CLIMATE IMPACTS – MID-ATLANTIC

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

The Mid-Atlantic Region includes the states of Delaware, New Jersey, Pennsylvania, the eastern half of Maryland, and the southern portion of New York.

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

Temperatures in the Mid-Atlantic are projected to increase 2.2 to 7.6 °F by the end of the century, with the greatest warming expected to occur during summer and fall.

The growing season in the Mid-Atlantic is generally expected to increase by 21 days or more by the end of the century, due to fewer days with a minimum temperatures below 32°F.

The Mid-Atlantic winter season will be shorter with milder winters, with less precipitation falling as snow and reduced snow cover and depth.

Precipitation patterns will be altered in the Mid-Atlantic, with projected increases in annual precipitation and potential for reduced growing season precipitation.

Intense precipitation events will continue to become more frequent in the Mid-Atlantic.

The timing and amount of stream flow is expected to change over the next century.

Sea levels along the Atlantic coast are expected to rise by 2 to 3 feet or more by the end of the century.

Soil moisture patterns will change in the Mid-Atlantic with the potential for drier soil conditions later in the growing season.

Many invasive species, insect pests, and pathogens in the Mid-Atlantic will increase or become more damaging.

Northern and boreal species are expected to face increasing stress from climate change in the Mid-Atlantic Region.

Southern or temperate species are expected to be favored by climate change in the Mid-Atlantic Region.

Winter streamflow patterns are expected to reflect hydrologic changes, resulting in higher winter flows

Flash flooding and higher peak flows will increase as a result of more frequent intense precipitation events

Water quality may decline due to warming temperatures, and changing precipitation regimes

Surface water temperatures are expected to rise due to warming air temperatures

Inland lakes are warming, and continued warming will decrease seasonal mixing of stratified lakes and reduce available dissolved oxygen

Seasonal variation in soil moisture and altered precipitation may influence the magnitude and duration of flood events.

Low streamflow events may become more frequent and deliver lower water volumes

Video presentation: Mid-Atlantic Forest Ecosystem Vulnerability Assessment and Synthesis

See forest type vulnerability on next page.

Table 26.—Summary of vulnerability determination for the forest communities considered in this assessment evaluated through the end of the 21st century

Forest community	Potential impacts	Adaptive capacity	Vulnerability	Evidence	Agreement
Coastal Plain					
Maritime forest	Negative	Moderate-Low	High	Medium-Robust	Medium-High
Oak-pine-hardwood	Moderate-Positive	High	Moderate-Low	Medium	Medium-High
Pine-oak barrens	Moderate	Moderate	Moderate-Low	Medium-Robust	Medium-High
Swamp	Moderate	Moderate-High	Moderate-Low	Medium	Medium
Tidal swamp	Moderate-Negative	Moderate-Low	Moderate-High	Medium	Medium-High
Interior					
Central oak-pine	Moderate-Positive	Moderate-High	Moderate-Low	Medium	Medium-High
Lowland conifer	Negative	Moderate-Low	High	Medium	Medium
Lowland and riparian hardwood	Moderate	Moderate	Moderate	Medium-Limited	Medium
Montane spruce-fir	Negative	Low	High	Medium-Robust	High
Northern hardwood	Moderate-Negative	Moderate	Moderate-High	Medium-Robust	Medium-High
Woodland, glade, and barrens	Positive	Moderate-High	Low	Medium	Medium-High

Table source: P. Butler-Leopold and others. 2019. Mid-Atlantic Forest Ecosystem Vulnerability Assessment and Synthesis. US Forest Service Northern Research Station.

Temperatures in the Mid-Atlantic are projected to increase 2.2 to 7.6 °F by the end of the century, with the greatest warming expected to occur during summer and fall.

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

Nelson Center for Climatic Research. 2016. Central-Eastern North American Landscape Conservation Cooperatives (LCCs).
K. Kunkel, L. Stevens, and others. 2013. Regional climate trends and scenarios for the U.S. National Climate Assessment: Northeast U.S. .
P. Butler-Leopold and others. 2019. Mid-Atlantic Forest Ecosystem Vulnerability Assessment and Synthesis. US Forest Service Northern Research Station.

The growing season in the Mid-Atlantic is generally expected to increase by 21 days or more by the end of the century, due to fewer days with a minimum temperatures below 32°F.

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.

Nelson Center for Climatic Research. 2016. Central-Eastern North American Landscape Conservation Cooperatives (LCCs).
K. Kunkel, L. Stevens, and others. 2013. Regional climate trends and scenarios for the U.S. National Climate Assessment: Northeast U.S. .
P. Butler-Leopold and others. 2019. Mid-Atlantic Forest Ecosystem Vulnerability Assessment and Synthesis. US Forest Service Northern Research Station.

The Mid-Atlantic winter season will be shorter with milder winters, with less precipitation falling as snow and reduced snow cover and depth.

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.

M. Notaro, D. Lorenz, and others. 2014. 21st century projections of snowfall and winter severity across central-eastern North America. Journal of Climate.
Nelson Center for Climatic Research. 2016. Central-Eastern North American Landscape Conservation Cooperatives (LCCs).
K. Kunkel, L. Stevens, and others. 2013. Regional climate trends and scenarios for the U.S. National Climate Assessment: Northeast U.S.
P. Butler-Leopold and others. 2019. Mid-Atlantic Forest Ecosystem Vulnerability Assessment and Synthesis. US Forest Service Northern Research Station.

Precipitation patterns will be altered in the Mid-Atlantic, with projected increases in annual precipitation and potential for reduced growing season precipitation.

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.

Nelson Center for Climatic Research. 2016. Central-Eastern North American Landscape Conservation Cooperatives (LCCs).
K. Kunkel, L. Stevens, and others. 2013. Regional climate trends and scenarios for the U.S. National Climate Assessment: Northeast U.S.
P. Butler-Leopold and others. 2019. Mid-Atlantic Forest Ecosystem Vulnerability Assessment and Synthesis. US Forest Service Northern Research Station.

Intense precipitation events will continue to become more frequent in the Mid-Atlantic.

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. 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.

Nelson Center for Climatic Research. 2016. Central-Eastern North American Landscape Conservation Cooperatives (LCCs).
L. Ning, E.E. Riddle, and others. 2015. Journal of Climate.
W. Gutowski, G. Hegerl, and others. 2008. Weather and Climate Extremes in a Changing Climate.
P. Butler-Leopold and others. 2019. Mid-Atlantic Forest Ecosystem Vulnerability Assessment and Synthesis. US Forest Service Northern Research Station.

The timing and amount of stream flow is expected to change over the next century.

The shifts in winter precipitation and temperature described above are expected to alter several hydrological variables. Warmer temperatures are expected to accelerate the hydrologic cycle by reducing winter snow cover and shifting an increasing amount of runoff to winter and away from spring and summer. Researchers project that peak (winter/spring) streamflow may advance by 10 to greater than 15 days by the end of the century, with the greater shifts in the north due to the influence of snowmelt on streamflow. Similarly, low streamflows are generally projected to be lower, particularly during the fall and under scenarios projecting greater warming (Hayhoe et al. 2007). Additionally, there is expected to be greater annual variation, with increases in both low- and high-flow events through the course of the year.

E. Demaria, R. Palmer, and others. 2015. Journal of Hydrology: Regional Studies.
P. Butler-Leopold and others. 2019. Mid-Atlantic Forest Ecosystem Vulnerability Assessment and Synthesis. US Forest Service Northern Research Station.

Sea levels along the Atlantic coast are expected to rise by 2 to 3 feet or more by the end of the century.

All global climate models agree that sea level will rise. Sea levels have increased over the past century, and this trend is expected to continue. Additional warming is expected to increase global sea levels by up to 1m (3 ft) by the end of the century. In the Mid-

Atlantic, sea-level rise is significantly greater than observed global sea-level rise, due to sinking of the land surface as it adjust to the melting of former ice sheets and the withdrawals of natural resources from underground.

Climate Change Science Program. 2009. Environmental Protection Agency.
P. Butler-Leopold and others. 2019. Mid-Atlantic Forest Ecosystem Vulnerability Assessment and Synthesis. US Forest Service Northern Research Station.

Soil moisture patterns will change in the Mid-Atlantic with the potential for drier soil conditions later in the growing season.

Given that warmer temperatures and seasonal changes in precipitation are expected across the region, it is reasonable to expect that soil moisture regimes will also shift. Longer growing seasons and warmer temperatures would generally be expected to result in greater evapotranspiration losses and lower soil-water availability later in the growing season, thereby increasing moisture stress on forests. Further, increases in extreme rain events suggest that greater amounts of precipitation may occur during fewer precipitation events, resulting in longer periods between rainfall. At the same time, there is substantial variation among model projections of growing season precipitation, which increases uncertainty regarding the potential for increases in precipitation sufficient to offset increases in evapotranspiration.

M. Ashfaq, L. Bowling, and others. 2010. Journal of Geophysical Research.
W. Gutowski, G. Hegerl, and others. 2008. Weather and Climate Extremes in a Changing Climate.
P. Butler-Leopold and others. 2019. Mid-Atlantic Forest Ecosystem Vulnerability Assessment and Synthesis. US Forest Service Northern Research Station.

Many invasive species, insect pests, and pathogens in the Mid-Atlantic will increase or become more damaging.

Changes in climate may allow some nonnative plant species, insect pests, and pathogens to expand their ranges farther north as the climate warms and the growing season increases. The abundance and distribution of some nonnative plant species may be able to increase directly in response to a warmer climate and also indirectly through increased invasion of stressed or disturbed forests. Similarly, forest pests and pathogens are generally able to respond rapidly to changes in climate and also disproportionately damage-stressed ecosystems. Thus, there is high potential for pests and pathogens to interact with other climate-mediated stressors. Unfortunately, we lack basic information on the climatic thresholds that apply to many invasive plants, insect pests, and pathogens. Further, there remains a limited ability to predict the mechanisms of infection (in the case of pests and diseases), dispersal, and spread for specific agents, as well as which specific nonnative species, pests, or pathogens may enter the region.

B. Bradley, D. Wilcove, and others. 2010. Biological Invasions.
J. Dukes, J. Pontius, and others. 2009. Responses of insect pests, pathogens, and invasive plant species to climate change in the forests of northeastern North America. Canadian Journal of Forest Research.
P. Butler-Leopold and others. 2019. Mid-Atlantic Forest Ecosystem Vulnerability Assessment and Synthesis. US Forest Service Northern Research Station.

Northern and boreal species are expected to face increasing stress from climate change in the Mid-Atlantic Region.

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 declines in suitable habitat and landscape-level biomass for northern and high elevation species such as black spruce, balsam fir, red spruce, and paper birch. Forest ecosystems dominated by boreal species, such as spruce-fir or paper birch, are consistently rated as the most vulnerable across numerous regional vulnerability assessments. 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.

L. Rustad, J. Campbell, and others. 2012. Changing climate, changing forests: Impacts of climate change on forests of the northeastern United States and eastern Canada. USDA Forest Service Northern Research Station.
Landscape Change Research Group. 2014. Climate Change Atlas. USDA Forest Service Northern Research Station.
P. Butler-Leopold and others. 2019. Mid-Atlantic Forest Ecosystem Vulnerability Assessment and Synthesis. US Forest Service Northern Research Station.

Southern or temperate species are expected to be favored by climate change in the Mid-Atlantic Region.

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 bitternut hickory, black oak, bur oak, and white oak 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.

Landscape Change Research Group. 2014. Climate Change Atlas. USDA Forest Service Northern Research Station.
P. Butler-Leopold and others. 2019. Mid-Atlantic Forest Ecosystem Vulnerability Assessment and Synthesis. US Forest Service Northern Research Station.

Low-diversity systems are at greater risk from climate change.

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.

T. Elmqvist , C. Folke, and others. 2003. Response diversity, ecosystem change, and resilience. Frontiers in Ecology and the Environment.
A. Hoffman and C. Sgrò. 2011. Climate change and evolutionary adaptation. Nature.

Species in 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 60 miles per century. Fragmentation makes this disparity even more challenging, because the landscape is essentially less permeable to migration.

L. Iverson, M. Schwartz, and others. 2004. How fast and far might tree species migrate in the eastern United States due to climate change? Global Ecology and Biogeography.
C. Woodall, C. Oswalt, and others. 2009. An indicator of tree migration in forests of the eastern United States. Forest Ecology and Management.

Systems that are limited to particular environments will have less opportunity to migrate in response to climate change.

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.

A. Jump and J. Peñuelas. 2005. Running to stand still: adaptation and the response of plants to rapid climate change. Ecology Letters.

Systems that are more tolerant of disturbance have less risk of declining on the landscape

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.

G. Nowacki and M. Abrams. 2008. The Demise of Fire and "Mesophication" of Forests in the Eastern United States. BioScience.

E. Gustafson and B. Sturtevant. 2013. Modeling Forest Mortality Caused by Drought Stress: Implications for Climate Change. Ecosystems.