CLIMATE IMPACTS – CENTRAL APPALACHIANS

From the Adaptation Workbook: www.adaptationworkbook.org/explore-impacts

This area covers almost 29 million acres in eastern Ohio, West Virginia, and western Maryland within Ecological Provinces M221 (Central Appalachian Broadleaf Forest) and 221 (Eastern Broadleaf Forest – Oceanic) of the National Hierarchical Framework of Ecological Units. Provinces are broad geographic areas that share similar coarse features, such as climate, glacial history, and vegetation types, a landscape comprised of some of the oldest and most biologically diverse forests in North America.

Summary of Climate Impacts (details and citations on subsequent pages):

Mean annual temperatures in the Central Appalachians will increase between nearly 2 and 8 °F by the end of the century, with more warming during summer and fall than winter and spring.

Winter snowpack in the Central Appalachians will be reduced from 20-50% by the end of the century.

Extremely hot days (over 95°F) will become more common in the Central Appalachians throughout the next century, as will multi-day heat waves.

The Central Appalachians growing season will increase by 30 to 70 days by the end of the century.

Precipitation patterns will be altered in the Central Appalachians, with projected increases in total precipitation during spring and even greater decreases in total preciptation during summer and fall.

Intense precipitation events will continue to become more frequent across the Central Appalachians.

The winter season will be shorter and milder winters in the Central Appalachians, with less precipitation falling as snow and reduced snow cover and depth.

Soil moisture patterns will change in the Central Appalachians, with drier soil conditions later in the growing season.

Climate change impacts on forest conditions will increase fire risks in the Central Appalachians by the end of the century

Many invasive species, insect pests, and pathogens in the Central Appalachians will increase or become more damaging.

Suitable habitat for northern species will decline in the Central Appalachians.

Suitable habitat for southern species will increase in the Central Appalachians.

Seedlings are expected to be more vulnerable than mature trees to changes in temperature, moisture, and other seedbed and early growth requirements in the Central Appalachians.

Low-diversity systems in the Central Appalachians are at greater risk from climate change.

Species in Central Appalachian fragmented landscapes will have less opportunity to migrate in response to climate change.

Central Appalachians systems that are limited by hydrologic regime or geological features may be topographically constrained.

Central Appalachians systems that are more tolerant of disturbance have less risk of declining on the landscape

Ecosystems occupying habitat in areas of high landscape complexity have more opportunities for persistence in pockets of refugia in the Central Appalachians.

Central Appalachians Forest Ecosystem Vulnerability Assessment and Synthesis

Video presentation: Central Appalachians Vulnerability Assessment

See forest type vulnerability on next page.

Table 23.—Vulnerability determination summaries for forest ecosystems considered in this assessment

Forest ecosystem	Potential impacts	Adaptive capacity	Vulnerability	Evidence	Agreement
Appalachian (hemlock)/ northern hardwood forest	Negative	Low-Moderate	High	Medium	Medium
Dry calcareous forest, woodland, and glade	Neutral-Negative	Low-Moderate	Moderate-High	Limited-Medium	Medium
Dry oak and oak/pine forest and woodland	Positive	Moderate-High	Low	Medium	Medium-High
Dry/mesic oak forest	Positive-Neutral	High	Low- Moderate	Medium	Medium-High
Large stream floodplain and riparian forest	Negative	Low	High	Medium	Medium
Mixed mesophytic and cove forest	Neutral-Negative	Moderate-High	Moderate	Limited-Medium	Medium
North-central interior beech/maple forest	Neutral	Moderate	Moderate	Limited-Medium	Medium
Small stream riparian forest	Negative	Moderate	Moderate-High	Medium	Medium
Spruce/fir forest	Negative	Moderate	High	Limited-Medium	Medium

Table source: P. Butler, L. Iverson, and others. 2015. Central Appalachians Forest Ecosystem Vulnerability Assessment. USDA Forest Service Northern Research Station.

Mean annual temperatures in the Central Appalachians will increase between nearly 2 and 8 °F by the end of the century, with more warming during summer and fall than winter and spring.

All global climate models project that temperatures will increase with continued increases in atmospheric greenhouse gas concentrations.

P. Butler, L. Iverson, and others. 2015. Central Appalachians Forest Ecosystem Vulnerability Assessment. USDA Forest Service Northern Research Station.

Winter snowpack in the Central Appalachians will be reduced from 20-50% by the end of the century.

Regional snow cover is projected to decrease by 1.2 to 4 inches by the end of the century. A variety of models project that across the Eastern US, more winter precipitation will be delivered as rain, more snow will melt between snowfall events, and the snowpack will not be as deep or consistent. In areas near Lake Erie, projected increases in air temperatures are expected to drive decreases in ice cover duration and extent on the Great Lakes, potentially allowing increased winter evaporation and the potential for increased lake-effect snow.

P. Butler, L. Iverson, and others. 2015. Central Appalachians Forest Ecosystem Vulnerability Assessment. USDA Forest Service Northern Research Station.

Extremely hot days (over 95°F) will become more common in the Central Appalachians throughout the next century, as will multi-day heat waves.

Studies from across the Midwest and Northeast consistently project 20 to 30 more hot days per year by the end of the century. The frequency of multi-day heat waves is also projected to increase by 3 to 6 days. The frequency of cold days and cold nights in the Central Appalachians is also projected to decrease by 12 to 15 days by the end of the century.

P. Butler, L. Iverson, and others. 2015. Central Appalachians Forest Ecosystem Vulnerability Assessment. USDA Forest Service Northern Research Station.

The Central Appalachians growing season will increase by 30 to 70 days by the end of the century.

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. As seasons shift so that spring arrives earlier and fall extends later into the year, phenology may shift for plant species that rely on temperature as a cue for the timing of leaf-out, reproductive maturation, and other developmental processes. Longer growing seasons could also result in greater growth and productivity of trees and other vegetation, but only if balanced by available water and nutrients.

P. Butler, L. Iverson, and others. 2015. Central Appalachians Forest Ecosystem Vulnerability Assessment. USDA Forest Service Northern Research Station.

Precipitation patterns will be altered in the Central Appalachians, with projected increases in total precipitation during spring and even greater decreases in total preciptation during summer and fall.

All global climate models agree that there will be changes in precipitation patterns across the Central Appalachians, but there is large variability among projections of future precipitation. Most climate models project increases in annual precipitation of up to 2 inches. 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 in either summer or fall.

P. Butler, L. Iverson, and others. 2015. Central Appalachians Forest Ecosystem Vulnerability Assessment. USDA Forest Service Northern Research Station.

Intense precipitation events will continue to become more frequent across the Central Appalachians.

Future climate projections for the contiguous U.S. indicate that the Central Appalachians may experience 2 to 4 more days of heavy (greater than 3 inches) precipitation. The frequency of dry days will also increase by 8 to 10 days annually, resulting in a more episodic regime of intense rain with long dry spells between events. The magnitude or frequency of flooding could also potentially increase in the winter and spring due to increases in total runoff and peak stream flow during those times. Increases in runoff after heavy precipitation events could also lead to an increase in soil erosion.

P. Butler, L. Iverson, and others. 2015. Central Appalachians Forest Ecosystem Vulnerability Assessment. USDA Forest Service Northern Research Station.

The winter season will be shorter and milder winters in the Central Appalachians, with less precipitation falling as snow and reduced snow cover and depth.

In general, warming temperatures may lead to a decrease in the overall frequency of ice storms and snowstorms due to a reduction in the number of days that are cold enough for those events to occur. However, there is research to suggest that snowfall in lake-effect areas may increase over the short term if the necessary conditions are present: reduced ice cover on the Great Lakes must result in increased evaporation from the open water, and winter temperatures must remain cold enough for the movement of increased moisture over the land surface to generate snow.

P. Butler, L. Iverson, and others. 2015. Central Appalachians Forest Ecosystem Vulnerability Assessment. USDA Forest Service Northern Research Station.

Soil moisture patterns will change in the Central Appalachians, with drier soil conditions later in the growing season.

Changes in soil moisture are largely driven by the balance of precipitation and evapotranspiration, and there will be an increase in precipitation (and also soil moisture) during the winter and spring. Conversely, decreases are expected in summer or fall, and late-season droughts may become more frequent and more severe, especially when higher air temperatures increase potential evapotranspiration. Many model simulations have projected an increase in summer drying, indicating increased risk of drought. Other studies have projected summer and fall decreases in soil moisture, with the greatest decrease (10%) in the West Virginia portion of the Central Appalachians.

P. Butler, L. Iverson, and others. 2015. Central Appalachians Forest Ecosystem Vulnerability Assessment. USDA Forest Service Northern Research Station.

Climate change impacts on forest conditions will increase fire risks in the Central Appalachians by the end of the century

An analysis of fire probability across the globe found the majority of models projected an increase in wildfire probability by the end of the century. This agreement is particularly high for temperate coniferous forests and temperate broadleaf and mixed forests, where fire probability models were most sensitive to mean temperature of the warmest month. If temperature and evapotranspiration increase drying of the forest floor in spring, amplify the effects of declining precipitation, or overwhelm modest precipitation increases, the annual area burned and length of the fire season will likely increase. Projected increases in lightning-producing convective storms may also increase ignition frequency. Another global study projected increased fire potential across the United States, including the Central Appalachians. Duration of the fire season is also projected to lengthen by several months by the end of the century, primarily due to warming.

P. Butler, L. Iverson, and others. 2015. Central Appalachians Forest Ecosystem Vulnerability Assessment. USDA Forest Service Northern Research Station.

Many invasive species, insect pests, and pathogens in the Central Appalachians will increase or become more damaging.

"Many invasive species that currently threaten forests in the Central Appalachians region may benefit directly from projected climate change or benefit from the slow response of native species. Increases in carbon dioxide have been shown to have positive effects on growth for many plant species, including some of the most invasive weeds in the U.S. Experiments with CO2 fertilization on kudzu seedlings have indicated increased growth, increased competition with native species, and range expansion. Increased carbon dioxide emissions and warmer winter temperatures will expand the northern ranges of invasive plants such as bush honeysuckle, privet, kudzu, and cogongrass. Warmer temperatures, moisture deficit, and compounding stressors will also increase the susceptibility of trees to insect pests and pathogens, in addition to increasing the abundance of pests and pathogens that are currently present in the Central Appalachians. For example, hemlock woolly adelgid populations are currently limited by low winter temperatures and freeze-thaw cycles, and populations of hemlock woolly adelgid have increased or expanded northward during mild winters. The emerald ash borer, currently devastating populations of ash species, has been observed to produce more generations under warmer conditions. Other pest outbreaks, including those of native species (e.g., forest tent caterpillar and spruce budworm), are more common when trees are stressed by factors such as drought."

P. Butler, L. Iverson, and others. 2015. Central Appalachians Forest Ecosystem Vulnerability Assessment. USDA Forest Service Northern Research Station.

Suitable habitat for northern species will decline in the Central Appalachians.

"Across northern latitudes, past periods of warmer temperatures have resulted in species' distribution changes toward the north and also upward in elevation. The ranges of eastern hemlock and red spruce lay largely to the north of the Central Appalachians, but these species currently persist in microhabitats that remain cool and moist enough to support them. Red spruce is more limited within the Central Appalachians, occurring at high elevations in the Allegheny Mountains section of West Virginia. Hemlock is more widespread, occupying cool and wet sites at lower elevations. As these species' ranges continue to shift northward, they may become rare or extirpated from the area. In the absence of other mortality agents, long-lived individuals already established in cool, wet microhabitats may persist for many years, even when habitat becomes unsuitable for regeneration or growth. Due to the geographic limitations of their current habitat, these species are unlikely to migrate even if newly suitable habitat became available elsewhere. Results from climate impact models also suggest declines in suitable habitat for northern species that are not so geographically limited, such as sugar maple. These species near the southern edge of their range may also be able to persist in southern refugia if potential new competitors from farther south are unable to colonize these areas, although they are expected to have reduced vigor and be under greater stress."

P. Butler, L. Iverson, and others. 2015. Central Appalachians Forest Ecosystem Vulnerability Assessment. USDA Forest Service Northern Research Station.

Suitable habitat for southern species will increase in the Central Appalachians.

Model results project that tree species currently at their northern range limits south of the Central Appalachians will become more abundant and more widespread. The range of eastern redcedar currently occupies a small portion of its range within the Central Appalachians. The range of loblolly pine lays largely to the south, although disjunct populations have been planted in some locations within Ohio and Maryland. Models agree that loblolly pine, shortleaf pine, and post oak will fare well in terms of habitat and basal area. Several species that do not currently exist within the Central Appalachians are projected to have new suitable habitat: water oak, water locust, and cedar elm. However, habitat fragmentation and the limited dispersal ability of seeds is expected to hinder movement of these southern species despite the increase in habitat suitability . Most tree species can be expected to migrate more slowly than their habitats will shift. As suitable habitat increases for some tree species and decreases for others, there will be new opportunities to become new components of novel forest types or commercial plantations.

P. Butler, L. Iverson, and others. 2015. Central Appalachians Forest Ecosystem Vulnerability Assessment. USDA Forest Service Northern Research Station.

Seedlings are expected to be more vulnerable than mature trees to changes in temperature, moisture, and other seedbed and early growth requirements in the Central Appalachians.

Evidence of climate change impacts on forest ecosystems is more likely to be seen in seedlings and early growth than in mature individuals. 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. For example, regeneration failure in balsam fir populations has been partially attributed to climate change. For species with seeds that disperse successfully, these changes may result in redistribution on the landscape as seeds germinate only where conditions are met. Others species may fail to regenerate under altered future conditions, or may germinate without having sufficient conditions to develop. Warmer winters may promote the establishment of eastern redcedar and other southern species, although warmer temperatures alone are unlikely to drive their establishment. After establishment, saplings are still more sensitive than mature trees to drought, heat stress, frost, and other disturbances, such as fire, flooding, and herbivory.

P. Butler, L. Iverson, and others. 2015. Central Appalachians Forest Ecosystem Vulnerability Assessment. USDA Forest Service Northern Research Station.

Low-diversity systems in the Central Appalachians are at greater risk from climate change.

In general, species-rich ecosystems have exhibited greater resilience to extreme environmental conditions and greater potential to recover from disturbance than less diverse ecosystems. This makes less diverse ecosystems inherently more susceptible to future changes and stressors. Conversely, ecosystems that have low species diversity or low functional diversity (where multiple species occupy the same niche) may be less resilient to climate change or its associated stressors. Forest stands with low diversity of species, age classes, and genotypes have been more vulnerable to insect and disease outbreaks than diverse stands. Genetic diversity within species is also critical for the ability of populations to adapt to climate change, because species with high genetic variation are more apt to have individuals that can withstand a wide range of environmental stressors.

P. Butler, L. Iverson, and others. 2015. Central Appalachians Forest Ecosystem Vulnerability Assessment. USDA Forest Service Northern Research Station.

Species in Central Appalachian fragmented landscapes will have less opportunity to migrate in response to climate change.

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 100 miles per century. Fragmentation makes this disparity even more challenging, because the landscape is essentially less permeable to migration.

P. Butler, L. Iverson, and others. 2015. Central Appalachians Forest Ecosystem Vulnerability Assessment. USDA Forest Service Northern Research Station.

Central Appalachians systems that are limited by hydrologic regime or geological features may be topographically constrained.

Communities that require specific hydrologic regimes, unique soils or geology, or narrow elevation ranges may not be able to shift across the landscape, even if conditions are favorable. For example, high-elevation spruce-fir ecosystems are found exclusively in the highest elevations of the Allegheny Mountains, as remnant populations surviving in the coolest and wettest habitats in the region. These ecosystems, which range from wetlands to uplands, are already constrained to the highest elevations, and if habitat becomes unsuitable, it is doubtful that there will be alternate sites or that they would be able to migrate over unsuitable habitat to reach potential northern sites.

P. Butler, L. Iverson, and others. 2015. Central Appalachians Forest Ecosystem Vulnerability Assessment. USDA Forest Service Northern Research Station.

Central Appalachians systems that are more tolerant of disturbance have less risk of declining on the landscape

Disturbances such as drought, flooding, wildfire, and insect outbreaks have the potential to increase in the Central Appalachians. Several ecosystems such as the Appalachian (hemlock)-northern hardwoods and north-central interior beech-maple forest are adapted to frequent gap-phase disturbances, but experience stand-replacing events on the scale of hundreds or thousands of years. Therefore, these systems may be less tolerant of more frequent stand-level disturbances, such as drought or fire. Mesic ecosystems can create conditions that could buffer against fire and drought to some extent. However, even species in mesic ecosystems could decline if soil moisture declines significantly. Forest ecosystems that are more tolerant of drought, flooding, or fire such as dry oak and pine oak forest and woodland will likely 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 ecosystems to experience too much disruption. For example, oak and pine ecosystems might cover a greater extent under drier conditions with more frequent fire, but these systems might also convert to barrens or open grasslands if fire becomes too frequent or drought becomes too severe.

P. Butler, L. Iverson, and others. 2015. Central Appalachians Forest Ecosystem Vulnerability Assessment. USDA Forest Service Northern Research Station.

Ecosystems occupying habitat in areas of high landscape complexity have more opportunities for persistence in pockets of refugia in the Central Appalachians.

Species diversity in the Central Appalachians has been linked to geophysical diversity of the area. With increasing topographic and landform complexity comes a greater number of landscape characteristics and microhabitats that buffer against climate changes. Many areas across West Virginia and Maryland, including the Appalachian range, have a high diversity of landscape characteristics, such as geophysical setting, landscape complexity, and connectivity, that contribute to the high species diversity. Even the relatively flat areas of the Central Appalachians contain complex ridge systems and associated soil moisture regimes that support a high diversity of species. Although climate will largely determine a species' potential range, it is the influence of geology that creates areas of microhabitat offering refugia against the effects of climate change.

P. Butler, L. Iverson, and others. 2015. Central Appalachians Forest Ecosystem Vulnerability Assessment. USDA Forest Service Northern Research Station.