline by the end of the century, including black spruce, red spruce, northern-white cedar and balsam fir.

These are northern species near their southern range limits in New England and northern New York. Multiple forest impact models tend to agree that these species are more likely to decline in suitable habitat and biomass across a range of climate scenarios by the end of the century. Impacts from climate change are projected to be less severe in the northern part of the assessment area, such as in Maine, allowing the dominant species to persist in some areas. Similarly, forests dominated by species with more southerly distributions, such as Atlantic white-cedar, may be less susceptible to changes in climate.

Warmer temperatures may allow balsam and hemlock woolly adelgid to increase, while dampening the effects of the eastern spruce budworm in the northern New England and New York.

Many insect species are limited by extremely cold temperatures, and evidence suggests that several insect species may increase in a warmer climate, including the balsam woolly adelgid and hemlock woolly adelgid. At the same time, the native spruce budworm may be reduced under the warmer conditions expected in the future as its range shifts farther northward into Canada.

Changes in herbivore populations may also have substantial effects on forest growth and composition.

Changes in snowfall amount and duration throughout the assessment area may change the wintertime foraging behavior for herbivores such as moose, white-tailed deer, and snowshoe hare. Moose are expected to be negatively affected by numerous changes in the future, including heat stress and increased parasitism from winter ticks. In contrast, deer may benefit in many parts of the region as warmer winter temperatures and reduced snow depth increase access to winter forage. Where deer populations expand into areas currently dominated by moose, deer may spread the brainworm parasite, which does not affect deer but causes mortality in moose. Expanded deer herbivory could affect recruitment of northern white-cedar, especially where snowpack and winter severity are reduced.

LOWLAND AND RIPARIAN FOREST

Lowland and riparian forests may have limited tolerance to changes in precipitation and water tables.

Climate change has the potential to substantially alter the hydrologic regimes in lowland and riparian systems. These hardwood forests are adapted to annual and seasonal water table fluctuations; however, more intense and variable precipitation events may present risks to this system through excessive flooding, inundation, streambank erosion, or prolonged droughts between heavy precipitation events. Extended droughts could cause significant damage to shallow-rooted species, but increased winter and spring precipitation may buffer summer droughts in low-lying areas on the landscape. Groundwater-fed systems may be less sensitive where cooler, wetter soil conditions can be maintained over time. There is substantial uncertainty regarding future precipitation patterns, and impacts may be greater in areas that are subject to changes in water level, such as vernal pools, floodplain systems, and wetlands.

Many tree species could tolerate limited increases in flooding and drought under climate change.

Many species in riparian and lowland forests can tolerate intermittent wet and dry conditions, and they can tolerate periodic floods and moisture stress. Extended droughts would cause significant damage to shallow-rooted species, but increased winter and spring precipitation could buffer summer droughts in low-lying areas on the landscape.

Many of the dominant tree species are projected to have similar or increased habitat, including American elm, eastern cottonwood, and silver maple.

This forest system contains many tree species that are tolerant of warmer temperatures and are located in the central to northern portion of their range in New England and northern New York. Multiple forest impact models tend to agree that these species are likely to increase in suitable habitat and biomass across a range of climate scenarios by the end of the century. Species such as American elm, eastern cottonwood, and silver maple are expected to gain suitable habitat across the assessment area under a range of climate futures.

Some tree species in lowland and riparian hardwood forests are expected to decline by the end of the century, including northern white-cedar, balsam fir, and paper birch.

Multiple forest impact models tend to agree that these species are likely to decline in suitable habitat and biomass across a range of climate scenarios by the end of the century. Many of these species are near their southern range limits in New England and northern New York. Species in these systems that are expected to undergo decreased habitat suitability include northern white-cedar, balsam fir, and paper birch.

Invasive species such as Japanese stiltgrass and buckthorn are expected to become more problematic under climate change.

There are many invasive plant species, insect pests, and forest diseases that have negative impacts on lowland and riparian hardwoods, many of which are expected to increase through the direct and indirect effects of climate change. Invasive species such as Japanese stiltgrass and buckthorn are existing threats to these forests, and invasive species are expected to increase in abundance under climate change, particularly where forests are disturbed.

Insect pests and forests diseases could become more problematic these forests under a warmer climate.

Studies suggest that insect pests may increase in northern forests due to increased metabolic activity in active periods and increased winter survival. Many insect species are limited by extremely cold temperatures, and evidence suggests that several insect species may increase in a warmer climate, including the hemlock woolly adelgid. Trees stressed by heat, drought, or disturbance are also typically more vulnerable to insect pests and diseases. Emerald ash borer and Dutch elm disease are expected to continue to limit ash and elm species.

NORTHERN HARDWOOD

Changes in herbivore populations may also have substantial effects on forest growth and composition in northern hardwood forests.

Changes in snowfall amount and duration throughout the assessment area may change the wintertime foraging behavior for herbivores such as moose, white-tailed deer, and snowshoe hare. Where present, moose are expected to be negatively affected by numerous changes in the future, including heat stress and increased parasitism from winter ticks. In contrast, deer may benefit in many parts of the region as warmer winter temperatures and reduced snow depth increase access to winter forage. Where deer populations expand into areas currently dominated by moose, deer may spread the brainworm parasite, which does not affect deer but causes mortality in moose.

High levels of diversity may increase the ability of forests to adapt to climate change.

These forests tend to have fairly high species diversity, which may increase the number of ways in which the ecosystem can adjust to changing conditions while maintaining important ecosystem functions. Many tree species are often present, representing a broad mix of tolerances and reproductive strategies.

Insect pests and forests diseases could become more problematic in northern hardwood forests under a warmer climate.

Climate change may amplify several major stressors that are already affecting this forest system. Several pests, including beech bark disease and hemlock woolly adelgid, currently affect many forests. Studies suggest that insect pests may increase in northern forests due to increased metabolic activity in active periods and increased winter survival. Insect pests, such as the hemlock woolly adelgid, are expected to cause more frequent and severe damage under climate change. Pests such as Asian longhorned beetle may present new risks as they expand, and new pests present unknown risks. Trees stressed by heat, drought, or disturbance are also typically more vulnerable to insect pests and diseases.

Invasive species such as buckthorn, honeysuckle, and garlic mustard are expected to become more problematic under climate change.

There are many invasive plant species, insect pests, and forest diseases that have negative impacts on central hardwood-pine forests, many of which are expected to increase through the direct and indirect effects of climate change. Invasive species such as buckthorn, honeysuckle, and garlic mustard are already threats to some forests, and invasive species are expected to increase in abundance under climate change, particularly where forests are disturbed.

Northern hardwood forests are widely distributed across a variety of sites, increasing adaptive capacity.

These forests are also prevalent across the region on a wide variety of soils and landforms. Not all areas are expected to be affected equally, and in general, areas that are north-facing, at higher elevations, or are farther north in the region are expected to undergo less change and may continue to support northern hardwoods in the future.

In these areas, it is also possible that sites that are currently too wet or cold to support northern hardwoods may become suitable over time and be colonized by these species. At the same time, northern hardwood forests that are farther south may have a reduced capacity to cope with future conditions, particularly where past land use, land development, fragmentation, invasive species, or other factors have already impaired the system.

Several dominant tree species are at risk of decling by the end of the century, including red spruce and balsam fir.

Multiple forest impact models tend to agree that several species are more likely to decline in suitable habitat and biomass across a range of climate scenarios by the end of the century, including red spruce and balsam fir. These are northern species near their southern range limits in New England and northern New York. Eastern hemlock, quaking aspen, yellow birch, and to a lesser extent, sugar maple, have substantial projected declines in habitat suitability and biomass under a hotter and drier climate scenario, suggesting that greater changes in climate will lead to more-negative consequences. Impacts from climate change are projected to be less severe in the northern part of the assessment area, allowing the dominant species to persist in some areas.

Some tree species may be more likley to persist or increase through the end of the century , such as red maple.

These species all tolerate a fairly wide range of conditions. Multiple forest impact models tend to agree that these species are more likely to increase or remain stable in suitable habitat and biomass under a mild climate scenario, but these species may fare worse under a hotter, drier future climate scenario. Red maple is not modeled to change substantially, but its current abundance, biological traits, and ability to respond to disturbance suggest that it may increase. Common associate species, such as American beech, American elm, and white ash, may not be able to increase as much as projected due to substantial impacts from insects and diseases. Some southerly-distributed hardwood species that are currently infrequent or absent in the assessment area are projected to gain additional suitable habitat, including white oak, sassafras, and yellow-poplar.

TRANSITION HARDWOOD

High levels of diversity in transition hardwood forests may increase the ability of forests to adapt to climate change.

These forests tend to have fairly high species diversity, which may increase the number of ways in which the ecosystem can adjust to changing conditions while maintaining important ecosystem functions. These forests are also found across a variety of landforms and local conditions and contain a mix of shade and moisture tolerances and reproductive strategies (e.g., seeding, sprouting). Species composition may change over time to reflect future conditions, and may ultimately transition to oak-pine forests in some locations. At the same time This suggests the potential for changes in the relative abundance of different species within this community, altering the “character” of forest composition.

Insect pests and forests diseases could become more problematic in transition hardwood forests under a warmer climate.

Climate change may amplify several major stressors that are already affecting this forest system. Several pests, including beech bark disease, gypsy moth, and hemlock woolly adelgid, currently affect many forests, and there is a disproportionately large impact on forest systems where hemlock is lost. Studies suggest that insect pests may increase in northern forests due to increased metabolic activity in active periods and increased winter survival. Insect pests, such as the hemlock woolly adelgid, are expected to cause more frequent and severe damage under climate change. Pests such as Asian longhorned beetle may present new risks as they expand, and new pests present unknown risks. Trees stressed by heat, drought, or disturbance are also typically more vulnerable to insect pests and diseases.

Changes in herbivore populations may also have substantial effects on forest growth and composition.

White-tailed deer populations may increase with warmer winters, which may hinder regeneration in this forest type. Herbivory may also limit the expansion of this forest type into new areas.

Invasive species such as buckthorn, honeysuckle, and garlic mustard are expected to become more problematic under climate change.

There are many invasive plant species, insect pests, and forest diseases that have negative impacts on central hardwood-pine forests, many of which are expected to increase through the direct and indirect effects of climate change. Invasive species such as buckthorn, honeysuckle, and garlic mustard are already threats to some forests, and invasive species are expected to increase in abundance under climate change, particularly where forests are disturbed.

Previous human influences, including fragmentation, may have reduced the adaptive capacity of some transition hardwood forests.

This forest type is often located in areas that have (or have had) higher levels of human disturbance; fragmentation, invasive species, or other stressors may have reduced the capacity of forests in some locations to cope with changing conditions. Further, trends toward more mesic tree species and a lack of future-adapted regeneration species like oak may reduce adaptive capacity.

Some of the common tree species in transition hardwood forests are projected to have similar or increased habitat, including black cherry and yellow-poplar.

This forest system contains several tree species that are tolerant of warmer temperatures and are located in the central to northern portion of their range in New England and northern New York. Multiple forest impact models tend to agree that these species, such as sugar maple and eastern white pine are likely to increase or remain stable in suitable habitat and biomass under a mild climate scenario but may fare worse under a hotter, drier future climate scenario. Several species that are at the middle or northern edge of their range are present in lower abundances and may increase, such as black cherry and yellow poplar. Red maple is not modeled to change substantially, but its current abundance, biological traits, and ability to respond to disturbance suggest that it may increase.

Some tree species may decline by the end of the century, including red spruce and balsam fir.

These are northern species near their southern range limits in New England and northern New York. Multiple forest impact models tend to agree that these species are more likely to decline in suitable habitat and biomass across a range of climate scenarios by the end of the century.

CENTRAL HARDWOOD-PINE

Central hardwood-pine forests are widely distributed across a variety of sites, increasing adaptive capacity.

These forests are also prevalent across the region on a wide variety of soils and landforms. In general, areas that are north-facing, at higher elevations, or are farther north in the region are expected to undergo less change compared to forests in warmer, drier, or more southerly locations.

Changes in herbivore populations may also have substantial effects on forest growth and composition.

White-tailed deer populations may increase with warmer winters, which may hinder regeneration in this forest type. Herbivory may also limit the expansion of this forest type into new areas.

High levels of diversity may increase the ability of forests to adapt to climate change.

These forests tend to have fairly high species diversity. These forests also contain a variety of oak and hickory species with diverse traits, including drought tolerance and varied reproductive strategies such as seeding and sprouting. This diversity may increase the number of ways in which the ecosystem can adjust to changing conditions while maintaining important ecosystem functions.

Insect pests and forests diseases could become more problematic in central hardwood-pine forests under a warmer climate.

Studies suggest that insect pests may increase in northern forests due to increased metabolic activity in active periods and increased winter survival. Insect pests, such as winter moth and southern pine beetle are expected to cause more frequent and severe damage under climate change, and new pests present unknown risks. Trees stressed by heat, drought, or disturbance are also typically more vulnerable to insect pests and diseases.

Invasive species such as buckthorn, honeysuckle, and garlic mustard are expected to become more problematic under climate change.

here are many invasive plant species, insect pests, and forest diseases that have negative impacts on central hardwood-pine forests, many of which are expected to increase through the direct and indirect effects of climate change. Invasive species such as buckthorn, honeysuckle, and garlic mustard are existing threats to these forests, and invasive species are expected to increase in abundance under climate change, particularly where forests are disturbed.

Many of the dominant tree species in central hardwood-pine forests are projected to have similar or increased habitat, including black, chestnut, scarlet, and white oak and pignut and shagbark hickory .

This forest system contains many tree species that are tolerant of warmer temperatures and are located in the central to northern portion of their range in New England and northern New York. Multiple forest impact models tend to agree that a large number of tree species found in these locations are generally expected to be able to persist on these sites into the future, including black, chestnut, scarlet, and white oak and pignut and shagbark hickory. These species may also potentially expand to new areas as conditions become suitable. At the same time, when extremely hot and dry conditions prevail, species establishment may be impaired for these trees in southern and coastal New England.

Previous human influences, including fragmentation and fire suppression, may have reduced the adaptive capacity of some central hardwood-pine forests.

This forest type is often found in areas that have a high degree of past or current human disturbance, and fragmentation, invasive species, or other threats that can reduce the adaptive capacity of particular locations. Many forests are located in fragmented landscapes. A history of fire suppression and reduced light reaching the forest floor has facilitated a shift to more mesic conditions and associated hardwood species (e.g., red and sugar maple, American beech, tuliptree). In many forests, regeneration of drought-tolerant oak and hickory trees is currently reduced due to fire suppression and competition from more shade-tolerant mesic species.

Some tree species in central hardwood-pine forests are projected to have reduced habitat in the future under scenarios of greater warming and change.

Multiple forest impact models tend to agree that many northern tree species are likely to decline in suitable habitat and biomass across by the end of the century. Some species, such as northern red oak and eastern white pine may persist under slightly warmed conditions, but are projected to have more substantial declines under scenarios projecting hotter and drier conditions.

PITCH PINE-SCRUB OAK

Previous human influences, including fragmentation and fire suppression, may have reduced the adaptive capacity of some forests.

This forest type is often found in areas that have a high degree of past or current human disturbance, and fragmentation, invasive species, or other threats that can reduce the adaptive capacity of particular locations. Many forests are located in fragmented landscapes. A history of fire suppression and reduced light reaching the forest floor has facilitated a shift to more mesic conditions and associated hardwood species (e.g., red and sugar maple, American beech, tuliptree). In many forests, regeneration of drought-tolerant oak and hickory trees is currently reduced due to fire suppression and competition from more shade-tolerant mesic species.

Low species diversity may reduce the ability of forests to adapt to climate change.

These forests tend to be dominated by two species: pitch pine and scrub oak. Forests with lower species diversity may be more vulnerable where one or a few species are particularly affected by changes in climate.

The dominant tree species, pitch pine and scrub oak, are expected to persist through the end of the century.

Considering the range of possible climate futures, scrub oak is projected to have little change in future habitat and pitch pine habitat may increase slightly. Likewise, other oak species that are minor components of this forest system are also generally expected to have similar or increased habitat and growth in the future. . Because these species are present on dry, low-nutrient sites, they may not face substantial competition from other species.

Insect pests and forests diseases could become more problematic these forests under a warmer climate.

Insect pests and diseases affecting this forest type, such as red pine shoot blight, may become more damaging under a warmer climate. Additionally, species such as southern pine beetle have been observed expanding northward, and these movements are expected to continue due to higher temperatures.

These forests may be tolerant of increased moisture stress due to climate change.

Warmer temperatures are generally not expected to have major effects on this community because it is at the northern extent of its range in the region and occurs on particularly warm and dry sites. It is uncertain how climate change would affect the low-lying frost pockets common in this forest type, which generally favor cold-hardy scrub oak. Over the long-term, substantially warmer temperatures could reduce the occurrence of these unique microclimates. Although pitch pine-scrub oak forests are generally expected to benefit under warmer and drier conditions, the close association of this forest type with sandy, nutrient-poor soils suggests that it may be unable to expand its extent appreciably.

These forests may be tolerant of increased wildfire activity due to climate change.

Fire is the dominant natural disturbance in this system. Fire suppression has created denser forests in many locations, and increases in fire occurrence would generally be expected to favor pitch pine over more mesic oak and hardwood species that encroach in the absence of fire. However, it is unclear how human response to increased fire risk from climate change may alter future forest fire conditions.