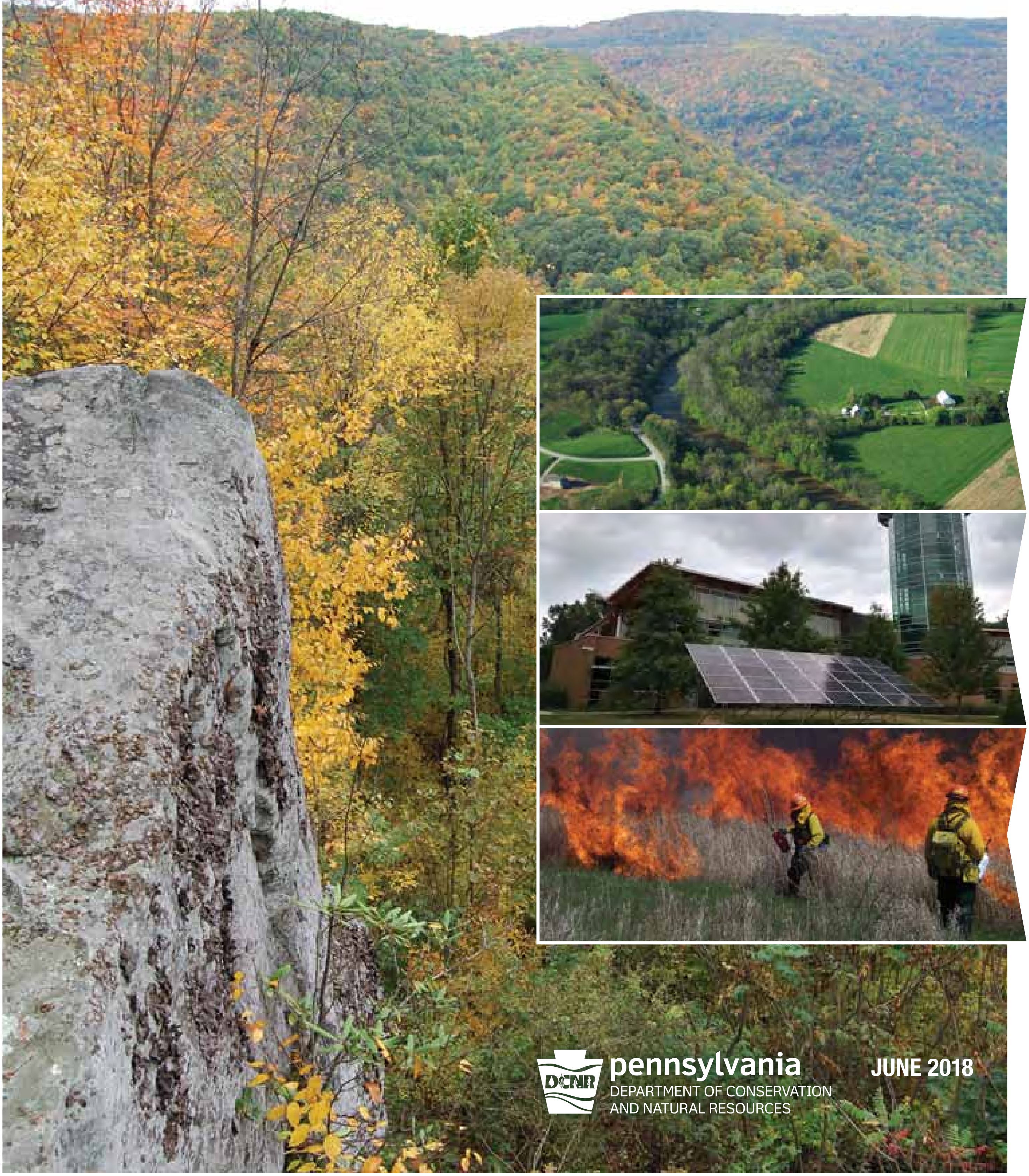
CLIMATE CHANGE

Adaptation and Mitigation Plan



pennsylvania
DEPARTMENT OF CONSERVATION
AND NATURAL RESOURCES

JUNE 2018

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Presque Isle State Park

COMMONWEALTH OF PENNSYLVANIA
OFFICE OF THE GOVERNOR
HARRISBURG

SECRETARY
DEPARTMENT OF CONSERVATION
AND NATURAL RESOURCES

Dear Citizens:

As Pennsylvania's conservation leader, the Department of Conservation and Natural Resources is taking action to ensure a commonwealth that is resilient to a changing climate.

During 2017, staff members from across all of DCNR's bureaus participated in a rigorous process to determine and prioritize the department's greatest climate change vulnerabilities, and identify strategies to address them.

The resulting Climate Change Adaptation Plan includes objectives to prepare for and mitigate the risks associated with potential climate impacts to Pennsylvania, including higher temperatures and more extreme weather events, range shifts for wildlife and plant species, and an increase in invasive species.

Over the next year, we will begin to implement recommendations to increase staff knowledge and expertise on climate change challenges and solutions through a newly formed communication and education team.

To test adaptive management practices on the ground, we are launching a climate change adaptation pilot project on public lands in the southcentral part of the state, including the 85,000-acre Michaux State Forest and Kings Gap, Pine Grove Furnace, and Caledonia state parks.

We also will continue our significant work over the past several years on energy conservation and renewable energy in our hundreds of buildings and vehicle fleet, and our leadership of the movement to plant trees along streams to improve water quality and address impacts from climate change.

With this plan, we are laying a framework for a more resilient and sustainable Pennsylvania. I encourage you to join us in creating a vibrant commonwealth that is environmentally responsible, and focused on solutions to a changing climate.

Sincerely,

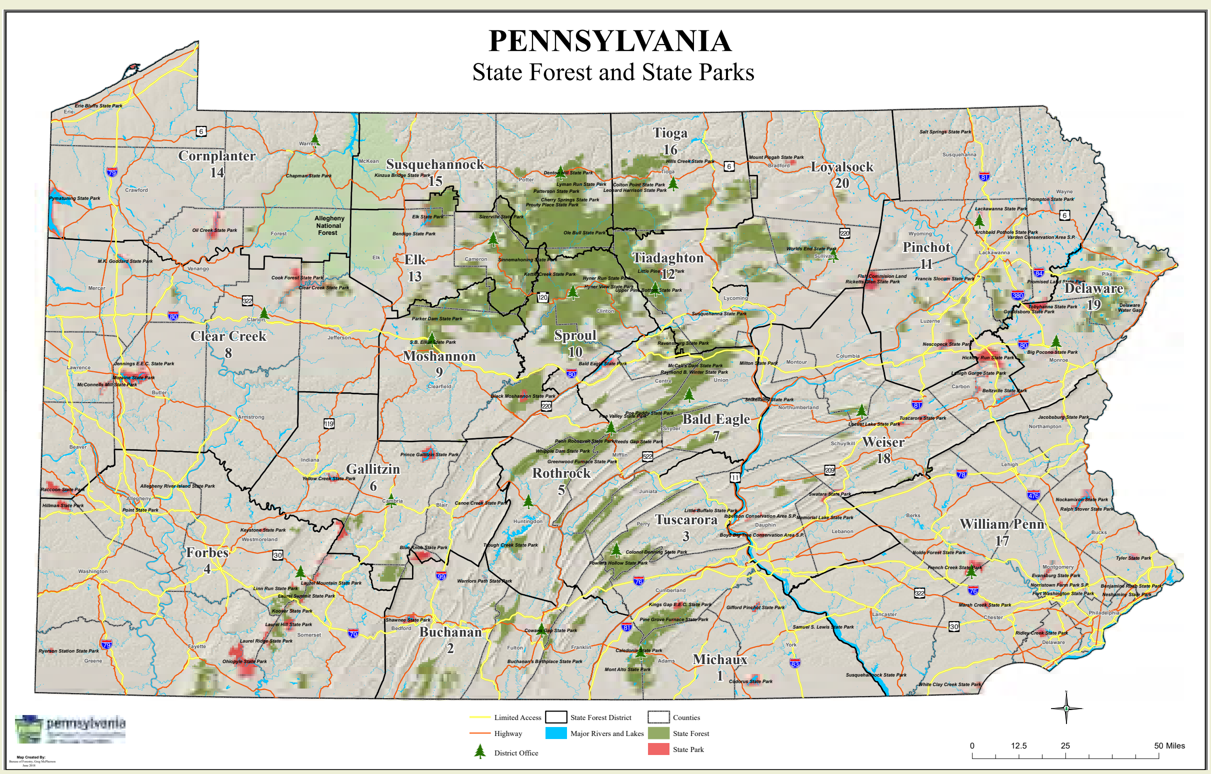
Cindy Adams Dunn
Secretary
Department of Conservation and Natural Resources

INTRODUCTION

The Pennsylvania Department of Conservation and Natural Resources (DCNR) is the caretaker of 2.2 million acres of state forests and 121 state parks, advisor to the owners of 15 million acres of private forest land, a leader in providing outdoor recreation, and the state's primary conservation agency. DCNR's mission is to conserve and sustain Pennsylvania's natural resources for present and future generations, giving the department a unique role and responsibility in helping the commonwealth reduce and adapt to climate change.

The department's land management practices can mitigate atmospheric carbon as well as ensure that our public lands remain resilient and can adapt to climate change. DCNR can also be a leader, serving as an example of climate-smart land management and green infrastructure development, and providing technical assistance and funding to help its constituents deal with climate change.

While climate change presents some very significant challenges, there is much we can do to both limit its effects and cope with the impacts. This plan provides an overview of the current and projected impacts of climate change on DCNR's lands and mission. It also lays out a framework for implementing the department's climate change strategy (see Appendix A) by reducing atmospheric



Clear Creek State Park

carbon and building resilience to the inevitable impacts of climate change.

Climate Change in Pennsylvania

Pennsylvania has seen measurable changes in temperature, precipitation, and storm intensity. Since the early 20th century, the commonwealth has seen a temperature increase of more than 1.8° F. Winter temperatures have risen even faster, increasing 1.3° F per decade from 1970 to 2000 in the northeastern U.S.

The frequency of very hot days has also increased significantly. Record high temperatures in the U.S. in 2017 outnumbered record lows by 9:1, and by the middle of the century the northeastern part of the country is expected to see 20 to 30 more days above 90° F.

Annual precipitation has increased about 10 percent over the past 100 years, and heavy precipitation events also have increased significantly. According to the 2014 National Climate Assessment, the heaviest downpours, which are the number of days where the total precipitation exceeded the top 1 percent of all rain and snow days, have increased by 71 percent in the Northeast.

Looking to the future, Pennsylvania is projected to be as much as 5.4° F warmer by the middle of this century than it was at the end of the last century if emissions aren't curtailed significantly. Additionally, annual precipitation is expected to be 8 percent higher by the middle of this century, and winter precipitation is expected to be 14 percent higher.

VULNERABILITIES AND ACTIONS

Jacobsburg Environmental Education Center

A team of more than 80 DCNR staff worked with the Northern Institute of Applied Climate Science to evaluate data on current and projected impacts to identify the department's top climate change vulnerabilities. Using a structured decision-making process, vulnerabilities were ranked based on their likelihood and severity (see Appendix B – Methodology).

The team developed detailed adaptation strategies for the Bureaus of Forestry, State Parks, Facility Design and Construction, Recreation and Conservation, and Topographic and Geologic Survey (see Appendix C – Bureau Adaptation Plans). Additionally, adaptation strategies were developed for riparian buffers and emergency management (see Appendix D – Topical Adaptation Plans).

From that detailed analysis and list of adaptation strategies, the following list of major department-wide vulnerabilities and general recommendations to address them emerged.

NATURAL RESOURCES

Interacting stressors such as insect pests, pathogens, and climate change will be, and are, affecting native trees and plants, animals, and rare and endangered species. These changes could lead to disruption of ecosystem processes and functions; changes in the timing of natural cycles; loss of diversity in native trees, shrubs, and understory plants; shifts in forest community composition; and impacts on the commonwealth's forest products industry.

Vulnerability:

CHANGING FOREST COMPOSITION

Species composition is expected to change due to the decline of some species, increases in others, hybridization, and immigration of southern species. Adding to these stressors are forest regeneration failures compounded by previous land use changes and forest fragmentation that impedes the movement of species. As conditions continue to change, decisions will need to be made as to which tree species the department manages for, which may be difficult to determine since species that will thrive in future conditions may not do well now.

Tuscarora State Forest

ACTIONS

- Distribute risk, reducing the likelihood that an entire system will decline; maintain and enhance species and structural diversity; and retain biological legacies such as old or rare trees, disease-resistant survivors, and unique natural communities.
- Sustain ecological functions, species diversity, and diverse age classes in forests.
- Facilitate forest community changes by:
  - Favoring native tree species and genotypes that are expected to be adapted to future conditions.
  - Managing for species with wide moisture and temperature tolerances.
  - Establishing new mixes of native species.
  - Moving at-risk species to locations that are expected to provide suitable habitat when practicable.
  - Guiding change in species compositions during the early stages of stand development.
- Allow for areas of natural regeneration to test for future-adapted species.
- Introduce new tree species that are better adapted to future conditions, but only to fill ecological or economic gaps created by the loss of native trees, and only after careful scientific analysis of potential impacts on the ecosystem.
- Reduce tree densities through silvicultural thinning, focusing on trees likely to be ill-suited to future climate conditions, thereby making more space available for trees better adapted to a warmer climate. Prioritize these treatments based on funding.
- Permit the use of seeds, germplasm, and other genetic material from across a greater geographic range.
- Utilize assisted migration when warranted and only after stringent scientific review.
- Use forest impact models, such as the U.S. Forest Service's Climate Change Tree Atlas, to inform decisions on tree management and planting.

Spadefoot toad

Vulnerability:

RARE SPECIES

Populations of rare, threatened, and endangered species, especially those near the edge of their range in Pennsylvania, are expected to decline faster and possibly disappear because of climate change and other stressors. Additionally, some species that are common now could become rare and new species may move into the state. Decisions will need to be made as to whether those new species should be listed as rare, threatened, or endangered.

ACTIONS

- Identify plant and animal species in Pennsylvania that are most at risk from climate change based on analyses using the Climate Change Vulnerability Index.
- Review and expand monitoring to ensure that changes in natural communities, species distribution, and populations are detected.
- Identify and conserve species, natural communities, and unique sites at risk from climate change.
- Consider establishing reserves for at-risk or displaced species.
- Manage habitats over a range of sites and conditions to increase ecosystem redundancy across the landscape.
- Work with other state and federal agencies, land conservancies, and scientific institutions across a species range to ensure a holistic approach to conservation.
- Develop conservation plans for new species moving into the state and declining populations of once common species.
- Maintain and enhance genetic diversity, thereby increasing the likelihood that a species will be able to withstand climate change.

Vulnerability:

FOREST PESTS

More frequent, severe, and widespread forest pest outbreaks will result in increased tree mortality and management and treatment costs. Forest pests will influence forest composition, and the loss of some tree and understory species may reduce the diversity of the current forest. Controlling these pests increases a forest's ability to withstand and adapt to climate change.

ACTIONS

- Identify and prioritize high-value forests to monitor for new and existing threats.
- Include the effects of climate change on long-term forest sustainability when developing pest response plans by using forest impact models (e.g., Tree Atlas, Landis).
- Manage for a diversity of species and forest types in landscapes that have seen significant damage and mortality from forest pests to increase resilience to climate change.
- Manage herbivory to promote regeneration of desired species.
- Evaluate, when necessary, whether manipulating the density, structure, or species composition of a forest may improve its ability to resist biological stressors.

Hemlock wooly adelgid mortality, Tuscarora State Forest

Removing invasive barberry

Vulnerability:

INVASIVE PLANT SPECIES

As the climate changes, new invasive species are expected to move into the commonwealth and those already here will increase in abundance. These invasives will further reduce the resilience of species and habitats to the impacts of climate change and may reduce diversity or contribute to species extirpation. In aquatic ecosystems, invasive species increase the potential for choked waterways, fish kills, toxic water, and harmful algae blooms. In terrestrial ecosystems, invasives may disrupt succession as they outcompete native tree regeneration in the understory and will influence fuel conditions and fuel loads for fires. Controlling invasives will require a significant increase in staff hours and funding.

ACTIONS

- Prioritize invasive species for removal or control by using existing decision-making processes and DCNR's Invasive Plant Management for Land Managers guide.
- Work with the PA Natural Heritage Program and the PA Invasive Species Council to identify new species coming from other states.
- Investigate new methods of invasive species control, including biocontrol agents.
- Increase funding for invasive vegetation removal and suppression.
- Work with other state agencies responsible for land management (e.g., PennDOT, Dept. of Military and Veterans Affairs, etc.) to develop and adopt statewide invasive species best management practices.

HABITAT CONNECTIVITY AND LANDSCAPE-SCALE CONSERVATION

Pine Creek Valley, Lycoming County

Vulnerability:

FRAGMENTED HABITATS

Climate impacts are expected to vary across the landscape according to elevation, topography, aspect, slope, and other variables. Some areas will see significant impacts, while more resistant habitats will become increasingly important for conservation planning and may influence where and how conservation dollars are spent. This will necessitate changes in land conservation priorities to create an interconnected system of habitats that allow species to move north and to higher elevations in response to climate change.

ACTIONS

- Conserve key tracts of land through acquisitions, easements, and stewardship plans to ensure habitat connectivity and potential migration corridors.
- Prioritize grant funding that addresses climate change impacts on species and natural communities, such as connecting parcels that facilitate the movement of species.
- Maintain or create refugia—areas that have resisted (or could potentially resist) widespread climatic changes and that often support relict populations of rare species.
- Identify and conserve biological legacies and unique ecological sites.

GEOLOGIC HAZARDS

Sinkholes

Vulnerability:

INCREASED DEMAND FOR RESEARCH AND ASSISTANCE

There will be an increased demand for data and technical assistance due to the impacts of climate change. Public education and outreach will become more important because of increased flooding, drought, dry wells, sinkholes, and other impacts. Hazard prediction, data collection, mapping, hydrographic modeling, and database updates will all be needed. Current staffing levels will be insufficient to meet the increased demand for technical assistance.

ACTIONS

- Develop research projects that look for relationships between the timing and intensity of weather events and sinkholes and landslides.
- Develop science-based key messages dealing with geologic hazards for multiple audiences.
- Prepare to respond to unanticipated novel issues.
- Create detailed information and maps on subsurface geology, particularly faults, stratigraphy, and reservoir characteristics.

RECREATION

Climate change is likely to have a significant impact on the types of recreation that occur in state parks and state forests, as well as the length of the recreation season. This in turn will increase the impact of recreation on natural resources and require changes in staffing needs throughout the year.

Bald Eagle State Park

Vulnerability:

FLUCTUATING LAKE LEVELS

Hotter summers may increase demand for water-based recreation and at the same time result in lower lake levels due to increased evaporation and the potential for drought conditions. The potential inability to sustain normal water levels during the peak recreation season could impact boating, swimming, fishing, marinas, and white-water rafting. The situation could be worse if water withdrawals are needed to maintain downstream flow levels and could result in state park closures.

ACTIONS

- Work with other agencies that control water releases, such as the Army Corps of Engineers, river basin commissions, etc., to maintain water levels and time water releases to minimize impacts on recreation.
- Consider other options for water-based recreation, such as additional swimming pools and splash areas, alternatives to watercraft-based recreation, and shifting the recreational focus from dammed lakes to natural flowing streams.
- Reevaluate appropriate boating restrictions.
- Develop and/or retrofit state park lakeshore infrastructure to be adaptable to changing pool depths.

Vulnerability:

EXTENDED RECREATION SEASON

A longer recreation season will result in increased visitor impact on natural resources and increased stress on ecosystem components. Very hot days during the summer may result in some state parks exceeding visitor carrying capacity and turning visitors away or closing. Additionally, the winter period during which maintenance and special projects are conducted will become shorter. More staff and resources will be needed to deal with these impacts.

ACTIONS

- Determine recreational sustainability and develop and apply recreational and resource carrying capacities.
- Limit access or types of uses in sensitive or high-use areas to minimize impacts.
- Design greater flexibility in scheduling seasonal employees. Investigate other avenues for flexible staffing (e.g., alternate full-time position, staggered work seasons, permanent part-time employees, etc.).

Snowshoeing

Vulnerability:

LIMITED WINTER RECREATION

Milder winters will lead to less winter recreation such as ice fishing, ice skating, snowmobiling, and cross-country skiing. The department will need to re-evaluate how money is allocated to winter recreation, as well as how it allocates personnel resources.

ACTIONS

- Reallocate funds to better match recreation demand and opportunities based on climate modelling and surveys.
- Expand specialized state park (e.g., ski resort) operations to incorporate warm-weather recreation in other seasons, thereby reducing impacts in low-snow years.

FLOODING

Vulnerability:

INCREASED FLOOD RISKS

Very heavy precipitation and flooding have increased significantly in Pennsylvania, and that is expected to continue. Infrastructure potentially at risk includes dams, trails, roads and bridges, historical and cultural resources, and buildings. Extreme rain events can also affect groundwater supply and reduce water quality below public thresholds for recreational use. Flooding may also lead to the closing of recreational facilities, strand park visitors, cause lakeshore and streambank erosion and sedimentation, and increase water treatment costs. These impacts are already being felt, and without existing federal funding to address them, several parks would have already been closed.

ACTIONS

- Evaluate trends in 50-year, 100-year, and 500-year floods.
- Protect and restore floodplain and riparian wetlands to maximize floodwater storage and groundwater recharge.
- Utilize technologies and best management practices that decrease stormwater runoff.
- Design infrastructure to be more resilient to flooding and stormwater runoff.
- Award grants based on the evaluation of a site's propensity to flood. Ensure that infrastructure improvements funded by the department are appropriate for the location or will be armored to make them resilient to flooding.
- Reroute roads out of floodplains when practicable.
- Avoid rebuilding in flood prone areas.
- Pave bridge approaches with asphalt in vulnerable areas and armor the bank slope with riprap to reduce the possibility of washout.
- Use alternative crossing structures designed to be overtopped and that can withstand impacts by woody debris or ice during floods.

(continued)

Dauphin County

Flooding continued

Scour protection, Laurel Hill State Park

- Identify bridges that are susceptible to flooding and monitor them during large storm events.
- Deploy flood-proofing on existing high-risk bridges.
- Incorporate flood-proof designs, such as reinforced bridge abutments, during bridge replacement projects so that they can handle larger flows and accumulation of debris.
- Redesign bridges using flow rates based on the most recent data or bankfull totals.
- Evaluate lake water depths every 2 to 3 years to identify shallow areas that need maintenance, and dredge lakes to remove sedimentation if necessary.
- Develop communication materials for the public about flooding issues and why we don't rebuild in flood-prone areas.
- Evaluate trail systems and make them more resilient to flooding and stormwater runoff.
- Assess and replace undersized drainage pipes, culverts, and stormwater conveyance systems that contribute to flooding and erosion issues.
- Evaluate the hydraulic capacities of dams and, where needed and practicable, increase the size of the spillway or provide overtopping protection for earthen dam embankments.
- Remove dams no longer serving their intended purpose.
- Collaborate with DEP to evaluate and identify the high-hazard dams with the highest potential for overtopping and failure. Develop a prioritized list of those that need to be rehabilitated.
- Evaluate and characterize Pennsylvania's aquifers and their properties for modeling future impacts.

LAKES AND STREAMS

Vulnerability:

WARMER WATER TEMPERATURES

Warmer air temperatures and changing hydrologic patterns are expected to result in warmer water temperatures, increased variability in lake levels, and changes in the duration and timing of ice cover. Higher water temperatures can also lead to changes in acidification, dissolved oxygen levels, productivity, destratification, and more, potentially resulting in a reduction or shift in keystone species. Riparian areas also face several threats including warming stream temperatures, erosion and scouring due to heavy rain events, invasive species, and the decline of hemlock, which functions as thermal cover.

Brown trout

ACTIONS

- Use the Bureau of Forestry's Riparian Buffer Guidelines and Brook Trout Conservation Plan to maintain coldwater habitat.
- Install low-level water releases on dams when completing major rehabilitation projects to release cooler water from deeper in the lake and help lower downstream temperatures.
- Assess and prioritize old dams lacking bottom release, with the ultimate goal of removal.
- Deploy monitoring equipment to determine impacts to lake and stream chemistry and temperature.
- Work with the Pennsylvania Fish and Boat Commission to determine if state park and state forest fisheries are being impacted.
- Ensure culverts, bridges, and stream crossings allow for connectivity of cold-water stream communities.
- Improve water quality and habitat for native aquatic flora and fauna through the elimination of impoundments having minimal recreational and operational value.
- Restore and enhance hydrologic connectivity between riparian areas and the surrounding landscape.
- Moderate stream temperature warming by increasing stream shading, especially in areas of cool water habitat such as low-order headwater streams.
- Protect and restore native riparian forests and vegetative cover to conserve species at risk of decline, such as stream-side salamanders, and to increase water retention and uptake of soils to reduce the impacts of flood events, erosion, and sedimentation.
- Plant species expected to be better adapted to future conditions by favoring currently present species that have wide ecological amplitude and can persist under a wide variety of climate and site conditions.
- Prioritize riparian restoration on streams that are most likely to retain cool, late-summer flows.

WILDFIRE AND SEVERE WEATHER

Prescribed fire

Vulnerability:

NATURAL DISASTERS AND PUBLIC SAFETY

Increased frequency of wildfire, blowdowns, and other natural disturbances will create challenges for operations and public safety. Damage to trails and roads in state parks or state forests could result in stranded visitors, and repeated events may lead to long-term loss of access to some areas.

Compared to the western U.S., fire has not been a major disturbance in Pennsylvania, but that is likely to change. There is already evidence of an extended fire season, with fires now happening year-round, not just in spring and fall. The demand for state resources to deal with emergency management, including assistance to the West and South Fire Compacts, is expected to increase.

ACTIONS

- Reduce the severity or extent of disturbance by altering forest structure or composition to reduce the risk of wildfire or storm damage.
- Prepare for intensifying disturbances by developing plans in advance, thereby allowing a faster and better coordinated response.
- Use drought monitoring and fire modelling to predict wildfire risk and danger.
- Revegetate sites promptly after a disturbance.
- Build capacity to respond to fire hazards by training more staff and volunteers.
- Increase resources for responding to disturbances, including trained firefighters and equipment for salvage and wildfire suppression.
- Develop protocols for incorporating climate change into restoration planning after natural disasters, including salvage where necessary and appropriate revegetation and invasive plant monitoring and management.
- Restore fire to fire-adapted ecosystems and use prescribed fire to conduct fuel mitigation in wildland urban interface areas for fire-wise communities.
- Establish fuel breaks to slow the spread of catastrophic fire.
- Provide Incident Command System (ICS) training to personnel throughout the department to ensure appropriate levels of staffing during emergency events.
- Continue to coordinate with PEMA and other state and local agencies to increase response effectiveness.

ENERGY CONSERVATION AND SUSTAINABLE DESIGN

Vulnerability:

ENERGY DEMAND AND INFRASTRUCTURE

Infrastructure will be significantly challenged by higher temperatures, increased flooding, and periodic drought. Higher temperatures will increase energy demand, and building envelopes and HVAC systems designed at today's standards may not be able to satisfactorily perform under these conditions. Alternating droughts and heavy rain may reduce the quality and/or quantity of ground and surface water used as drinking water sources. These water sources may have higher concentrations of pathogenic microorganisms, algae, minerals, or contaminants, making them unsafe or resulting in poor taste and odors.

ACTIONS

- Use sustainable site selection criteria when developing new infrastructure to minimize impacts.
- Develop and enforce more stringent building design and energy conservation standards that will perform well under increasing temperature extremes throughout a building's life span.
- Implement energy reduction strategies such as automated lighting controls, occupant energy waste reductions, and increased use of renewable energy sources.
- Implement passive solar and solar thermal conservation strategies such as roof overhangs, tinted glazing, highly insulated windows, mass wall construction, low-heat absorbing materials, and expanded landscaping to help control glare, limit thermal gain/loss, and moderate the impact of temperature extremes on indoor environment.
- Prioritize the use of geothermal systems that utilize constant ground temperatures not impacted by outside weather extremes instead of using air heat pumps or fossil fuel burning systems for heating and cooling.
- Implement preventive maintenance schedules and re- or retro-commissioning of building systems to ensure operation at peak design and efficiency.
- Utilize proper well-head protection methods to minimize the risk of groundwater contamination.
- Tie into municipal water systems when possible to avoid the need to treat water and to minimize the amount of distribution lines in state parks.
- Increase the frequency of system operator inspections for DCNR water distribution systems (annually at minimum), and identify and repair systems with excessive losses.

Tom Ridge Environmental Center

Ohiopyle State Park

RESOURCE MANAGEMENT AND PLANNING

Presque Isle State Park

Vulnerability:

THE MOST SERIOUS EFFECTS ARE YET TO COME

While climate change impacts are already being felt in Pennsylvania, the most serious effects are yet to come. Integrating climate change into decision-making processes will ensure that our state parks, state forests, infrastructure, and DCNR's core functions are resilient to climate change.

ACTIONS

- Incorporate climate change considerations into grant selection criteria, stewardship plans, infrastructure planning, and landscape-level projects and programs.
- Consider modifying grant scoring criteria to favor applications that evaluate climate change impacts such as flooding, drought, changes in recreation seasons, etc.
- Develop monitoring programs to track the impacts of climate change and DCNR's adaptation efforts.
- Integrate climate change into all bureau plans (i.e., forest district plans, State Forest Resource Management Plan, state park management plans, Statewide Comprehensive Outdoor Recreation Plan, etc.) by identifying climate vulnerabilities and incorporating adaptation strategies.
- Use forest climate impact models, heat and hardiness zone projections, and other resources when developing species conservation, land management, and silvicultural plans.

CARBON SEQUESTRATION

Pennsylvania lumber

Vulnerability:

REDUCING ATMOSPHERIC CARBON

Climate change is attributed in large part to anthropogenic emissions of carbon dioxide. Forest ecosystems absorb and sequester a significant portion of U.S. carbon emissions, but that capability is influenced by land management activities, forest health, tree productivity, and the ability of forests to adapt to climate change. Carbon dioxide can also potentially be stored underground in geologic formations and used to help extract oil and gas deposits in a process called Carbon Capture Use and Storage.

ACTIONS

- Increase forest carbon stocks by increasing forest coverage and avoiding conversion of forest to non-forest uses.
- Decrease forest carbon loss by adjusting timber harvesting intensities and rotations.
- Continue to participate in and advocate for regional studies and funding opportunities for geologic carbon sequestration.
- Utilize durable wood-based products whenever possible in construction projects.

HUMAN HEALTH AND SAFETY

Asian tiger mosquito

Vulnerability:

PUBLIC SAFETY AND HEALTH RISKS

Human health and safety concerns such as tick and mosquito-borne diseases, severe storms, heat-related illness, and poor air quality are becoming more of a concern. The number, geographic distribution, and length of time during the year that ticks and mosquitos are active have been increasing, thereby increasing employee and visitor exposure to vector-borne diseases such as Lyme disease. Visitors may also be at greater risk of heat-related illness and dehydration on hot days, and severe weather is expected to increase the need for emergency management services and storm-safe areas. Staff may need to spend more time on hazard tree removal, salvage operations, and risk assessment and maintenance of public use areas and campgrounds. Severe weather and vector-borne illnesses are also expected to increase worker absences and worker's compensation.

ACTIONS

- Review and update preparedness plans to account for changing risk profiles.
- Train staff about climate-related threats, threat planning, and awareness of shifts in the weather and the resulting impacts.
- Adjust field season planning and scheduling, when practicable, to minimize exposure to hazards.
- Increase monitoring and control of ticks and mosquitos.

POLICY


State forest logging

Vulnerability:

POSSIBLE POLICY CONFLICTS

Adapting to climate change will require new management approaches that may conflict with or not be addressed by current departmental policies. Issues such as terrestrial and geologic carbon sequestration, enhancing genetic diversity, habitat refugia, assisted migration, and changing silvicultural practices may require policy changes. The department should also work with other state agencies as they develop climate change adaptation strategies and policies.

ACTIONS

- Integrate climate change into existing policies and guidelines. Where necessary, develop new policies and guidelines, such as for carbon sequestration and assisted migration.
- Establish a multi-agency climate change adaptation team for the commonwealth to coordinate efforts and funding and share information and practices.

OUTREACH AND COMMUNICATION

Vulnerability:

PUBLIC EDUCATION AND UNDERSTANDING

Implementing the recommendations in this plan will result in changes to land management, recreational opportunities, grant funding criteria, and more. Public education will be essential to help visitors and constituents understand the need for these changes. Through direct experience in natural classrooms or via a wide range of outreach options, the public can come to understand how climate change is impacting the commonwealth's resources, what DCNR is doing to adapt its management and practices, and how members of the public themselves may also become good stewards.

As part of its climate change adaptation efforts, the department will emphasize the importance of public engagement and place-based citizen science and incorporate climate change into the daily conversations staff have with visitors.

ACTIONS

- Form a communication team to provide support, tools, messages, and training to staff to communicate with the public and community partners on DCNR's adaptation plans and practices.
- Empower staff to serve as climate change ambassadors to partners, visitors, and local stakeholders to promote a deeper understanding of climate change impacts and solutions.
- Educate the public in advance of any major operational or land management changes necessary to adapt to climate change.
- Update and expand climate change resources on DCNR's climate web page on a regular basis.

STAFF TRAINING AND CAPACITY

Susquehannock State Forest

Vulnerability:

INCREASING CHALLENGES

DCNR staff will face increasing challenges in managing state resources, providing educational programs, and responding to hazards and emergencies due to the impacts of climate change. The department will need additional staff to implement the actions outlined in this plan. Staff will need to be trained on topics related to climate science, adaptation, and mitigation.

ACTIONS

- Develop climate change training for DCNR staff.
- Designate individuals within each of the bureaus to serve as climate change ambassadors who are familiar with the latest climate science and trends and who can assist with implementing the adaptation strategies recommended in this plan.
- Ensure adequate staffing levels to address the action items outlined in this plan.

CONCLUSION

Lancaster County

Presque Isle State Park

As the climate changes, so will species, natural communities, and the ecological, societal, and economic services they provide. Consequently, the department needs to embrace a conservation paradigm that facilitates, manages, and copes with change in the natural world. As our scientific understanding of climate change advances and as we implement and learn which adaptation strategies are and are not successful, this plan will continually evolve.

APPENDIX A - DCNR CLIMATE CHANGE STRATEGY

January 25, 2017

Position Statement

Climate change is real and is impacting the commonwealth's ecological and recreational resources. As the state's leading conservation agency, DCNR will use the best available science to develop and implement climate change adaptation and mitigation strategies within each of its bureaus to minimize these impacts and serve as a role model for the citizens of Pennsylvania.

Background

The Pennsylvania Department of Conservation and Natural Resources is charged with maintaining and preserving 121 state parks and 2.2 million acres of state forest land, conserving native wild plants, and providing information about the state's ecological and geologic resources. The department also provides information and technical advice to private forest landowners and establishes community conservation partnerships through grants and technical assistance to benefit rivers, trails, greenways, local parks and recreation, heritage regions, open space, and natural areas.

Climate change has already begun to manifest itself in the commonwealth in the form of higher temperatures, increased annual precipitation, significantly higher numbers of large storm events, changes in peak stream flows, decreased snow cover, changes in recreational use patterns, and the movement of some species to the north and to higher elevations. In addition to these direct impacts, climate change is a threat-multiplier, magnifying the impacts of other environmental stressors such as invasive species, habitat fragmentation, and deer overpopulation. Climate change impacts the state's communities, lands, waters, plants, fish, air, visitors, and wildlife. It also affects DCNR's ability to manage these resources for the long-term benefit of the public. Consequently, the need to act on climate change is now.

Approach

DCNR is in a unique position to help the commonwealth reduce risk and adapt to climate change. This will require a new conservation paradigm that focuses on managing for change, preserving ecosystem services, and recognizing the need to reevaluate conservation goals and policies in response to climate change. The department's land management practices can also directly mitigate atmospheric carbon as well as ensure that our public lands remain resilient and can adapt to a changing climate.

The department will take the following steps to implement this strategy:

- Appoint a Climate Action Steering Team (CAST) comprised of bureau directors to provide resources, monitor progress, and ensure that climate change mitigation and adaptation are integrated into the department's operations and mission.
- Refine and adapt strategies identified in *DCNR and Climate Change – Planning for the Future*, as well as other relevant sources, to create and implement a climate change adaptation and mitigation plan.
- Evaluate the department's carbon footprint and mitigate greenhouse gases by reducing energy consumption and increasing forest carbon sequestration.
- Develop a climate change communications plan to engage and educate the public and DCNR staff.
- Work cooperatively with state and federal agencies, non-governmental organizations, and universities to conduct research, share tools and resources, and coordinate our response to climate change.

Legal Authority

- *Article I, Section 27* of the *Pennsylvania Constitution* guarantees the commonwealth's citizens the "right to clean air, pure water and to the preservation of the natural, scenic, historic and aesthetic values of the environment. Pennsylvania's public natural resources are the common property of all the people, including generations yet to come. As trustee of these resources, the commonwealth shall conserve and maintain them for the benefit of all the people." PA. CONST. art.I, § 27.
- *Conservation and Natural Resources Act (Act 18 of June 28, 1995, P.L. 89, 71 P.S. §§ 1340.101-1340.1143).*
- *Wild Resource Conservation Act of June 23, 1982, P.L. 597, No. 170*

APPENDIX B - METHODOLOGY

To address climate change impacts across the department, the Bureaus of Forestry, State Parks, Facility Design and Construction, Recreation and Conservation, and Topologic and Geologic Survey each formed an adaptation team to identify vulnerabilities and adaptation actions.

The teams worked with the Northern Institute of Applied Climate Science (NIACS) using a process adapted from *Forest Adaptation Resources: Climate Change Tools and Approaches for Land Managers, 2nd edition.* The publication serves as a decision-support tool for incorporating climate change assessment and adaptation into planning and management activities. It does not provide recommendations, but rather provides a menu of adaptation strategies and approaches.

As a first step, NIACS proposed three questions to the climate teams:

- What major management challenges do you deal with at work?
- What are some of the ways this work will be affected by climate change?
- What are some of the general ways to respond to the challenges presented by climate change?

Riparian corridor

The responses were used by the teams to compile an initial list of impacts and vulnerabilities. During several day-long meetings, the teams used resources such as the Pennsylvania Climate Change Plan, the Mid-Atlantic Vulnerability Assessment, the National Climate Assessment, and Climate Change Tree Atlas to better define and characterize the vulnerabilities.

From their list of bureau-specific impacts and vulnerabilities, they identified the highest priorities for climate change adaptation using a risk matrix. Risk levels were assessed by considering the severity of the impact and the likelihood that it will occur.

Likelihood	Severity of Impacts: Negligible	Minor	Moderate	Major	Severe
Very Likely	Med. Low	Medium	Med. High	High	High
Likely	Low	Med. Low	Medium	Med. High	High
Possible	Low	Med. Low	Medium	Med. High	Med. High
Unlikely	Low	Med. Low	Med. Low	Medium	Med. High
Very Unlikely	Low	Low	Med. Low	Medium	Med. High

Risk Matrix for Bureau Impacts and Vulnerabilities

The definitions of severity (assuming it will happen) were:

- Negligible: There is little visible, functional, or economic consequence.
- Minor: There is some visible, functional, or economic consequence, but within the range of normal variability.
- Moderate: Visible, functional, or economic consequence is slightly outside the range of normal variability.
- Major: Visible, functional, or economic consequence is detrimental to operations and must be addressed for operations to continue.
- Severe: Visible, functional, or economic consequence results in mission failure and requires intervention by other state or federal agencies.

The categories of likelihood (over roughly the next 3 to 5 years) were:

- Very likely: It's already beginning or has already happened.
- Likely: It's imminent that it will happen.
- Possible: There's evidence to support it happening, but depends on other factors.
- Unlikely: There's evidence predominantly supporting that it won't happen.
- Very unlikely: It would be against all odds to see it happen, but it's still possible.

Based on the severity and likelihood ratings, the matrix provided an overall risk rating for each impact/vulnerability (low, medium-low, medium, medium-high, and high).

Recognizing that they don't have the capacity to address all the climate risks at once, the bureaus only developed adaptation strategies for vulnerabilities listed as medium-high risk and above. The strategies were developed in consultation with experts from NIACS and utilizing the latest scientific information.

Tuscarora State Forest

APPENDIX C - BUREAU ADAPTATION PLANS

The climate change vulnerabilities and adaptation actions listed below are supported by information from *DCNR and Climate Change – Planning for the Future* , *the Mid-Atlantic Forest Ecosystem Vulnerability Assessment and Synthesis*, and other sources. Because the department does not have the capacity to address the full suite of impacts and vulnerabilities, the bureaus rated and prioritized the most important vulnerabilities to address over the next 3 to 5 years. More information on the risk analysis process can be found in Appendix B.

BUREAU OF FORESTRY ADAPTATION PLAN

The DCNR Bureau of Forestry's mission is to ensure the long-term health, viability, and productivity of the commonwealth's forests and to conserve native wild plants. The bureau accomplishes this mission by:

- Managing state forests under sound ecosystem management to retain their wild character and maintain biological diversity while providing pure water, opportunities for low-density recreation, habitats for forest plants and animals, sustained yields of quality timber, and environmentally sound utilization of mineral resources.
- Protecting forestlands, public and private, from damage and/or destruction by fires, insects, diseases, and other agents.
- Promoting forestry and the knowledge of forestry by advising and assisting other government agencies, communities, landowners, the forest industry, and the public in the wise stewardship and utilization of forest resources.
- Protecting and managing native wild flora by determining status, classifying, and conserving native wild plants.

Climate Change Vulnerabilities and Adaptation Actions

VULNERABILITY: **The Bureau of Forestry lacks the technical expertise, staff, and policy guidance needed to effectively deal with the impacts of climate change (High Risk).** There is a shortage of staff expertise, such as a forest geneticist, as well as climate change-related information and data. Policies addressing nonnative species, terrestrial carbon sequestration, maintaining and enhancing genetic diversity, habitat refugia, assisted migration, and old growth forests are also needed.

ACTIONS:

- Integrate climate change into existing policies and guidelines. Where necessary, develop new policies and guidelines, such as for carbon sequestration and assisted migration.
- Expand funding for monitoring of climate-vulnerable species and habitats (e.g., ongoing EPA-funded Pennsylvania high-elevation peatland monitoring project).
- Expand partnerships with other organizations to pool resources and share the latest climate change-related data and scientific knowledge.

VULNERABILITY: **Increased flooding and stormwater runoff is expected to result in damage to equipment and facilities (High Risk).** Costs related to drinking water treatment and repair of infrastructure, trails, roads, and bridges are expected to rise. Flooding is expected to increase runoff into streams, lakes, and reservoirs and may result in human health and safety issues such as more frequent evacuations and closing areas in danger zones.

ACTIONS:

- Develop communication materials for the public about flooding issues and why we don't rebuild in flood-prone areas.
- Design new infrastructure to be flood resistant.
- Use green stormwater management (e.g., wetlands) and green design ideas from the Bureau of Facility Design and Construction.
- Reinvigorate existing road closure criteria.
- Collaborate with the Bureaus of Topographic and Geologic Survey and Facility Design and Construction to assess the risk of floods, sinkholes, and landslides on new construction or rebuilding projects.

VULNERABILITY: Cold water ecosystems, including native and stocked trout habitat, are at risk due to stream warming (High Risk). Riparian areas face several threats including warming stream temperatures, erosion and scouring due to heavy rain events, invasive species, and the decline of hemlock, which functions as thermal cover. In turn, these threaten trout, which is a keystone and indicator species for coldwater aquatic ecosystems. Although the Bureau of Forestry does not directly manage trout populations, it is responsible for managing and protecting clean water and implementing the Riparian Buffer Program.

ACTIONS:

- Use the Bureau of Forestry's Riparian Buffer Guidelines and Brook Trout Conservation Plan to maintain coldwater habitat.
- Restore riparian buffers.
- Plant conifers such as red spruce, resistant hemlock, or white pine along streams for thermal cooling. Refer to DCNR's hemlock conservation plan for guidance on which species to choose.
- Add coarse woody debris to streams to improve trout habitat.
- Educate the public about the benefits of thermal cover and woody debris in streams.
- Assess and prioritize old dams lacking bottom release, with the ultimate goal to remove them.
- Assess groundwater sources in state forests and develop land protection standards that would improve high-quality trout streams.
- Review permitting standards for development of residential wells on state forest land to reduce impacts on water recharge.
- Ensure culverts, bridges, and stream crossings allow for connectivity of cold-water stream communities.

VULNERABILITY: More frequent, severe, and widespread forest pest outbreaks will result in increased tree mortality and management and treatment costs (High Risk). Forest pests, including insects, pathogens, and other herbivores, will influence forest composition, and the loss of some tree and understory species may reduce the diversity of the current forest. The loss of a keystone species could be catastrophic for some ecosystems (e.g., hemlock mortality amplifying the warming of trout streams). These changes will affect many facets of the bureau's responsibilities and planning efforts and may take resources away from other programs. Controlling these pests increases a forest's ability to withstand and adapt to climate change.

ACTIONS:

- Reduce the impact of biological stressors, such as insects and pathogens, which can interact to amplify the effects of climate change on trees. Actions to manipulate the density, structure, or species composition of a forest may improve the ability of forests to resist biological stressors.
- Identify and prioritize high-value forests to monitor for new/existing threats.
- Include the effects of climate change on long-term forest sustainability when developing pest response plans by using forest impact models (e.g., Tree Atlas, Landis).
- Manage for a diversity of species and forest types in landscapes that have seen significant damage and mortality from forest pests to increase resilience to climate change.
- Manage herbivory to promote regeneration of desired species.

Invasive Japanese stiltgrass, Forbes State Forest

VULNERABILITY: The number, growth rates, and abundance of invasive plant species are expected to increase in aquatic and terrestrial habitats (High Risk). In aquatic ecosystems, invasive species increase the potential for choked waterways, fish kills, toxic water, and harmful algae blooms. In terrestrial ecosystems, invasives may disrupt succession as they outcompete native tree regeneration in the understory. Increased competition may reduce diversity or contribute to species extirpation. Changes in species composition are also expected to influence fuel conditions and fuel loads for fires.

ACTIONS:

- Develop triage plans to control invasive species using the bureau's Early Detection and Rapid Response protocol.
- Identify nonnative species that are not invasive and that may serve important forest ecosystem functions in a changing climate.
- Work with the PA Natural Heritage Program and the PA Invasive Species Council to identify new species coming from other states.
- Investigate new methods of invasive species control, including biocontrol agents.
- Increase the capacity of the bureau to remove invasive species by participating in state programs or other ongoing efforts.
- Educate the public about the importance of invasive species management.
- Seek additional funding to combat invasives.

VULNERABILITY: Populations of rare, threatened, and endangered species, especially those near the edge of their range in Pennsylvania, are expected to decline faster and possibly disappear because of climate change and other stressors (High Risk). Some species that are common now could become rare and new species may move into the state. Decisions will need to be made as to whether those new species should be listed as rare, threatened, or endangered. It's also possible that some species that were listed in the past may become more competitive under warmer conditions and may even become problematic. Lotus, for example, was listed as a species of concern 20 years ago and is now considered problematic. Detecting changes in species composition will require more field work and monitoring.

Timber rattlesnake, Tuscarora State Forest

ACTIONS:

- Identify plant and animal species in Pennsylvania that are most at risk from climate change based on analyses using the Climate Change Vulnerability Index.
- Review and expand monitoring to ensure that changes in natural communities, species distribution, and populations are detected.
- Identify and conserve species, natural communities, and unique sites at risk from climate change.
- Consider establishing reserves for at-risk or displaced species.
- Manage habitats over a range of sites and conditions to increase ecosystem redundancy across the landscape.
- Promote landscape connectivity by reducing habitat fragmentation and creating migration corridors through reforestation and restoration.
- Work with other state and federal agencies, land conservancies, and scientific institutions across a species range to ensure a holistic approach to conservation.
- Develop conservation plans and protocols for new species moving into the state and declining populations of once common species (e.g., ash).

VULNERABILITY: Increased frequency of wildfire, blowdowns, and other natural disturbances will create challenges for operations and public safety (High Risk). There will be an increased need for maintenance, clean-up, and communication with the public. Additionally, the cost of managing and maintaining ecosystems may also increase, depending on an ecosystem's tolerance for disturbance. With increased disturbance, invasive species are also expected to increase. It will be necessary to reduce the risk and long-term impacts of severe disturbances.

ACTIONS:

- Reduce the severity or extent of disturbance by altering forest structure or composition to reduce the risk of wildfire or storm damage.
- Prepare for intensifying disturbances by developing plans in advance, thereby allowing a faster and better coordinated response.
- Add resources as needed to respond to disturbances (e.g., equipment for salvage and wildfire suppression).
- Promptly revegetate sites after a disturbance.
- Build capacity to respond to blowdown and fire hazards by training staff and volunteers.
- Continue working with local and state emergency management agencies to share resources.
- Develop protocols for incorporating climate change into restoration planning after natural disasters, including salvage where necessary and appropriate, and invasive plant monitoring and management.
- Use drought monitoring and fire modeling to help predict wildfire risk and danger.

VULNERABILITY: Hotter summer temperatures combined with moisture deficits are expected to increase the risk of wildfire (High Risk). Compared to the western U.S., fire has not been a major disturbance in Pennsylvania, but that is likely to change. There is already evidence of an extended fire season, with fires now happening year-round, not just in spring and fall. Demand for state resources to deal with emergency management, including assistance to the West and South Compacts, is expected to increase.

ACTIONS:

- Apply for more funding for fire-wise communities to reach more people and reduce the risk and spread of wildfire.
- Restore fire to fire-adapted ecosystems and use prescribed fire to conduct fuel mitigation in wildland urban interface areas for fire-wise communities.
- Develop new ways to communicate about fire hazards and fire safety with state forest users and adjacent landowners.
- Increase resources for responding to disturbances, including trained firefighters and equipment for salvage and wildfire suppression.
- Alter forest structure or composition to reduce risk or severity of wildfire.
- Establish fuel breaks to slow the spread of catastrophic fire.

VULNERABILITY: Public and political pressure to respond to climate change is increasing (Medium-High Risk). Climate change is not fully integrated into the bureau's planning or funding and program priorities.

ACTIONS:

- When developing land conservation and funding priorities, consider the impacts of climate change and the role those lands might play in habitat connectivity and forest carbon sequestration.
- Integrate climate change into all bureau plans (i.e., forest district plans, State Forest Research Management Plan, Bureau of Forestry strategic plan, etc.).

Prescribed fire

Dog tick

VULNERABILITY: Human health and safety concerns such as tick and mosquito-borne diseases, severe storms, heat-related illness, and poor air quality are becoming more of a concern (Medium-High Risk). The number, geographic distribution, and length of time during the year that ticks and mosquitos are active have all been increasing, thereby increasing employee and visitor exposure to vector-borne diseases such as Lyme disease. Visitors may also be at greater risk of heat-related illness and dehydration on hot days, and severe weather is expected to increase the need for emergency management services and storm-safe areas. Staff may need to spend more time on hazard tree removal, salvage operations, and risk assessment and maintenance of public use areas and campgrounds. Severe weather and vector-borne illnesses are also expected to increase worker absences and worker's compensation.

ACTIONS:

- Train staff about climate-related threats and threat-planning, and to be aware of shifts in the weather and the resulting impacts.
- Adjust field season planning and scheduling to minimize exposure to hazards.
- Staff should be prepared for hazards in the field by carrying sufficient water, safety gear, first aid supplies, etc.
- Purchase additional tick repellent products for use in the field, such as permethrin-treated clothing.
- Increase monitoring and control of ticks and mosquitos.

VULNERABILITY: Warmer temperatures may result in water deficits, including short term drought (Medium-High Risk). The risk of drought-related stress on vegetation is expected to be widespread, thereby increasing fire risk. Shale areas may be especially vulnerable to drought. Extended drought may also cause lake levels to drop, which could stress aquatic vegetation, trout streams, and other fisheries. Lower lake levels could also reduce water-based recreation.

ACTIONS:

- Restore on-site hydrology and connectivity to forested wetlands and lowlands, and increase water retention and storage for groundwater recharge.
- Maintain water storage capacity of forest soils, especially in shallow forest soils, by optimizing stocking to increase humus depth.
- Moderate surface water temperature increases by increasing canopy cover.

VULNERABILITY: Milder winters will reduce opportunities for winter recreation, such as snowmobiling, as well as frozen ground, increasing stress on forest roads during timber harvest operations (Medium-High Risk). The bureau will need to re-evaluate how it allocates money and personnel for winter recreation. Changing ground conditions may affect timber contracts if more time is required to complete the sale, and less predictability in harvest timing may result in lost revenue.

ACTIONS:

- Incorporate climate change considerations into recreation planning and resource allocation.
- Extend timber contracts to later in the winter season in vulnerable areas.

VULNERABILITY: Interacting stressors such as insect pests, pathogens, and climate change will, and are, affecting native trees and native wild plants (e.g., hemlock, ash). Species composition is expected to change due to the decline of some species, increases in others, hybridization, and immigration of southern species (Medium-High Risk). These changes can lead to disruption of ecosystem processes and functions (especially when a keystone species is lost), as well as loss of diversity in tree species, understory plants, insects, and wildlife. Adding to these stressors are forest regeneration failures compounded by previous land use changes and forest fragmentation that impedes the movement of species. As conditions continue to change, decisions will need to be made as to which tree species the department plants, which is difficult to determine since species that will thrive in future conditions may not do well now. Additionally, as new species move in, the department will need to establish guidelines regarding their status and whether to list them as species of concern.

ACTIONS:

- Conserve key tracts of land through acquisitions and easements that enhance forest connectivity and potential migration corridors.
- Sustain ecological functions, species diversity, and diverse age classes in forests.
- Determine the potential impacts of climate change on native wild plant and tree species.

Tuscarora State Forest

- Facilitate forest community changes by favoring native tree species and genotypes that are expected to be adapted to future conditions, managing for species with wide moisture and temperature tolerances, establishing new mixes of native species, moving at-risk species to locations that are expected to provide suitable habitat when practicable, and guiding change in species compositions during the early stages of stand development.
- Allow for areas of natural regeneration to test for future-adapted species.
- Realign significantly disrupted ecosystems to meet expected future conditions.
- Introduce new tree species that are better adapted to future conditions, but only to fill ecological or economic gaps created by the loss of native trees, and only after careful scientific analysis of potential impacts on the ecosystem.
- Reduce tree densities through silvicultural thinning, focusing on trees likely to be ill-suited to future climate conditions, thereby making more space available for trees better adapted to a warmer climate. Prioritize these treatments based on funding.
- Permit the use of seeds, germplasm, and other genetic material from across a greater geographic range.

VULNERABILITY: Climate change impacts will vary across the landscape according to elevation, topography, aspect, slope, and other variables (Medium-High Risk). Some areas will see significant impacts, while more resistant habitats will become increasingly important for conservation planning and may influence where and how conservation dollars are spent.

ACTIONS:

- Practice adaptation at the forest stand level.
- Identify and conserve biological legacies and unique ecological sites.
- Establish reserves to maintain ecosystem function.
- Protect or create refugia harboring species and ecosystems at risk from climate change.

Frost damage

VULNERABILITY: Climate change is disrupting the timing of natural cycles such as migration, emergence from dormancy or hibernation, and leaf development and blooming (Medium-High Risk). These phenological changes result in mismatches between predators and prey, pollinators and the plants that depend on them, and frost damage to trees that bud or flower during early warm spells prior to the last freeze. This can impact recreation opportunities such as fall foliage viewing, increase damage from invasive species, reduce forest regeneration, and lead to cascading ecological impacts.

ACTIONS:

- Integrate observations of phenological changes (i.e. arrival of migratory birds, nesting dates, etc.) with predictive models to help inform conservation planning.

Mitigation and Carbon Sequestration

Forest ecosystems play a critical role in the global carbon cycle and offset a significant portion of U.S. annual greenhouse gas emissions. The capacity of forest ecosystems to absorb and sequester carbon depends in large part on their health, productivity, resilience, and ability to adapt to changing conditions. The Bureau of Forestry can increase forest carbon sequestration through forest management and afforestation.

ACTIONS:

- Pursue a policy of no-net-loss of forest cover and work to increase forest carbon stocks by increasing forest acreage.
- Increase forest carbon sequestration across the landscape by promoting suitable species and using forest management techniques to promote forest growth and increase stocking levels when possible.
- Limit emissions associated with disturbance to soils and burning fossil fuels.
- Utilize durable wood-based products whenever possible in construction projects.

Climate Change Vulnerabilities Not Addressed

Listed below are climate change vulnerabilities that were identified as being low to medium risk. They should not be viewed as unimportant, but rather don't present as immediate a threat, or limited staff and financial resources preclude them from being addressed at this time.

- Hotter summers may result in increased energy demand for cooling offices, shops, and facilities. May have to cool buildings not currently air-conditioned (Medium Risk).
- Land acquisition may change with changing needs based on climate vulnerabilities (e.g., for migration corridors, connectivity, landscape position, refugia, etc.) (Medium-Low Risk).
- Temperature extremes (e.g., very hot days) may reduce public participation in deer hunting, which has already declined, but not necessarily due to climate change (Low Risk).

BUREAU OF FACILITY DESIGN AND CONSTRUCTION ADAPTATION PLAN

The Bureau of Facility Design & Construction manages the design and construction of Pennsylvania's state park and state forest infrastructure projects. It provides multi-disciplined technical support in the areas of project design, project inspection, construction management, contract administration, and surveying, and other technical advice and consultation. The bureau already employs many climate change adaptation strategies through its use of green building design and best management practices. These strategies include:

- Designing buildings with highly insulated wall envelopes to provide interior comfort even in extreme hot or cold weather.
- Use of geothermal heat pumps that provide clean and renewable energy for heating and cooling and hence reducing carbon emissions.
- Using grade control structures, humps, and water bars to reduce velocity and redirect flow.
- Redesigning road surfaces from inslope to outslope.
- Increasing ground cover and vegetated "roughness" of slopes to slow runoff.
- Incorporating soil stabilization techniques into road design to minimize soil shrinking and swelling due to moisture changes.
- Improving freeze-thaw resistance of concrete.
- Ensuring that bridge joints can accommodate anticipated thermal expansion.
- Regrading of unpaved roads to minimize erosion.
- Decommissioning and revegetating haul roads or converting them to other uses, where practical, such as trails.
- Rerouting high-risk trails.
- Removing culverts on haul roads after harvesting operations are complete.

Working with the Green initiative team, the bureau has developed a new policy on selection of buildings to be certified for sustainability. Sustainable buildings possess climate change adaptation features like highly insulated wall envelopes that help ensure a comfortable building interior in extreme cold or extreme hot weathers.

Climate Change Vulnerabilities and Adaptation Actions

VULNERABILITY: **There is a staff shortage in this bureau that amplifies all other climate-related impacts and vulnerabilities (High Risk).** The bureau will need additional staff to meet the challenges presented by climate change. Without additional people, more of the bureau's budget will need to be spent on consultants, which will reduce the amount of money available for construction projects. Additionally, existing staff will need to be trained on climate-related issues and technologies.

ACTIONS:

- Hire more staff to fill currently open positions.
- Provide staff training on climate change and related new equipment and technology.

VULNERABILITY: **Increased flooding in wide floodplains is likely to result in more frequent overtopping of roads, especially where bridge approaches are already prone to washing out (High Risk).** Most approaches are stone and thus more vulnerable to washing out.

ACTIONS:

- Identify state forest areas that are most vulnerable to washing out based on bridge reports, location in low-lying areas, or other indicators.
- Pave bridge approaches with asphalt in vulnerable areas and armor the bank slope with riprap to reduce the possibility of washout.
- Use alternative crossing structures designed to be overtopped and that can withstand impacts by woody debris or ice during floods.
- Reroute roads out of floodplains when practicable.
- Educate other bureaus on flooding issues and how to avoid rebuilding in flood prone areas.

Road flooding

VULNERABILITY: Increased flooding and runoff is likely to overwhelm storm drains and pipes and result in damaged infrastructure (High Risk). Flood control and stormwater design is likely to become more challenging with more precipitation and flooding. Stormwater conveyance structures (culverts, pipes, etc.) may be undersized, contributing to increased erosion and washouts of roads, trails, and other infrastructure. Proper stormwater design is critical but time consuming, and the bureau's staff is already undersized.

ACTIONS:

- Use state climatologist data or other high-quality climate records to identify trends in 25-year, 50-year, 100-year, and 500-year floods.
- Reassess stormwater drain measures and improve all stormwater conveyance systems to accommodate larger flows.
- Use standard bridge reports and historical flood data from the state climatologist to assess culvert size and identify those that are inadequate for increasing extreme water events.
- Enlarge undersized culverts, considering the uncertainty and frequency of flood events and using FDC's recently adopted *Stream Crossing Culvert Practices for Aquatic Organism Passage.*
- Use bottomless culvert designs to allow for sediment and debris to safely pass during a flood.
- Reconnect stream channels to the riparian floodplain to reduce shear velocities and instream energy, leading to reduced scour.
- Communicate the importance of upstream protection of stream channels.

VULNERABILITY: Increased intensity of rainstorms, coupled with aging or failing infrastructure, could result in greater hydraulic overload of wastewater treatment facilities and surcharging of collection/conveyance systems (High Risk). Overloaded treatment systems may result in ineffective treatment, and surcharge/overflow issues may result in health and safety issues. Old infrastructure (such as bad pipe joints, offset manhole frames, etc.), combined with more frequent extreme rainfall events, can cause hydraulic overload, weaken waste strength, and ultimately create difficulties meeting regulatory requirements. This may be exacerbated when outside entities contribute flows to DCNR's collection/conveyance systems.

ACTIONS:

- DCNR system operators should inspect the integrity of collection/conveyance systems more frequently (at least annually).
- Identify and repair systems that have excessive inflow/infiltration.
- Tie DCNR systems into larger municipal systems where practicable. This will allow the department to focus on tightening its system rather than plant operations.
- Provide dedicated regional and central office staff to coordinate and support sewage treatment options.

VULNERABILITY: Warmer lake temperatures may result in warmer water temperatures downstream from dams (Medium-High Risk). Warmer water downstream is expected to stress fish and other aquatic organisms and promote algae and aquatic invasives. The Bureaus of Forestry and State Parks are likely to request modifications or removal of dams to address these concerns, which will be costly for those bureaus. Because about 75 percent of DCNR dams have spillways with uncontrolled release, FDC expects to spend more staff time and funding to address these impacts.

ACTIONS:

- Install low-level water releases where practicable to release cooler water from deeper within lakes.

VULNERABILITY: Increased flooding and runoff may exacerbate problems with aging bridge infrastructure and result in bridge collapse (Medium-High Risk). FDC will likely see an increased workload identifying at-risk bridges, responding to infrastructure failure, and designing replacement bridges.

ACTIONS:

- Identify bridges that are susceptible to flooding and monitor them during large storm events.
- Deploy flood-proofing on existing high-risk bridges.
- Incorporate flood-proof designs, such as reinforced bridge abutments, during bridge replacement projects so that they can handle larger flows and accumulation of debris.
- Redesign bridges using flow rates based on the most recent data or bankfull totals.

Streambank improvement, Pymatuning State Park

VULNERABILITY: Heavy rain events and flooding may result in more washouts of stream embankments, especially unprotected embankments that run parallel to roads (Medium-High Risk). Road closures may increase and repetitive repair of flood-prone embankments will become more common.

ACTIONS:

- Add riprap or plant vegetation on stream banks to stabilize soil based on velocity of the stream.
- Add bends and unchannelize streams where possible to reduce stream velocity and scouring.

VULNERABILITY: Extreme precipitation may result in increased siltation and sedimentation in lakes (Medium-High Risk). Very shallow lakes may require dredging or other costly measures to sustain adequate pool levels for recreation.

ACTIONS:

- Evaluate water depths every 2 to 3 years to identify shallow areas that need maintenance.
- Dredge lakes to remove sedimentation, and work with the Bureau of State Parks to determine where to deposit the dredged material so that it doesn't return to the stream.
- Support the Riparian Buffer Program wherever possible to help reduce erosion and siltation that ultimately ends up in lakes. FDC can evaluate projects within and along the streams and limit the encroachment of the project into these zones. Where encroachment is expected, FDC can recommend and provide proper re-vegetative cover for a stream buffer which would coincide with the standards outlined in DCNR Concept for Multifunctional Riparian Forest Buffers.

VULNERABILITY: Warmer temperatures may result in increased evaporation, which may result in lower lake levels (Medium-High Risk). Some dams are required to have minimum flow releases, resulting in even lower water levels. The potential inability to sustain normal pool levels during peak recreational seasons could impact boating, swimming, fishing, marinas, and docks.

ACTIONS:

- Evaluate the operation of each dam and determine impacts downstream when water levels are reduced.
- Employ measures to compensate for low flows such as releasing compensation flow downstream to address conservation or recreation impacts.
- Evaluate the impacts of lower water levels on lake infrastructure.

Pine Grove Furnace State Park

VULNERABILITY: More frequent flooding may result in dam overtopping or dam failure (Medium-High Risk). Higher pool levels could cause additional pressure on earthen embankments and cause them to become unstable. DCNR owns ~50 high-hazard and significant-hazard dams, which have the potential for loss of life or damage to infrastructure. Many dams also have inadequate spillways.

ACTIONS:

- Retrofit or upgrade dams to meet Department of Environmental Protection (DEP) dam safety requirements.
- Evaluate and modify spillways to help pass large flood flows.
- Collaborate with DEP to evaluate and identify the high-hazard dams with the highest potential for overtopping and failure. Develop a prioritized list of those that need to be rehabilitated.

VULNERABILITY: Changes in temperature, precipitation, growing season, and other climate-related variables may result in changes in suitable habitats and distribution for trees, shrubs, and other landscaping plants (Medium-High Risk). Combined with other threats such as insect pests and disease, common landscaping trees and plants may no longer be suitable. There is also increased concern over public safety due to hazard trees.

ACTIONS:

- Evaluate which tree species are likely to do well under a range of future climate conditions.
- Develop a triage plan to deal with nonnative invasive species.
- Manage vegetation around buildings to prevent storm damage.

VULNERABILITY: Alternating droughts and heavy rain may reduce the quality and/or quantity of ground and surface water used as drinking water sources (Medium-High Risk). These water sources may have higher concentrations of pathogenic microorganisms, algae, minerals, or contaminants, making them unsafe or resulting in poor taste and odors. Fine materials associated with runoff and erosion can cause damage to filter units, resulting in increased maintenance costs.

ACTIONS:

- Maintain buffers around surface water sources to minimize runoff, and work with landowners upstream to support the DCNR Riparian Buffer Program.
- Utilize proper well-head protection methods to minimize the risk of groundwater contamination.
- Tie into municipal water systems when possible to avoid the need to treat water and to minimize the amount of distribution lines.
- Increase the frequency of system operator inspections for DCNR distribution systems (annually at minimum), and identify and repair systems with excessive losses.
- Provide dedicated regional and central office staff to coordinate and support water treatment operations.
- Adjust withdrawal levels from reservoirs if practical.

VULNERABILITY: More frequent and severe hot and cold temperature extremes may result in increased energy demand to meet human comfort and practical needs (Medium-Risk). Building envelopes and HVAC systems designed at today's standards may not be able to satisfactorily perform under harsher conditions.

ACTIONS:

- Develop and enforce more stringent building design and energy conservation standards that will perform well under increasing temperature extremes throughout a building's life span.
- Implement energy reduction strategies such as automated lighting controls, occupant energy waste reductions, and increased use of renewable energy sources.
- Implement passive solar and solar thermal conservation strategies such as roof overhangs, tinted glazing, highly insulated windows, mass wall construction, low-heat absorbing materials, and expanded landscaping to help control glare, limit thermal gain/loss, and moderate the impact of temperature extremes on indoor environment.
- Prioritize the use of geothermal systems that utilize constant ground temperatures not impacted by outside weather extremes instead of using air heat pumps or fossil fuel burning systems for heating and cooling.
- Implement preventive maintenance schedules and re- or retro-commissioning of building systems to ensure operation at peak design and efficiency.
- Expand building occupant education about energy reduction techniques, such as adjusting blinds and limiting artificial lighting and electrical equipment use during high temperature events.
- Increase FDC staff technical knowledge to foster innovative solutions.

Geothermal heating system, Kinzua Bridge State Park

Climate Change Vulnerabilities Not Addressed

Listed below are climate change vulnerabilities that were identified as being low to medium risk. They should not be viewed as unimportant, but rather don't present as immediate a threat, or limited staff and financial resources preclude them from being addressed at this time.

- Warmer air temperatures will increase lake temperatures, which will be more susceptible to vegetation growth, algae blooms, microbial issues, and changes in aquatic species (Medium Risk).
- Changes in the timing and nature of precipitation (more extreme rain events) may result in increased flooding in areas that are not currently considered floodplains (Medium Risk).
- Extremely hot days combined with periods of short-term drought may result in increased risk of wildfire, which may put structures at risk (Medium Risk).
- Increased temperature variability, amount or pH of precipitation, etc., may increase or decrease nutrient digestion rates in wastewater systems (Medium Risk).
- Decreasing rainfall and increasing drought conditions may result in reduced groundwater supply, and consequently wells may go dry (Medium-Low Risk).
- Extreme high temperatures may result in pavement softening because asphalt-covered surfaces are more susceptible to damage during heat waves than concrete surfaces (Medium-Low Risk).
- Increasing frequency and severity of extreme weather events may result in increased damage to infrastructure and less time available for outdoor construction projects (Medium-Low Risk).
- Warmer winters and less snow may result in shifting public use, such as less opportunity for cross-country or downhill skiing, snowmobiling, and other winter recreation activities (Medium-Low Risk).
- Increases in maximum temperatures, heat extremes, and multiday heat waves will be worse in urban areas (heat island effect) and may result in power brown-outs (Medium-Low Risk).

BUREAU OF RECREATION AND CONSERVATION ADAPTION PLAN

The Bureau of Recreation and Conservation (BRC) is guided by the knowledge that:

- Counties, communities, and partners across the commonwealth have control of substantial conserved lands, currently estimated at more than 700,000 acres. These lands include eased lands, 6,000 local parks, community open space lands, and natural areas. Any effort to influence the long-term sustainability of Pennsylvania's natural resources must involve communities and other local partners.
- Natural, heritage, and recreational resources that are connected to a community contribute significantly to its citizens' quality of life.
- The economy and health of our communities and citizens are directly tied to the availability of open space and recreational and outdoor opportunities.
- A lack of planning, lack of connection to nature and parks, and lack of coordinated government services contribute to the decline of our communities and the health of their citizens.
- Citizens who appreciate the outdoors and have access to recreational opportunities, creeks, trails, and paths are more likely to enact a natural resource stewardship ethic.

Pennsylvania Grand Canyon, Leonard Harrison State Park

Climate Change Vulnerabilities and Adaptation Actions

VULNERABILITY: **Shortage of personnel knowledgeable in climate change science and adaptation (High Risk).** The impacts of climate change, such as changes in habitat, movement of species, and changing natural systems, will require new partnerships with other bureaus and science partners.

ACTIONS:

- Utilize expertise available within and outside the agency to help incorporate green infrastructure guidelines and climate change adaptation into the bureau's work.
- Organize/sponsor climate change forums to expand staff knowledge.
- Provide climate change outreach and training opportunities and materials to all BRC's partners, including municipalities and Heritage Areas.

VULNERABILITY: **Climate change impacts will occur across the landscape, necessitating changes in land conservation priorities. The criteria used by the bureau and other conservation organizations to develop those priorities do not take climate change into account (Medium-High Priority).** Incorporating climate change into BRC's priorities could lead to more resilient landscapes, the funding of mitigation and adaptation plans for grantees, and education programs for landowners.

ACTIONS:

- Incorporate climate change considerations into grant selection criteria and stewardship plans. Consider modifying scoring criteria to favor applications that evaluate climate change impacts such as flooding, drought, changes in recreation seasons, etc.
- Encourage habitat connectivity in land stewardship plans.
- Launch an outreach campaign that promotes the climate resilient strategies identified in BRC's white paper, which is currently under development.
- Prioritize projects that address climate change impacts on species and natural communities, such as connecting parcels that facilitate the movement of species.
- Support Growing Greener 3 and other conservation efforts that support climate change adaptation.

Severe weather flooding

VULNERABILITY: Increased flooding will impact planning and investments, where recreation can occur, and ultimately which projects receive grant funding (Medium Risk). Some areas that typically didn't flood in the past now do, jeopardizing the "useful life" requirement of some grant-funded projects. Maintenance in parks and recreation areas is less efficient and costlier when elements and features are not sustainably designed and constructed. BRC will need to incorporate climate change and potential flooding risk into selection criteria for grants.

ACTIONS:

- Evaluate a site's propensity to flood and ensure that infrastructure improvements funded by the department are appropriate for the location or will be armored to make them resilient to flooding.
- Promote the use of BRC's Greening Parks and Sustainable Practices webpage by grantees for ideas about managing stormwater and best management practices.
- Prioritize investments that have lower long-term maintenance costs.
- Modify BRC's Green Park best practices as new information on flooding and impacts from severe weather becomes available.

VULNERABILITY: Changing recreation patterns and seasons due to milder winters and hotter summers will affect the types of projects that receive grant funding (Medium Risk). Municipalities may want to build more water-based recreation facilities and fewer winter-based recreation facilities. Additionally, the extended spring, summer, and fall recreation seasons will likely lead to increased maintenance costs for trails and other recreation infrastructure.

ACTIONS:

- Modify funding priorities based on input from municipal partners and changes in recreational demand.

Climate Change Vulnerabilities Not Addressed

Listed below are climate change vulnerabilities that were identified as being low to medium risk. They should not be viewed as unimportant, but rather don't present as immediate a threat, or limited staff and financial resources preclude them from being addressed at this time.

- New techniques, products, and processes may be needed to successfully manage lands, which will require additional training for staff and more public outreach, particularly in relation to invasive species control and water trails (Low Risk).

BUREAU OF STATE PARKS ADAPTATION PLAN

The primary mission of Pennsylvania state parks is to provide opportunities for enjoying healthful outdoor recreation and serve as outdoor classrooms for environmental education. In meeting these purposes, the conservation of the natural, scenic, aesthetic, and historical values of parks should be given first consideration. Stewardship responsibilities should be carried out in a way that protects the natural outdoor experience for the enjoyment of current and future generations.

South Mountain education program

Climate Change Vulnerabilities and Adaptation Options

VULNERABILITY: Shortage of knowledgeable personnel (High Risk). Currently there are only a few people within the bureau with climate change expertise. To address the impacts of climate change and educate park visitors about those impacts and our management actions to deal with them, we need staff that are competent and confident in this arena.

ACTIONS:

- Include discussion of climate-related impacts in relevant programs and projects.
- Train staff on climate change impacts, species range changes, weather pattern shifts, and other climate-related impacts.
- Use a variety of different tools and resources to provide climate change information and to explain the reasons behind our climate adaptation strategies.
- Recruit new staff that have a climate change background.

VULNERABILITY: Terrestrial ecosystem health is at risk because forests within state parks aren't being managed with climate change in mind (High Risk). The composition of many forests within state parks is changing. Inventories and management strategies for plant and animal communities that will thrive under future climate conditions are needed.

ACTIONS:

- As park management plans and resource management plans are updated, incorporate climate change considerations such as migration corridors, refugia, and changing species composition.
- Include climate change in monitoring and inventory work to fill data gaps. Partner with the Bureau of Forestry when possible.
- Increase staff to help with planning and management.

VULNERABILITY: Aquatic ecosystem health is at risk, as warming temperatures threaten native fish habitat in lakes and coldwater streams (High Risk). Higher water temperatures can lead to changes in acidification, dissolved oxygen levels, productivity, destratification, and more, potentially resulting in a reduction or shift in keystone species. This impact can be worsened by fishery management, inadequate management of riparian buffers, warm water released from dam spillways, increases in non-native aquatic vegetation, and harmful algal blooms, potentially leading to the decline of native fish species and reduced trout fishing opportunities.

ACTIONS:

- Install low-level water releases on dams when completing major rehabilitation projects to release cooler water from deeper in the lake and help lower downstream temperatures.
- Work with partners to address watershed issues occurring outside of state parks that magnify climate change impacts on downstream habitat within state parks.
- Maintain tree cover for shade along riparian buffers.
- Restore surface water connectivity to groundwater through floodplain and riparian wetlands restoration.
- Identify streams in high-value areas and manage them to maintain a coldwater habitat.
- Improve water quality and habitat for native aquatic flora and fauna through the elimination of impoundments having minimal recreational/operational value.
- Deploy monitoring equipment to determine impacts to lake and stream chemistry and temperature.
- Work with the Pennsylvania Fish and Boat Commission to determine if state park fisheries are being impacted.

Fly fishing

VULNERABILITY: Increased frequency and intensity of flooding and stormwater runoff may result in impacts to infrastructure and recreational and ecological resources (High Risk). Infrastructure potentially at risk includes dams, trails, roads and bridges, historical and cultural resources, and park buildings. Extreme rain events can also affect groundwater supply and reduce water quality below public thresholds for recreational use. Flooding may also lead to the closing of recreational facilities, strand park visitors, cause lakeshore and streambank erosion and sedimentation, and increase water treatment costs. These impacts are already being felt, and without existing federal funding to address them, several parks would have already been closed.

ACTIONS:

- Evaluate trail systems and make them more resilient to flooding and stormwater runoff.
- Identify and prioritize park amenities and systems that must be kept open after major storms.
- Remove park amenities from floodplains and palustrine buffers.
- Develop an assessment tool for new construction siting that evaluates potential climate and geological, biological, ecological, and social impacts.
- Assess and replace undersized drainage pipes, culverts, and stormwater conveyance systems that contribute to flooding and erosion issues.
- Restore floodplain and riparian wetlands to maximize floodwater storage and groundwater recharge.
- Work with the Bureau of Facility Design and Construction, townships, and developers to develop infrastructure resilient to heavy rain and runoff (e.g., improving wastewater treatment and municipal separate storm sewer systems, building more drainage basins, and designing green infrastructure).
- Evaluate, prioritize, and implement technologies and best management practices that decrease stormwater runoff.
- Evaluate the hydraulic capacities of state park dams, and where needed and practicable increase the size of the spillway or provide overtopping protection for earthen dam embankments.
- Remove dams no longer serving their intended purpose.

Bottomless culvert

VULNERABILITY: Increase in growth rate, abundance, and number of invasive species will contribute to habitat loss, and controlling them will require a significant increase in staff hours and funding (High Risk).

ACTIONS:

- Use existing decision-making processes to prioritize which invasive species will be addressed and/or which natural areas should be targeted for removal/control.
- Enforce and enable aquatic invasive species prevention strategies.
- Manage native understory species to prevent the establishment of invasives.
- Work with local nurseries to prevent the sale of invasive ornamental plants.
- Increase the staff complement tasked with invasive vegetation removal and suppression.
- Work with other state agencies responsible for land management (PennDOT, Dept. of Military and Veterans Affairs, etc.) to develop and adopt statewide invasive species best management practices.

VULNERABILITY: More variability in lake levels and discharges (High Risk). Hotter summers may increase demand for water-based recreation and at the same time result in lower lake levels due to increased evaporation and the potential for drought conditions. The potential inability to sustain normal water levels during the peak recreation season could impact boating, swimming, fishing, marinas, and white-water rafting. The situation would be even worse if water withdrawals are needed to maintain downstream flow levels and may even result in park closures.

ACTIONS:

- Shift visitor perceptions of an optimal water-based experience through a public education program.
- Develop low water level procedures for lakes and streams.
- Develop and implement a recreational opportunity spectrum that matches recreation with changing site conditions.
- Conduct water releases that mimic historical and natural variability.
- Work with other agencies that control water releases, such as the Army Corps of Engineers, Basin Commissions, etc., to maintain water levels and time water releases to minimize impacts on recreation.
- Consider other options for water-based recreation, such as additional swimming pools, alternatives to watercraft-based recreation, splash areas, and shifting the recreational focus from dammed lakes to natural flowing streams.
- Reevaluate appropriate boating restrictions.
- Develop and/or retrofit park lakeshore infrastructure to be adaptable to changing pool depths.
- Evaluate the potential for increasing normal pool levels at dams prior to the hotter summer months. Factors to consider would be operational impacts due to increased pool levels, environmental impacts, and structural impacts and costs to the dam structure.

VULNERABILITY: A longer recreation season will result in increased visitor impact on natural resources and increased stress on ecosystem components (High Risk). Very hot days during the summer may result in some parks exceeding visitor carrying capacity and turning visitors away or closing. Additionally, the winter period during which maintenance and special projects are conducted will become shorter. More staff and resources will be needed to deal with these impacts.

ACTIONS:

- Determine recreational sustainability and develop and apply recreational and resource carrying capacities.
- Limit access or types of uses in sensitive or high-use areas to minimize impacts (e.g., no horses on wet trails, close areas during the wet season, limit the number of people in some areas, etc.).
- Design greater flexibility in scheduling seasonal employees. Investigate other avenues for flexible staffing (e.g., alternate full-time position, staggered work seasons, permanent part-time employees, etc.).

VULNERABILITY: Forest composition will change, and some tree species may be lost due to climate change and other stressors (High Risk). Disruption of ecosystem functions and processes will occur as species, particularly keystone species, are lost. Examples include changes to riparian areas as hemlocks succumb to the hemlock wooly adelgid (which will no longer be kept in check by cold winter temperatures), impacts on the maple sugaring program as sugar maples decline, and an overall loss of biodiversity.

ACTIONS:

- Use forest impact models, such as the U.S. Forest Service's Climate Change Tree Atlas, to inform decisions on tree planting and management.
- Redefine expectations for future desired conditions and measures of success. Determine the ideal modified plant community based on predicted changes in forest plant communities due to climate change and manage the habitat for those species.
- Identify and solicit research to fill data gaps related to which species and natural communities will be best adapted to future climatic conditions.
- Manage species in decline while positioning for species and groups that are better adapted to future climate conditions that fill the same ecological functions.
- Identify climate refugia in state parks and manage for their persistence.
- Utilize assisted migration when warranted and only after stringent scientific review.

VULNERABILITY: Milder winters will lead to less winter recreation such as ice fishing, ice skating, snowmobiling, and cross-country skiing (High Risk). The bureau will need to re-evaluate how money is allocated to winter recreation, as well as how it allocates personnel resources.

ACTIONS:

- Reallocate funds to better match recreation demand and opportunities based on climate modelling and surveys.
- Expand specialized park (e.g., ski resorts) operations to incorporate warm-weather recreation in other seasons, thereby reducing impacts in low-snow years.
- Incorporate climate change considerations into project planning and resource allocation.

Climate Change Vulnerabilities Not Addressed

Listed below are climate change vulnerabilities that were identified as being low to medium-high risk. They should not be viewed as unimportant, but rather don't present as immediate a threat, or limited staff and financial resources preclude them from being addressed at this time.

- For some parks, impacts on well-known landmarks or landscape features (e.g., cathedral hemlock forest) could change a park's character and aesthetics and threaten its identity (Medium-High Risk)
- Less ice cover may result in increased shoreline erosion in some parks (e.g., Presque Isle) (Medium-High Risk).
- More extreme heat, storms, and increased fire risk may increase risks to human health and safety (Medium-High Risk).
- Changes in phenology can result in asynchrony with migratory species' arrival and food availability and general ecological disruption between plants, animals, and pollinators (Medium-High Risk).
- Rising temperatures, changing precipitation patterns and extreme weather events may result in changing distribution and abundance of ticks, mosquitoes, and other pests (Medium-High Risk).
- Increased number of storms and very hot days will result in more days that are unfavorable for outdoor summer programs (Medium-High Risk).
- Warmer, shorter winters may result in shifting public use and fewer winter-dependent education programs (Medium Risk).
- Extreme high temperature softens asphalt and damages roads and trails (Medium-Low Risk).
- Hotter summers may result in increased energy demand for cooling offices and recreational facilities/lodging (Medium-Low Risk).
- Extremes in temperatures (e.g., very hot days) may decrease public participation in hunting (Medium-Low Risk).
- A longer growing season may result in increased productivity for trees and crops, which may also be at higher risk of frost damage when new growth or buds are exposed to freezing temperatures (Medium-Low Risk).
- Increasing extreme temperatures and moisture will degrade nonpersonal media (e.g., waysides, signs) more quickly (Low Risk).
- There is a lack of policy on assisted migration and the use of nonnative species in state parks (Low Risk).

BUREAU OF TOPOGRAPHIC AND GEOLOGIC SURVEY ADAPTATION PLAN

The Mission of the Bureau of Topographic and Geologic Survey is, "To serve the citizens of Pennsylvania by collecting, preserving, and disseminating impartial information on the commonwealth's geology, geologic resources, and topography in order to contribute to the understanding, wise use, and conservation of its land and included resources."

Marcellus gas well

Climate Change Vulnerabilities and Adaptation Actions

VULNERABILITY: Lack of data and knowledge of subsurface geology such as faults, stratigraphy, reservoir characteristics, etc., which are needed before subsurface carbon sequestration can be considered (High Priority). The bureau is currently receiving funding to gather some of this data, which provides valuable information to the public and other DCNR bureaus. There is considerable interest in this work because Marcellus gas wells could potentially be used to sequester carbon (see mitigation options below).

ACTIONS:

- Create detailed information and maps on subsurface geology, particularly faults, stratigraphy, and reservoir characteristics.
- Explore possible collaboration with the Bureau of Forestry and exploration companies to gather seismic data.

VULNERABILITY: Increased demand for data and technical assistance due to the impacts of climate change (Medium-High Risk). Public education and outreach will become more important because of increased flooding, drought, dry wells, sinkholes, and other impacts. Hazard prediction, data collection, mapping, hydrographic modeling, and database updates will all be needed. Current staffing levels will be insufficient to meet the increased demand for technical assistance.

ACTIONS:

- Acquire new LIDAR data by partnering with the U.S. Geologic Survey or other organizations.
- Develop research projects that look for relationships between the timing and intensity of weather events and sinkholes and landslides.
- Develop science-based key messages dealing with geologic hazards for multiple audiences.
- Be prepared to respond to unanticipated novel issues.
- Assign a staff member as a climate change point-of-contact for the bureau to keep the agency informed on climate-related information and issues coming from the bureau.

VULNERABILITY: Increased flooding and stormwater runoff will impact groundwater supply and drinking water wells (Medium-High Risk). These impacts have already begun in some areas, and increasing demand on water sources will exacerbate these effects. Adding to the problem is a lack of detailed knowledge of the state's aquifer characteristics and lack of accountability of water well drilling companies.

ACTIONS:

- Advocate for water well construction standards.
- Work with legal counsel to resolve liability issues related to driller licenses.
- Incorporate public water well standards (ANSI/NGWA) into well drilling standards for driller licenses.
- Evaluate and characterize Pennsylvania's aquifers and their properties for modeling future impacts.

Carbon Sequestration

Carbon can potentially be stored underground in geologic formations. In addition to just sequestration, waste carbon dioxide can also be used to help move oil and gas from unproductive formations to recovery wells. This is called Carbon Capture Use and Storage. The bureau has identified several mitigation options that could facilitate this program.

- Communicate the co-benefits of this technology to the public and government agencies.
- Continue to participate in and advocate for regional studies and funding opportunities for subsurface carbon sequestration.

Climate Change Vulnerabilities Not Addressed

Listed below are climate change vulnerabilities that were identified as being low to medium risk. They should not be viewed as unimportant, but rather don't present as immediate a threat, or limited staff and financial resources preclude them from being addressed at this time.

- Increased energy demand could potentially increase the workload needed to keep the oil and gas database current (Medium Risk).
- Extreme heat and safety concerns related to climate change (e.g., more ticks, hazard trees, etc.) may shift the timing and length of fieldwork season (Medium Risk).
- Changes in snow cover and snow melt may reduce groundwater recharge. This, combined with an increased risk of drought and increased population pressure, may result in water shortages (Medium-Low Risk).

APPENDIX D - TOPICAL ADAPTATION PLANS

RIPARIAN CORRIDOR ADAPTATION STRATEGIES

Riparian areas face several impacts from climate change, including increased stream temperatures, erosion and scouring, invasive species establishment, and the decline of hemlock, which provides thermal cover for many streams. In turn, these changes threaten trout, which is a keystone and indicator species for coldwater aquatic ecosystems.

The following adaptation strategies will help those who fund, design, and implement riparian corridor restoration projects to achieve their goals in a changing climate. This list should be viewed as a menu from which to choose adaptation strategies that best fit project plans, management goals, and site and ecosystem characteristics.

Wherever possible, project plans should be descriptive in how a strategy will be implemented. For example, a plan should list:

- The climate change impacts that are being addressed and the adaptation strategies being implemented.
- Timing of the adaptation strategy.
- Equipment necessary to complete the adaptation strategy.
- Professional resources and materials.

STRATEGY: Restore and enhance hydrologic connectivity between riparian areas and the surrounding landscape (i.e., floodplains) by:

- Adding wetlands and swales in floodplains adjacent to creeks and rivers.
- Protecting more headwater streams through Farm Bill incentives and state programs.
- Vegetating intermittent ephemeral streams that are good at processing nutrients.

STRATEGY: Moderate stream temperature increases by increasing stream shading, especially in areas of cool water habitat such as low-order headwater streams. Ensure that tree species planted in buffers will survive hotter temperatures and soil conditions.

STRATEGY: Reduce soil erosion and sediment loading in rivers and streams. This can be accomplished by:

- Delaying harvests in multifunctional buffers following heavy rains.
- Retaining or adding coarse woody debris to enhance soil structure and stabilize the soil surface.
- Reducing bare-ground conditions adjacent to flowing waters and riparian buffers by revegetating or using man-made materials.
- Using livestock fencing to prevent grazers from trampling streambanks.

Forested riparian corridor

STRATEGY: Protect and restore native riparian forests and vegetative cover to conserve species at risk of decline, such as stream-side salamanders, and to increase water retention and uptake of soils to reduce the impacts of flood events, erosion, and sedimentation.

STRATEGY: Plant species expected to be better adapted to future conditions (See Appendix E).

- Use drought-tolerant plant varieties to help protect riparian buffers.
- In flood-prone settings, plant species that can tolerate more severe or lasting periods of inundation.
- Favor currently present species that have wide ecological amplitude and can persist under a wide variety of climate and site conditions.

STRATEGY: Prevent the establishment of invasive species in riparian areas. This can be accomplished by:

- Removing new populations and eradicating existing populations or seed sources of invasive plants upstream.
- Maintaining closed-canopy conditions to reduce the ability of light-loving invasive species to enter the understory.
- Managing herbivory to promote regeneration and growth of desired species.

STRATEGY: Prioritize riparian restoration on streams that are most likely to retain cool, late-summer flows.

STRATEGY: Facilitate natural community adjustments through species transitions. This can be accomplished by:

- Underplanting a variety of native species to increase overall species diversity and age structure.
- Avoiding species vulnerable to pest and diseases (e.g., ash, hemlock, etc.). Plant conifers such as red spruce, resistant hemlock, or white pine along streams for thermal cooling. Refer to DCNR's hemlock conservation plan for guidance.
- Removing unhealthy individuals of a declining species to promote other species expected to fare better. This does not imply that all individuals should be removed, and healthy individuals of declining species can be retained as legacies.
- Protecting healthy legacy trees that fail to regenerate while deemphasizing their importance in the mix of species being promoted for regeneration.

EMERGENCY MANAGEMENT ADAPTATION PLAN

Flooding, wind damage, severe weather, and wildfires are all expected to increase due to climate change. Of particular concern are fires in the wildland/urban interface, where the potential for loss of life and dwellings is high. Pennsylvania has a higher percentage of homes in the wildland-urban interface than any other state in the nation.

DCNR emergency response personnel are being called on more frequently to respond to these events both within and outside of the commonwealth. Since 1973, more than 150 crews from the Bureau of Forestry have been mobilized for deployment to aid with wildfire suppression and hurricane emergency aid throughout the lower 48 states and Alaska.


Wildfire

The climate change vulnerabilities and adaptation options listed below were identified by DCNR's emergency management staff. Because the department does not have the capacity to address the full suite of impacts and vulnerabilities, staff rated and prioritized the most important vulnerabilities to address over the next 3 to 5 years. More information on the risk analysis process can be found in Appendix B.

Climate Change Vulnerabilities and Adaptation Actions

VULNERABILITY: **Increasing temperatures, periodic drought, and significant reductions in winter snow cover have extended the length and severity of the state's fire season, which now extends later into the fall and begins earlier in the spring (High Risk).** This trend is expected to continue as climate change progresses. The department's ability to deal with the increased fire risk is compounded by outdated equipment and not enough staff and volunteers to fight the fires.

ACTIONS:

- Increase capacity of existing resources through additional training and experience.
- Increase resources for responding to fires, including more trained firefighters and new equipment for wildfire suppression.
- Strengthen existing cooperative relationships and develop additional cooperative relationships where possible.
- Use drought monitoring and fire modelling to predict wildfire risk and danger.
- Develop new ways to communicate wildfire risk and danger to the public.
- Increase use of prescribed fire on DCNR lands to make ecosystems more resilient to wildfires.
- Maintain capacity within the volunteer Forest Fire Warden program for wildfire response.

VULNERABILITY: **Climate change impacts such as flooding, wind damage, and ice storms will require more elaborate and extensive emergency response (High Risk).** These events are likely to result in damage to infrastructure and could also lead to the Pennsylvania Emergency Management Agency (PEMA) requesting DCNR resources (personnel, response teams, equipment, etc.) for situations outside of DCNR lands. Damage to trails and roads in state parks or state forests could result in stranded visitors, and repeated events may lead to long-term loss of access to some areas.

ACTIONS:

- Integrate climate change impacts into all phases of emergency management.
- Increase capacity of DCNR personnel to respond to emergencies.
- Provide Incident Command System (ICS) training to personnel throughout the department.
- Continue to develop relationships with PEMA and other state and local agencies to increase response effectiveness.

VULNERABILITY: **As the number of wildfires and severe weather events increases, our ability to respond will be challenged, particularly when multiple events occur (Medium-High).** The number of DCNR staff and volunteers available, their skill level, and the equipment needed may be insufficient, and we may need to call on the National Guard or out-of-state resources, which will result in delayed responses and significantly increased costs.

ACTIONS:

- Review and update preparedness activities based on changing risk profiles and their consequences.
- Anticipate emergency response challenges and develop new strategies to manage more frequent and complex disasters.
- Conduct exercises with other state and local agencies that are potential cooperators.

VULNERABILITY: **DCNR emergency response staff and teams are being called upon to respond to out-of-state events such as wildfires, hurricanes, and severe weather with greater frequency because of climate change (Medium-High).** When DCNR staff respond outside the commonwealth, they are not available to respond to emergencies arising within the state, impacting our readiness to respond. Additionally, this can impact the department's productivity, because responders are unavailable to perform their normal daily duties (DCNR staff spent 39,000 hours responding to out-of-state emergencies in 2017).

ACTIONS:

- Monitor staff time and balance commitments as needed.
- Invest in development of interagency partnerships, such as in dispatching and mobilizing resources, to ensure a balanced approach to emergency response workload.
- Continue to strengthen relationships with federal and state partners, such as U.S. Forest Service and PEMA.

APPENDIX E - CLIMATE CHANGE PROJECTIONS FOR INDIVIDUAL TREE SPECIES

Pennsylvania's forests will be affected by a changing climate during this century. These fact sheets summarize predicted changes in tree species habitat in four of Pennsylvania's physiographic regions. Two additional Pennsylvania regions, the Erie and Ontario Lake Plain and the Coastal Plain, were too small for analysis, so they were combined with the larger Mid-Atlantic region. Also included are projections of hardiness and heat zones, which can be used to determine if an area will be suitable for planting.

Mountainous view of state forest land

CLIMATE CHANGE PROJECTIONS FOR INDIVIDUAL TREE SPECIES

WESTERN ALLEGHENY PLATEAU (PENNSYLVANIA SUBREGION 1)

Pennsylvania's forests will be affected by a changing climate during this century. A team of forest managers and researchers created an assessment that describes the vulnerability of forests in the Mid-Atlantic region (https://forestadaptation.org/mid-atlantic/vulnerability-assessment). This handout is summarized from the full assessment, but focuses on one region in Pennsylvania. Model results for additional regions can be found online at (https://forestadaptation.org/PA-DISTRIB).

TREE SPECIES INFORMATION:
The DISTRIB model of the Climate Change Tree Atlas uses inputs of tree abundance, climate, and environmental attributes to simulate current and future species habitat under two climate scenarios. Results for "low" and "high" climate scenarios can be compared on page 2 of this handout.

Remember that models are just tools, and they're not perfect. Output from DISTRIB does not consider many biological or disturbance factors which favor or limit tree establishment, growth, or mortality. For example, the susceptibility of ash species to emerald ash borer is causing widespread mortality and it will likely do even worse than the model suggests. For the 30 most common species, we present such factors not included in the model that may cause species to do better or worse than models suggest.

Despite their limitations, models provide useful information about future expectations. It's important to think of these projections as indicators of potential change in the amount of suitable habitat for a species, but that human choices and other factors will continue to influence tree distribution, movement, and forest composition at individual sites.

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NIACS
Northern Institute of Applied Climate Science

www.forestadaptation.org

SPECIES	ADDITIONAL CONSIDERATIONS
LIKELY TO DECREASE	
American beech	Susceptible to beech diseases, very shade tolerant
Bigtooth aspen	Early-sucessional colonizer, susceptible to drought
Chokecherry	Shade intolerant, sensitive to browsing and competition
Eastern hemlock	Hemlock woolly adelgid causes widespread mortality
Quaking aspen	Early-sucessional colonizer, susceptible to heat and drought
Yellow birch	Good disperser, susceptible to fire, insects, and disease
MAY DECREASE	
American basswood	Tolerates shade, susceptible to fire
Black cherry	Susceptible to insects and fire, somewhat drought-tolerant
Chestnut oak	Establishes from seed or sprout, adapted to fire
Eastern white pine	Good disperser, but susceptible to drought and insects
Northern red oak	Susceptible to insect pests
Red maple	Competitive colonizer in many sites, disturbance-tolerant
Serviceberry	Competative colonizer, susceptible to drought
Sugar maple	Grows across a variety of sites, tolerates shade
Sweet birch	Susceptible to drought, fire topkill, and insects
White ash	Emerald ash borer causes widespread mortality
NO CHANGE	
American hornbeam	Tolerates shade, susceptible to fire and drought
Black locust	Early colonizer, but susceptible to locust borer & heart rot
Slippery elm	Shade-tolerant, susceptible to Dutch elm disease & fire
MIXED MODEL RESULTS	
American elm	Grows on a variety of sites, Dutch elm disease
Sassafras	Early-successional colonizer, susceptible to fire topkill
Yellow-poplar	Competitive colonizer tolerant of diverse sites
MAY INCREASE	
Eastern hophornbeam	Grows across a variety of sites, tolerates shade
White oak	Fire-adapted, grows on a variety of sites
LIKELY TO INCREASE	
Black oak	Drought tolerant, susceptible to insect pests and diseases
Black walnut	Good disperser, but intolerant of shade and drought
Blackgum	Shade tolerant, fire adapted
Flowering dogwood	Shade tolerant
Pignut hickory	Susceptible to bark beetles and drought
Scarlet oak	Establishes from seed/sprout, susceptible to fire/disease

SOURCE: Prasad, AM; Iverson, LR; Peters, MP; Matthews, SN. 2014. Climate change tree atlas. Northern Research Station, U.S. Forest Service, Delaware, OH. http://www.nrs.fs.fed.us/atlas.

FUTURE PROJECTIONS

The DISTRIB model uses Forest Inventory and Analysis (FIA) data to calculate an Importance Value (IV) for each species on the landscape in order to evaluate potential IV's at the end of this century (2070 – 2099). Those changes are classified in the table below as:

▲ **INCREASE**
Projected increase of >20% by 2100

● **NO CHANGE**
Little change (<20%) projected by 2100

▼ **DECREASE**
Projected decrease of >20% by 2100

★ **NEW HABITAT**
Tree Atlas projects new habitat for species not currently present

ADAPTABILITY

Factors not included in the Tree Atlas model, such as the ability to respond favorably to disturbance, may make a species more or less able to adapt to future stressors. Specific considerations are provided on page 1 for the 30 most abundant species.

+ high
Species may perform better than modeled

o medium

– low
Species may perform worse than modeled

SPECIES	FIA IV	MODEL RELIABILITY	LOW CLIMATE CHANGE (PCM B1)	HIGH CLIMATE CHANGE (GFDL A1FI)	ADAPT
American basswood	93	M	●	▼	o
American beech	520	H	▼	▼	o
American chestnut	8	M	●	▼	o
American elm	197	M	▼	▲	o
American hornbeam	139	M	●	●	o
American mountain-ash	3	M	▼	▼	-
Balsam fir	0	H	▼	▼	-
Balsam poplar	2	H	▼	▼	o
Bear oak; scrub oak	2	L	●	●	o
Bigtooth aspen	196	H	▼	▼	o
Bitternut hickory	23	L	●	▲	+
Black ash	5	H	▼	●	-
Black cherry	2021	H	●	▼	-
Black hickory	0	H	★	★	o
Black locust	159	L	●	●	o
Black maple	1	L	▼	▼	o
Black oak	159	H	▲	▲	o
Black walnut	70	M	▲	▲	o
Black willow	54	L	●	▲	-
Blackgum	123	H	▲	▲	+
Blackjack oak	0	M	★	★	+
Blue ash	0	L	▼	▼	-
Boxelder	38	M	●	▲	+
Bur oak	4	M	▼	▲	+
Butternut	9	L	●	▼	-
Chestnut oak	166	M	●	▼	+
Chinkapin oak	2	M	▲	▲	o
Chokecherry	126	L	▼	▼	o
Common persimmon	2	M	▲	▲	+
Cucumbertree	68	H	▲	▼	o
Eastern cottonwood	18	L	●	▲	o
Eastern hemlock	290	H	▼	▼	-
Eastern hophornbeam	121	M	●	▲	+
Eastern redbud	2	M	▲	▲	o
Eastern redcedar	0	M	★	★	o
Eastern white pine	111	H	●	▼	o
Flowering dogwood	183	H	▲	▲	o
Gray birch	2	M	▼	▼	o
Green ash	40	M	▲	▲	o
Hackberry	9	M	▲	▲	+
Honeylocust	1	L	●	▲	+
Jack pine	6	H	▼	▼	o
Loblolly pine	0	H	NA	★	o
Mockernut hickory	68	H	▲	▲	+
Mountain maple	2	H	▼	▼	+
Northern catalpa	2	L	▼	●	o
Northern red oak	540	H	●	▼	+
Osage-orange	9	M	●	▲	+
Paper birch	4	H	▼	▼	o
Pawpaw	2	L	●	●	o
Pignut hickory	80	H	▲	▲	o
Pin cherry	55	M	▼	▼	o
Pin oak	9	L	●	▲	-
Pitch pine	15	H	●	▲	o
Quaking aspen	163	H	▼	▼	o
Red maple	1763	H	●	▼	+
Red pine	27	M	▼	▼	o
Red spruce	5	H	▼	▼	-
Rock elm	5	L	●	▲	-
Sassafras	356	H	▲	●	o
Scarlet oak	73	H	▲	▲	o
Serviceberry	130	M	●	▼	o
Shagbark hickory	32	M	▲	▲	o
Shingle oak	25	M	▲	▲	o
Silver maple	24	M	▼	▲	+
Slippery elm	184	M	●	●	o
Sourwood	1	H	▲	▼	+
Striped maple	59	H	▼	▼	o
Sugar maple	783	H	●	▼	+
Swamp white oak	18	L	●	▼	o
Sweet birch	324	H	●	▼	-
Sycamore	22	M	▲	▲	o
Tamarack (native)	1	H	▼	●	-
Virginia pine	10	H	▲	▲	o
White ash	597	H	●	▼	-
White oak	304	H	●	▲	+
White spruce	13	M	▼	▼	o
Yellow birch	112	H	▼	▼	o
Yellow buckeye	11	M	●	●	-
Yellow-poplar	264	H	▲	▼	+

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CLIMATE CHANGE PROJECTIONS FOR INDIVIDUAL TREE SPECIES

NORTHERN ALLEGHENY PLATEAU (PENNSYLVANIA SUBREGION 3)

Pennsylvania's forests will be affected by a changing climate during this century. A team of forest managers and researchers created an assessment that describes the vulnerability of forests in the Mid-Atlantic region (https://forestadaptation.org/mid-atlantic/vulnerability-assessment). This handout is summarized from the full assessment, but focuses on one region in Pennsylvania. Model results for additional regions can be found online at (https://forestadaptation.org/PA-DISTRIB).

TREE SPECIES INFORMATION:

The DISTRIB model of the Climate Change Tree Atlas uses inputs of tree abundance, climate, and environmental attributes to simulate current and future species habitat under two climate scenarios. Results for "low" and "high" climate scenarios can be compared on page 2 of this handout.

Remember that models are just tools, and they're not perfect. Output from DISTRIB does not consider many biological or disturbance factors which favor or limit tree establishment, growth, or mortality. For example, the susceptibility of ash species to emerald ash borer is causing widespread mortality and it will likely do even worse than the model suggests. For the 30 most common species, we present such factors not included in the model that may cause species to do better or worse than models suggest.

Despite their limitations, models provide useful information about future expectations. It's important to think of these projections as indicators of potential change in the amount of suitable habitat for a species, but that human choices and other factors will continue to influence tree distribution, movement, and forest composition at individual sites.

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NIACS Northern Institute of Applied Climate Science

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SPECIES	ADDITIONAL CONSIDERATIONS
LIKELY TO DECREASE	
American beech	Susceptible to beech diseases, very shade tolerant
Quaking aspen	Early-sucessional colonizer, susceptible to heat and drought
Striped maple	Shade tolerant and easily established, susceptible to drought
Sugar maple	Grows across a variety of sites, tolerates shade
MAY DECREASE	
Bigtooth aspen	Early-sucessional colonizer, susceptible to drought
Black cherry	Susceptible to insects and fire, somewhat drought-tolerant
Eastern hemlock	Hemlock woolly adelgid causes widespread mortality
Eastern white pine	Good disperser, but susceptible to drought and insects
Red maple	Competitive colonizer in many sites, disturbance-tolerant
Serviceberry	Competative colonizer, susceptible to drought
Sweet birch	Susceptible to drought, fire topkill, and insects
White ash	Emerald ash borer causes widespread mortality
Yellow birch	Good disperser, susceptible to fire, insects, and disease
NO CHANGE	
American basswood	Tolerates shade, susceptible to fire
American hornbeam	Tolerates shade, susceptible to fire and drought
Eastern hophornbeam	Grows across a variety of sites, tolerates shade
Northern red oak	Susceptible to insect pests
MIXED MODEL RESULTS	
American elm	Grows on a variety of sites, Dutch elm disease
Chestnut oak	Establishes from seed or sprout, adapted to fire
Gray birch	Susceptible to leaf miners, cankers, and fire topkill
LIKELY TO INCREASE	
Bear oak: scrub oak	Shade intolerant, susceptible to fire topkill and flood
Black oak	Drought tolerant, susceptible to insect pests and diseases
Blackgum	Shade tolerant, fire adapted
Flowering dogwood	Shade tolerant
Mockernut hickory	Susceptible to fire topkill
Pignut hickory	Susceptible to bark beetles and drought
Sassafras	Early-successional colonizer, susceptible to fire topkill
Scarlet oak	Establishes from seed/sprout, susceptible to fire/disease
White oak	Fire-adapted, grows on a variety of sites
Yellow-poplar	Competitive colonizer tolerant of diverse sites

SOURCE: Prasad, AM; Iverson, LR; Peters, MP; Matthews, SN. 2014. Climate change tree atlas. Northern Research Station, U.S. Forest Service, Delaware, OH. http://www.nrs.fs.fed.us/atlas.

FUTURE PROJECTIONS

The DISTRIB model uses Forest Inventory and Analysis (FIA) data to calculate an Importance Value (IV) for each species on the landscape in order to evaluate potential IV's at the end of this century (2070 – 2099). Those changes are classified in the table below as:

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● **NO CHANGE** — *Little change (<20%) projected by 2100*

▼ **DECREASE** — *Projected decrease of >20% by 2100*

★ **NEW HABITAT** — *Tree Atlas projects new habitat for species not currently present*

ADAPTABILITY

Factors not included in the Tree Atlas model, such as the ability to respond favorably to disturbance, may make a species more or less able to adapt to future stressors. Specific considerations are provided on page 1 for the 30 most abundant species.

+ high — *Species may perform better than modeled*

o medium

– low — *Species may perform worse than modeled*

SPECIES	FIA IV	MODEL RELIABILITY	LOW CLIMATE CHANGE (PCM B1)	HIGH CLIMATE CHANGE (GFDL A1FI)	ADAPT
American basswood	108	M	●	●	o
American beech	1402	H	▼	▼	o
American chestnut	32	M	▲	▲	o
American elm	53	M	▼	▲	o
American hornbeam	166	M	●	●	o
American mountain-ash	4	M	▼	▼	-
Balsam fir	0	H	▼	▼	-
Balsam poplar	6	H	▼	▼	o
Bear oak; scrub oak	58	L	▲	▲	o
Bigtooth aspen	167	H	●	▼	o
Bitternut hickory	9	L	●	▲	+
Black ash	2	H	▼	▼	-
Black cherry	845	H	●	▼	-
Black hickory	0	H	NA	★	o
Black locust	25	L	▲	▲	o
Black oak	123	H	▲	▲	o
Black spruce	1	H	▼	▼	o
Black walnut	17	M	▲	▲	o
Black willow	16	L	▼	▲	-
Blackgum	75	H	▲	▲	+
Boxelder	6	M	●	▲	+
Bur oak	1	M	▼	▲	+
Butternut	13	L	●	▼	-
Chestnut oak	383	M	▲	●	+
Chinkapin oak	2	M	▼	▲	o
Chokecherry	32	L	●	▼	o
Cucumbertree	34	H	●	▼	o
Eastern cottonwood	3	L	▼	▲	o
Eastern hemlock	502	H	●	▼	-
Eastern hophornbeam	229	M	●	●	+
Eastern redbud	1	M	▲	▲	o
Eastern redcedar	11	M	●	▲	o
Eastern white pine	300	H	●	▼	o
Flowering dogwood	64	H	▲	▲	o
Gray birch	61	M	▲	▼	o
Green ash	11	M	●	▲	o
Hackberry	1	M	●	▲	+
Honeylocust	2	L	▼	▲	+
Jack pine	1	H	▼	▼	o
Mockernut hickory	52	H	▲	▲	+
Mountain maple	8	H	▼	▼	+
Northern catalpa	1	L	▼	●	o
Northern red oak	574	H	●	●	+
Northern white-cedar	0	H	▼	▼	o
Osage-orange	1	M	▼	▲	+
Paper birch	45	H	▼	▼	o
Pignut hickory	60	H	▲	▲	o
Pin cherry	38	M	▼	▼	o
Pin oak	9	L	●	●	-
Pitch pine	46	H	▲	▲	o
Quaking aspen	199	H	▼	▼	o
Red maple	2194	H	●	▼	+
Red pine	38	M	▼	▼	o
Red spruce	12	H	▼	▼	-
River birch	3	L	▼	▼	o
Sassafras	123	H	▲	▲	o
Scarlet oak	86	H	▲	▲	o
Serviceberry	235	M	●	▼	o
Shagbark hickory	20	M	●	▲	o
Shingle oak	3	M	▼	▲	o
Shortleaf pine	0	H	★	★	o
Shumard oak	0	H	NA	★	+
Silver maple	27	M	▼	▲	+
Slippery elm	29	M	▲	▲	o
Sourwood	1	H	▲	▲	+
Southern red oak	0	H	NA	★	+
Striped maple	234	H	▼	▼	o
Sugar maple	1037	H	▼	▼	+
Swamp white oak	4	L	●	●	o
Sweet birch	543	H	●	▼	-
Sweetgum	1	H	▲	▲	o
Sycamore	23	M	▲	▲	o
Tamarack (native)	20	H	▼	▼	-
Virginia pine	12	H	▼	▲	o
White ash	738	H	●	▼	-
White oak	444	H	▲	▲	+
White spruce	8	M	▼	▼	o
Winged elm	1	H	▼	▲	o
Yellow birch	171	H	●	▼	o
Yellow-poplar	49	H	▲	▲	+

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CLIMATE CHANGE PROJECTIONS FOR INDIVIDUAL TREE SPECIES

RIDGE AND VALLEY (PENNSYLVANIA SUBREGION 4)

Pennsylvania's forests will be affected by a changing climate during this century. A team of forest managers and researchers created an assessment that describes the vulnerability of forests in the Mid-Atlantic region (https://forestadaptation.org/mid-atlantic/vulnerability-assessment). This handout is summarized from the full assessment, but focuses on one region in Pennsylvania. Model results for additional regions can be found online at (https://forestadaptation.org/PA-DISTRIB).

TREE SPECIES INFORMATION:

The DISTRIB model of the Climate Change Tree Atlas uses inputs of tree abundance, climate, and environmental attributes to simulate current and future species habitat under two climate scenarios. Results for "low" and "high" climate scenarios can be compared on page 2 of this handout.

Remember that models are just tools, and they're not perfect. Output from DISTRIB does not consider many biological or disturbance factors which favor or limit tree establishment, growth, or mortality. For example, the susceptibility of ash species to emerald ash borer is causing widespread mortality and it will likely do even worse than the model suggests. For the 30 most common species, we present such factors not included in the model that may cause species to do better or worse than models suggest.

Despite their limitations, models provide useful information about future expectations. It's important to think of these projections as indicators of potential change in the amount of suitable habitat for a species, but that human choices and other factors will continue to influence tree distribution, movement, and forest composition at individual sites.

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SPECIES	ADDITIONAL CONSIDERATIONS
LIKELY TO DECREASE	
American basswood	Tolerates shade, susceptible to fire
American beech	Susceptible to beech diseases, very shade tolerant
American mountain-ash	Requires specific habitat, intolerant of fire and shade
Atlantic white-cedar	Requires specific habitat, intolerant of fire and drought
Balsam poplar	Vegetative resprout following fire
Bigtooth aspen	Early-sucessional colonizer, susceptible to drought
Black ash	Narrow requirements; Emerald ash borer causes mortality
Black spruce	Prone to sawfly and budworm attacks, drought-sensitve
Butternut	Prone to butternut canker, drought-sensitive
Chokecherry	Shade intolerant, sensitive to browsing and competition
Eastern hemlock	Hemlock woolly adelgid causes widespread mortality
MAY DECREASE	
Black cherry	Susceptible to insects and fire, somewhat drought-tolerant
Chestnut oak	Establishes from seed or sprout, adapted to fire
Cucumber tree	Susceptible to fire topkill
NO CHANGE	
Black locust	Early colonizer, but susceptible to locust borer & heart rot
MIXED MODEL RESULTS	
American chestnut	prone to chestnut blight; intolerant of fire
American hornbeam	Tolerates shade, susceptible to fire and drought
Black willow	Intolerant of shade, fire, and drought
Bur oak	Drought-tolerant, fire-resistant, adaptS to a variety of sites
Eastern cottonwood	Intolerant of shade, fire, defoliators and cankers
MAY INCREASE	
American elm	Grows on a variety of sites, Dutch elm disease
Black oak	Drought tolerant, susceptible to insect pests and diseases
Boxelder	Widespread and tolerant of drought and shade
Chinkapin oak	Tolerates a gradient of temperatures, very adaptable species
Eastern hophornbeam	Grows across a variety of sites, tolerates shade
LIKELY TO INCREASE	
Bear oak: scrub oak	Shade intolerant, susceptible to fire topkill and flood
Bitternut hickory	Drought-tolerant, susceptible to insects and fire topkill
Black walnut	Good disperser, but intolerant of shade and drought
Blackgum	Shade tolerant, fire adapted
Persimmon	Shade tolerant

SOURCE: Prasad, AM; Iverson, LR; Peters, MP; Matthews, SN. 2014. Climate change tree atlas. Northern Research Station, U.S. Forest Service, Delaware, OH. http://www.nrs.fs.fed.us/atlas.

FUTURE PROJECTIONS

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- ● **NO CHANGE** — *Little change (<20%) projected by 2100*
- ▼ **DECREASE** — *Projected decrease of >20% by 2100*
- ★ **NEW HABITAT** — *Tree Atlas projects new habitat for species not currently present*

ADAPTABILITY

Factors not included in the Tree Atlas model, such as the ability to respond favorably to disturbance, may make a species more or less able to adapt to future stressors. Specific considerations are provided on page 1 for the 30 most abundant species.

- \+ high — *Species may perform better than modeled*
- o medium
- – low — *Species may perform worse than modeled*

SPECIES	FIA IV	MODEL RELIABILITY	LOW CLIMATE CHANGE (PCM B1)	HIGH CLIMATE CHANGE (GFDL A1FI)	ADAPT
American basswood	98	M	▼	▼	o
American beech	286	H	▼	▼	o
American chestnut	55	M	▲	●	o
American elm	87	M	●	▲	o
American hornbeam	56	M	▼	▲	o
American mountain-ash	1	M	▼	▼	-
Atlantic white-cedar	1	L	▼	▼	-
Balsam poplar	2	H	▼	▼	o
Bear oak; scrub oak	111	L	▲	▲	o
Bigtooth aspen	123	H	▼	▼	o
Bitternut hickory	27	L	▲	▲	+
Black ash	1	H	▼	▼	-
Black cherry	1129	H	●	▼	-
Black locust	217	L	●	●	o
Black maple	1	L	▼	▼	-
Black oak	361	H	●	▲	o
Black spruce	4	H	▼	▼	o
Black walnut	90	M	▲	▲	o
Black willow	4	L	▼	▲	-
Blackgum	352	H	▲	▲	+
Boxelder	79	M	●	▲	+
Bur oak	2	M	▼	▲	+
Butternut	15	L	▼	▼	-
Chestnut oak	1160	M	●	▼	+
Chinkapin oak	2	M	●	▲	o
Chokecherry	57	L	▼	▼	o
Cucumbertree	13	L	●	▼	o
Eastern cottonwood	367	H	▼	▲	-
Eastern hemlock	134	M	▼	▼	+
Eastern hophornbeam	26	M	●	▲	o
Eastern redbud	49	M	▲	▲	o
Eastern redcedar	274	H	▲	▼	o
Eastern white pine	203	H	●	▼	o
Flowering dogwood	59	M	▲	▼	o
Gray birch	51	M	●	●	o
Green ash	23	M	●	▲	+
Hackberry	2	L	●	▲	+
Honeylocust	2	H	●	▲	o
Jack pine	114	H	▼	▼	+
Mockernut hickory	2	H	▲	▲	+
Northern red oak	881	H	●	▼	+
Osage-orange	1	M	●	▲	+
Paper birch	11	H	▼	▼	o
Pawpaw	5	L	●	●	o
Persimmon	2	M	▲	▲	+
Pignut hickory	128	H	▲	▲	o
Pin cherry	43	M	▼	▼	o
Pin oak	17	L	●	▲	-
Pitch pine	96	H	●	●	o
Quaking aspen	54	H	▼	▼	o
Red maple	2021	H	●	▼	+
Red mulberry	6	L	●	▲	o
Red pine	40	M	▼	▼	o
Red spruce	9	H	▼	▼	-
River birch	7	L	●	▲	o
Sassafras	449	H	▲	●	o
Scarlet oak	187	H	▲	▲	o
Serviceberry	166	M	●	▼	o
Shagbark hickory	45	M	●	▲	o
Shellbark hickory	1	L	▼	▲	o
Shingle oak	4	M	●	▲	o
Shortleaf pine	2	H	●	▲	o
Silver maple	27	M	▼	▲	+
Slippery elm	94	M	●	▲	o
Sourwood	0	H	★	★	+
Southern red oak	1	H	●	▲	+
Striped maple	220	H	●	▼	o
Sugar maple	515	H	●	▼	+
Swamp white oak	12	L	●	▼	o
Sweet birch	826	H	●	▼	-
Sweetgum	1	H	●	▲	o
Sycamore	38	M	▲	▲	o
Table mountain pine	7	M	▼	●	+
Tamarack (native)	16	H	●	▼	-
Virginia pine	117	H	●	▲	o
White ash	844	H	●	▼	-
White oak	502	H	●	▲	+
White spruce	17	M	●	●	o
Yellow birch	81	H	▼	▼	o
Yellow-poplar	224	H	▲	▼	+

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CLIMATE CHANGE PROJECTIONS FOR INDIVIDUAL TREE SPECIES

PIEDMONT (PENNSYLVANIA SUBREGION 5)

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TREE SPECIES INFORMATION:

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SPECIES	ADDITIONAL CONSIDERATIONS
LIKELY TO DECREASE	
Black cherry	Establishes from seed or sprout, adapted to fire
Eastern white pine	Good disperser, but susceptible to drought and insects
Sweet birch	Susceptible to drought, fire topkill, and insects
White ash	Emerald ash borer causes widespread mortality
MAY DECREASE	
American beech	Susceptible to beech diseases, very shade tolerant
Black locust	Susceptible to fire topkill
Black walnut	Drought-tolerant, susceptible to insects and fire topkill
Chestnut oak	Widespread and tolerant of drought and shade
Eastern hemlock	Intolerant of shade, fire, and drought
Flowering dogwood	Shade tolerant
Northern red oak	Susceptible to insect pests
Pignut hickory	Susceptible to bark beetles and drought
Red maple	Competitive colonizer in many sites, disturbance-tolerant
Scarlet oak	Establishes from seed or sprout, susceptible to fire and disease
Sugar maple	Grows across a variety of sites, tolerates shade
Virginia pine	Intolerant of shade and pollution
Yellow-poplar	Competitive colonizer tolerant of diverse sites
NO CHANGE	
Blackgum	Shade tolerant, fire adapted
MIXED MODEL RESULTS	
American elm	Requires specific habitat, intolerant of fire and drought
Pawpaw	Shade tolerant; susceptible to drought
Sassafras	Early-successional colonizer, susceptible to fire topkill
Silver maple	Early-successional colonizer, susceptible to fire topkill and drought
MAY INCREASE	
Black oak	Early colonizer, but susceptible to locust borer & heart rot
Boxelder	Shade tolerant
Pin oak	Susceptible to insect pests and disease
LIKELY TO INCREASE	
Eastern redcedar	Drought tolerant, shade intolerant, susceptible to fire and insects
Mockernut hickory	Susceptible to fire topkill
Sweetgum	Establishes by seed or sprouting, susceptible to fire and drought
Sycamore	Generally tolerant of a wide range of soils
White oak	Fire-adapted, grows on a variety of sites

SOURCE: Prasad, AM; Iverson, LR; Peters, MP; Matthews, SN. 2014. Climate change tree atlas. Northern Research Station, U.S. Forest Service, Delaware, OH. http://www.nrs.fs.fed.us/atlas.

FUTURE PROJECTIONS

The DISTRIB model uses Forest Inventory and Analysis (FIA) data to calculate an Importance Value (IV) for each species on the landscape in order to evaluate potential IV's at the end of this century (2070 – 2099). Those changes are classified in the table below as:

- ▲ **INCREASE** — *Projected increase of >20% by 2100*
- ● **NO CHANGE** — *Little change (<20%) projected by 2100*
- ▼ **DECREASE** — *Projected decrease of >20% by 2100*
- ★ **NEW HABITAT** — *Tree Atlas projects new habitat for species not currently present*

ADAPTABILITY

Factors not included in the Tree Atlas model, such as the ability to respond favorably to disturbance, may make a species more or less able to adapt to future stressors. Specific considerations are provided on page 1 for the 30 most abundant species.

- \+ high — *Species may perform better than modeled*
- o medium
- – low — *Species may perform worse than modeled*

SPECIES	FIA IV	MODEL RELIABILITY	LOW CLIMATE CHANGE (PCM B1)	HIGH CLIMATE CHANGE (GFDL A1FI)	ADAPT
American basswood	10	M	▼	▼	o
American beech	152	H	●	▼	o
American chestnut	15	M	●	●	o
American elm	60	M	▼	▲	o
American holly	0	H	★	★	o
American hornbeam	44	M	●	●	o
Balsam poplar	0	H	▼	▼	o
Bear oak; scrub oak	27	L	▲	▲	o
Bigtooth aspen	30	H	▼	▼	o
Bitternut hickory	12	L	▲	▲	+
Black cherry	472	H	▼	▼	-
Black hickory	0	H	★	★	o
Black locust	51	L	●	▼	o
Black oak	217	H	●	▲	o
Black walnut	85	M	●	▼	o
Black willow	13	L	▼	▲	-
Blackgum	189	H	●	●	+
Boxelder	119	M	▲	●	+
Butternut	34	L	▼	▼	-
Chestnut oak	365	M	●	▼	+
Chinkapin oak	1	M	▲	▲	o
Chokecherry	18	L	●	▼	o
Cucumbertree	1	H	●	▼	o
Eastern cottonwood	8	L	▼	▲	o
Eastern hemlock	70	H	●	▼	-
Eastern hophornbeam	32	M	●	▲	+
Eastern redbud	13	M	▲	▲	o
Eastern redcedar	94	M	▲	▲	o
Eastern white pine	61	H	▼	▼	o
Flowering dogwood	189	H	●	▼	o
Gray birch	9	M	▼	●	o
Green ash	25	M	▼	▲	o
Hackberry	24	M	●	▲	+
Honeylocust	1	L	▼	▲	+
Loblolly pine	2	H	▲	▲	o
Mockernut hickory	93	H	▲	▲	+
Mountain maple	1	H	●	▼	+
Northern catalpa	12	L	▼	●	o
Northern red oak	303	H	●	▼	+
Northern white-cedar	0	H	▼	▼	o

SPECIES	FIA IV	MODEL RELIABILITY	LOW CLIMATE CHANGE (PCM B1)	HIGH CLIMATE CHANGE (GFDL A1FI)	ADAPT
Nuttall oak	0	H	●	●	+
Osage-orange	1	M	▼	▲	+
Paper birch	1	H	▼	▼	o
Pawpaw	49	L	▲	▼	o
Persimmon	4	M	▲	▲	+
Pignut hickory	108	H	●	▼	o
Pin cherry	8	M	●	▼	o
Pin oak	47	L	▲	●	-
Pitch pine	37	H	▼	▼	o
Quaking aspen	3	H	▼	▼	o
Red maple	727	H	●	▼	+
Red mulberry	8	L	●	▲	o
Red pine	14	M	▼	▼	o
Red spruce	2	H	▼	▼	-
River birch	8	L	●	▲	o
Sassafras	200	H	▲	▼	o
Scarlet oak	90	H	●	▼	o
Serviceberry	21	M	●	▼	o
Shagbark hickory	22	M	▲	▲	o
Shortleaf pine	1	H	▲	▲	o
Shumard oak	0	H	NA	★	+
Silver maple	46	M	▼	▲	+
Slippery elm	33	M	●	●	o
Sourwood	0	H	★	★	+
Southern red oak	1	H	▲	▲	+
Striped maple	6	H	▼	▼	o
Sugar maple	125	H	●	▼	+
Swamp white oak	14	L	●	▼	o
Sweet birch	161	H	▼	▼	-
Sweetgum	68	H	▲	▲	o
Sycamore	45	M	▲	▲	o
Tamarack (native)	9	H	▼	▼	-
Virginia pine	45	H	●	▼	o
Water tupelo	10	M	●	▲	-
White ash	619	H	▼	▼	-
White oak	202	H	▲	▲	+
White spruce	15	M	●	●	o
Winged elm	0	H	★	★	o
Yellow birch	16	H	▼	▼	o
Yellow-poplar	325	H	●	▼	+

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CLIMATE CHANGE PROJECTIONS FOR INDIVIDUAL TREE SPECIES

ERIE AND ONTARIO LAKE PLAIN (SUBREGION 2)

The region's forests will be affected by a changing climate during this century. A team of forest managers and researchers created an assessment that describes the vulnerability of forests in the Mid-Atlantic region (Butler-Leopold et al. in review). This report includes information on the current landscape, observed climate trends, and a range of projected future climates. It also describes many potential climate change impacts to forests and summarizes key vulnerabilities for major forest types. This handout is summarized from the full assessment.

Remember that models are just tools, and they're not perfect. Model projections don't account for some factors that could be modified by climate change, like droughts, wildfire activity, and invasive species. If a species is rare or confined to a small area, Tree Atlas results may be less reliable. These factors, and others, could cause a particular species to perform better or worse than a model projects. Human choices will also continue to influence forest distribution, especially for tree species that are projected to increase. Planting programs may assist the movement of future-adapted species, but this will depend on management decisions.

TREE SPECIES INFORMATION:

This assessment uses two climate scenarios to "bracket" a range of possible futures. These future climate projections were used with two forest impact models (Tree Atlas and LANDIS) to provide information about how individual tree species may respond to a changing climate. More information on the climate and forest impact models can be found in the assessment. Results for "low" and "high" climate scenarios can be compared on page 2 of this handout.

Despite these limits, models provide useful information about future expectations. It's perhaps best to think of these projections as indicators of possibility and potential change. The model results presented here were combined with information from published reports and local management expertise to draw conclusions about potential risk and change in the region's forests.

SPECIES	ADDITIONAL CONSIDERATIONS - 30 MOST COMMON SPECIES
LIKELY TO DECREASE	
American beech	Susceptible to beech bark disease, very shade tolerant
Black ash	Narrow requirements; Emerald ash borer causes mortality
Black walnut	Good disperser, but intolerant of shade and drought
Chokecherry	Shade intolerant, sensitive to browsing and competition
Red pine	Shade intolerant; susceptible to many pests & diseases
Slippery elm	Shade-tolerant, susceptible to Dutch elm disease & fire
MAY DECREASE	
American basswood	Tolerates shade, susceptible to fire
Black willow	Intolerant of shade, fire, and drought
Eastern hemlock	Hemlock woolly adelgid causes widespread mortality
Eastern hophornbeam	Drought-tolerant, intolerant of shade, fire, and insects
Eastern white pine	Good disperser, but susceptible to drought and insects
Quaking aspen	Early-successional colonizer, susceptible to heat and drought
Silver maple	Early colonizer, susceptible to fire topkill and drought
Sugar maple	Grows across a variety of sites, tolerates shade
Yellow birch	Good disperser, susceptible to fire, insects, and disease

SPECIES	ADDITIONAL CONSIDERATIONS - 30 MOST COMMON SPECIES
NO CHANGE	
American elm	Susceptible to Dutch elm disease
American hornbeam	Tolerates shade, susceptible to fire and drought
Bigtooth aspen	Early-successional colonizer, susceptible to drought
Green ash	Shade- intolerant; emerald ash borer causes mortality
MAY INCREASE	
Black cherry	Susceptible to insects and fire, mildly drought-tolerant
Boxelder	Widespread and tolerant of drought and shade
Eastern cottonwood	Intolerant of shade, fire, defoliators and cankers
Mockernut hickory	Susceptible to fire topkill
Pignut hickory	Susceptible to bark beetles and drought
Red maple	Competitive colonizer in many sites, disturbance-tolerant
White ash	Emerald ash borer causes widespread mortality
White oak	Fire-adapted, grows on a variety of sites
LIKELY TO INCREASE	
Black locust	Early colonizer, but susceptible to locust borer & heart rot
Northern red oak	Susceptible to insect pests
Serviceberry	Competitive colonizer, susceptible to drought

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FUTURE PROJECTIONS

Data for the end of the century are summarized for two forest impact models under two climate change scenarios. The Climate Change Tree Atlas (www.fs.fed.us/nrs/atlas) models future suitable habitat, while LANDIS models changes in forest growth over time (future tree density presented in this table; additional data are available in the assessment).

▲ **INCREASE**
Projected increase of >20% by 2100

● **NO CHANGE**
Little change (<20%) projected by 2100

▼ **DECREASE**
Projected decrease of >20% by 2100

★ **NEW HABITAT**
Tree Atlas projects new habitat for species not currently present

ADAPTABILITY

Factors not included in the Tree Atlas model, such as the ability to respond favorably to disturbance, may make a species more or less able to adapt to future stressors (see reverse page for considerations for the 30 most common species).

+ high
Species may perform better than modeled

· medium

– low
Species may perform worse than modeled

SPECIES	LOW CLIMATE CHANGE (PCM B1) TREE ATLAS	LOW CLIMATE CHANGE (PCM B1) LANDIS	HIGH CLIMATE CHANGE (GFDL A1FI) TREE ATLAS	HIGH CLIMATE CHANGE (GFDL A1FI) LANDIS	ADAPT
American basswood	▼	●	▼	●	·
American beech	▼		▼		·
American elm	●		●		·
American hornbeam	●		●		·
Atlantic white-cedar	▼		▼		-
Balsam fir	▼	▲	▼	▼	-
Bigtooth aspen	●		●		·
Bitternut hickory	●		▲		+
Black ash	▼		▼		-
Black cherry	●	●	▲	●	-
Black locust	▲		▲		·
Black oak	●	●	▲	●	·
Black walnut	▲		▲		·
Black willow	●		▼		-
Blackgum	▲		▲		+
Blackjack oak	N/A		★		+
Boxelder	●		▲		+
Bur oak	▼		▼		+
Butternut	▼		▼		-
Cedar elm	N/A		★		·
Chestnut oak	▲	▼	▲	▲	+
Chinkapin oak	●		▲		·
Chokecherry	▼		▼		·
Cucumbertree	●		▼		·
Eastern cottonwood	●		▲		·
Eastern hemlock	▼	●	▼	▼	-
Eastern hophornbeam	●		▼		+
Eastern redbud	★		★		·
Eastern redcedar	▲		▲		·
Eastern white pine	▼	●	▼	▼	·
Flowering dogwood	▲		▲		·
Gray birch	▼		▼		·
Green ash	●		●		·
Hackberry	N/A		★		+
Honeylocust	N/A		★		+
Loblolly pine	N/A		★		·
Mockernut hickory	●		▲		+
Northern red oak	●	●	▲	▲	+
Northern white-cedar	▼	▼	▼	▼	·
Ohio buckeye	★		★		·

SPECIES	LOW CLIMATE CHANGE (PCM B1) TREE ATLAS	LOW CLIMATE CHANGE (PCM B1) LANDIS	HIGH CLIMATE CHANGE (GFDL A1FI) TREE ATLAS	HIGH CLIMATE CHANGE (GFDL A1FI) LANDIS	ADAPT
Osage-orange	▲		▲		+
Paper birch	▼		▼		·
Pawpaw	★		★		·
Persimmon	N/A		★		+
Pignut hickory	●	●	▲	●	·
Pin cherry	▼		▼		·
Pin oak	N/A		★		-
Pitch pine	●	▼	●	●	·
Post oak	N/A		★		+
Quaking aspen	▼	●	▼	▼	·
Red maple	●	●	▲	●	+
Red mulberry	★		★		·
Red pine	▼		▼		·
Red spruce	▼	▼	▼	▼	-
Rock elm	▼		●		-
Sassafras	▲		▲		·
Scarlet oak	▲	●	▲	▲	·
Serviceberry	▲		▲		·
Shagbark hickory	●	●	▲	▲	·
Shellbark hickory	N/A		★		·
Shingle oak	●		★		·
Shortleaf pine	N/A		★		·
Shumard oak	N/A		★		+
Silver maple	●		▼		+
Slippery elm	▲		▲		·
Southern red oak	N/A		★		+
Striped maple	▼		▼		·
Sugarberry	N/A		★		·
Sugar maple	●	●	▼	●	+
Swamp white oak	▼		▼		·
Sweet birch	●		▲		-
Sweetgum	N/A		★		·
Sycamore	▲		▲		·
Tamarack	▼		▼		-
Tulip tree	▲	●	▲	▲	+
Virginia pine	★		★		·
White ash	●	●	●	▲	-
White oak	●	●	▲	▲	+
White spruce	▼		▼		·
Yellow birch	▼	●	▼	▼	·

SOURCE: Butler-Leopold et al. (in review). Mid-Atlantic forest ecosystem vulnerability assessment and synthesis: a report from the Mid-Atlantic Climate Change Response Framework, Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station.
www.forestadaptation.org/mid-atlantic/vulnerability-assessment

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CLIMATE CHANGE PROJECTIONS FOR INDIVIDUAL TREE SPECIES
COASTAL PLAIN (SUBREGION 6)

The region's forests will be affected by a changing climate during this century. A team of forest managers and researchers created an assessment that describes the vulnerability of forests in the Mid-Atlantic region (Butler-Leopold et al. in review). This report includes information on the current landscape, observed climate trends, and a range of projected future climates. It also describes many potential climate change impacts to forests and summarizes key vulnerabilities for major forest types. This handout is summarized from the full assessment.

Remember that models are just tools, and they're not perfect. Model projections don't account for some factors that could be modified by climate change, like droughts, wildfire activity, and invasive species. If a species is rare or confined to a small area, Tree Atlas results may be less reliable. These factors, and others, could cause a particular species to perform better or worse than a model projects. Human choices will also continue to influence forest distribution, especially for tree species that are projected to increase. Planting programs may assist the movement of future-adapted species, but this will depend on management decisions.

TREE SPECIES INFORMATION:
This assessment uses two climate scenarios to "bracket" a range of possible futures. These future climate projections were used with two forest impact models (Tree Atlas and LANDIS) to provide information about how individual tree species may respond to a changing climate. More information on the climate and forest impact models can be found in the assessment. Results for "low" and "high" climate scenarios can be compared on page 2 of this handout.

Despite these limits, models provide useful information about future expectations. It's perhaps best to think of these projections as indicators of possibility and potential change. The model results presented here were combined with information from published reports and local management expertise to draw conclusions about potential risk and change in the region's forests.

SPECIES	ADDITIONAL CONSIDERATIONS - 30 MOST COMMON SPECIES
LIKELY TO DECREASE	
Atlantic white-cedar	Requires specific habitat, intolerant of fire and drought
Blackgum	Shade tolerant, fire adapted
MAY DECREASE	
American holly	Requires specific habitat, intolerant of fire
Black locust	Early-successional colonizer, susceptible to insect pests
Northern red oak	Susceptible to insect pests
Sassafras	Early-successional colonizer, susceptible to fire topkill
Tulip tree	Competitive colonizer tolerant of diverse sites
Virginia pine	Intolerant of shade and pollution
NO CHANGE	
American hornbeam	Tolerates shade, susceptible to fire and drought
Flowering dogwood	Shade tolerant
Pitch pine	Early-successional colonizer, susceptible to insect pests
MIXED MODEL RESULTS	
American beech	Susceptible to beech bark disease, extremely shade tolerant
Black cherry	Susceptible to insects and fire, somewhat drought-tolerant

SPECIES	ADDITIONAL CONSIDERATIONS - 30 MOST COMMON SPECIES
MIXED MODEL RESULTS CONTINUED	
Black oak	Drought tolerant, susceptible to insect pests & diseases
Chestnut oak	Establishes from seed or sprout, adapted to fire
Mockernut hickory	Susceptible to fire topkill
Pignut hickory	Susceptible to insect pests and drought
Red maple	Competitive colonizer, tolerant of disturbance
Scarlet oak	Seeds and sprouts, susceptible to fire and disease
White ash	Emerald ash borer causes mortality
White oak	Fire-adapted, grows on a variety of sites
MAY INCREASE	
Boxelder	Drought & shade tolerant, competitive in a range of sites
Eastern red cedar	Shade intolerant, susceptible to fire and insects
Loblolly pine	Susceptible to insect pests, invasive plants, and drought
Persimmon	Shade tolerant
Southern red oak	Tolerant of a range of temperature gradients
Sweetbay	Resistant to fire topkill, susceptible to insect pests
Sweetgum	Seeds and sprouts, susceptible to fire and drought
Willow oak	Establishes across a range of temperature gradients
Water oak	Intolerant of shade and fire topkill

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FUTURE PROJECTIONS

Data for the end of the century are summarized for two forest impact models under two climate change scenarios. The Climate Change Tree Atlas (www.fs.fed.us/nrs/atlas) models future suitable habitat, while LANDIS models changes in forest growth over time (future tree density presented in this table; additional data are available in the assessment).

▲ **INCREASE** *Projected increase of >20% by 2100*

● **NO CHANGE** *Little change (<20%) projected by 2100*

▼ **DECREASE** *Projected decrease of >20% by 2100*

★ **NEW HABITAT** *Tree Atlas projects new habitat for species not currently present*

ADAPTABILITY

Factors not included in the Tree Atlas model, such as the ability to respond favorably to disturbance, may make a species more or less able to adapt to future stressors (see reverse page for considerations for the 30 most common species).

\+ high *Species may perform better than modeled*

· medium

– low *Species may perform worse than modeled*

SPECIES	LOW CLIMATE CHANGE (PCM B1) TREE ATLAS	LOW CLIMATE CHANGE (PCM B1) LANDIS	HIGH CLIMATE CHANGE (GFDL A1FI) TREE ATLAS	HIGH CLIMATE CHANGE (GFDL A1FI) LANDIS	ADAPT
American beech	●	▲	▼	▼	·
American chestnut	▼		▼		·
American elm	▲		▲		·
American holly	●		▼		·
American hornbeam	●		●		·
Atlantic white-cedar	▼		▼		–
Baldcypress	▲		▲		·
Bear oak:scrub oak	▼		●		·
Bigtooth aspen	▼		▼		·
Bitternut hickory	●		▲		+
Black cherry	▼	▲	▼	●	–
Black hickory	★		★		·
Black locust	●		▼		·
Black oak	●	▲	▼	●	·
Black walnut	●		▼		·
Black willow	▼		▲		–
Blackgum	▼		▼		+
Blackjack oak	▲		▲		+
Bluejack oak	N/A		★		·
Boxelder	▲		●		+
Cedar elm	N/A		★		·
Cherrybark oak	▲		▲		·
Chestnut oak	▼	▲	▼	▲	+
Chinkapin oak	★		★		·
Eastern cottonwood	▼		▲		·
Eastern hemlock	▲	▼	▲	▼	–
Eastern hophornbeam	▲		▲		+
Eastern redbud	●		▲		·
Eastern red cedar	●		▲		·
Eastern white pine	▼	▼	▼	▼	·
Flowering dogwood	●		●		·
Gray birch	●		●		·
Green ash	●		▲		·
Hackberry	●		▲		+
Honeylocust	N/A		★		+
Laurel oak	★		★		·
Loblolly pine	▲	●	▲	●	·
Longleaf pine	★		★		·
Mockernut hickory	▼		▲		+
Northern catalpa	▲		▲		·
Northern red oak	▼	●	▼	▼	+
Osage-orange	N/A		★		+
Overcup oak	N/A		★		–
Pawpaw	▼		▼		·
Persimmon	▲		▲		+
Pignut hickory	▼	▲	●	▼	·
Pin cherry	●		▼		·
Pin oak	▲		▲		–
Pitch pine	●	●	●	●	·
Pond pine	▲		▲		–
Post oak	▲		▲		+
Quaking aspen	▼	●	▼	●	·
Red maple	●	●	▼	▲	+
Red mulberry	●		▲		·
River birch	▲		▲		·
Sassafras	●		▼		·
Scarlet oak	▼	▲	▼	▼	·
Serviceberry	▼		▼		·
Shagbark hickory	▲	▲	▲	●	·
Shingle oak	●		▲		·
Shortleaf pine	▲		▲		·
Silver maple	▼		▲		+
Slippery elm	●		▲		·
Sourwood	▲		▼		+
Southern red oak	▲		▲		+
Sugar maple	▲	●	▼	▼	+
Swamp chestnut oak	▲		●		·
Swamp tupelo	▲		▲		–
Swamp white oak	▼		▼		·
Sweet birch	▼		▼		–
Sweetbay	▲		●		·
Sweetgum	▲		▲		·
Sycamore	●		▲		·
Tulip tree	▼	●	▼	●	+
Virginia pine	▼	●	▼	▼	·
Water oak	▲		▲		·
Water tupelo	▲		▲		–
White ash	●	▲	▼	▼	–
White oak	●	●	▼	▲	+
Willow oak	▲		▲		·

SOURCE: *Butler-Leopold et al. (in review). Mid-Atlantic forest ecosystem vulnerability assessment and synthesis: a report from the Mid-Atlantic Climate Change Response Framework, Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station.*
www.forestadaptation.org/mid-atlantic/vulnerability-assessment

www.forestadaptation.org

PENNSYLVANIA CLIMATE EFFECTS

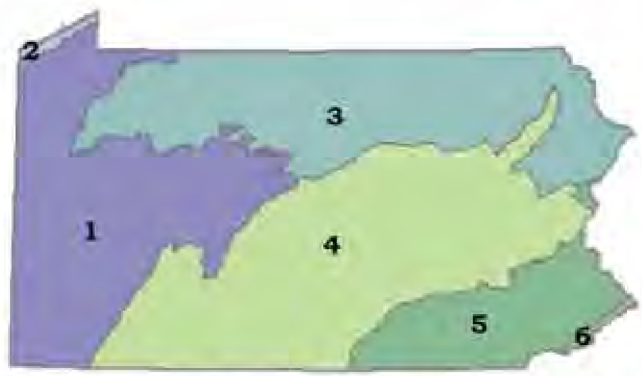
HEAT AND HARDINESS ZONES

PREDICTED FOREST CHANGE

The region's forests will be affected by a changing climate during this century, but individual tree species will respond uniquely to climate change, depending on their particular silvics and ecological tolerances in a given location.

The vulnerability of many common species were assessed using the Climate Change Tree Atlas, which simulates changes in projected tree species suitable habitat in Pennsylvania. Tree Atlas results for Pennsylvania regions can found at: https://forestadaptation.org/PA).

Some trees were not modeled by Tree Atlas. For these species, climate change effects can be assessed by examining future projections of hardiness zones and heat zones for regions of Pennsylvania (right). Current hardiness zones and heat zones are used to determine suitability for planting. As temperatures increase, it is expected that hardiness and heat zones will shift.



Physiographic Regions of Pennsylvania

- 1 – Western Allegheny Plateau
- 2 – Erie and Ontario Lake Plain
- 3 – Northern Allegheny Plateau
- 4 – Ridge and Valley
- 5 – Piedmont
- 6 – Coastal Plain

MORE INFORMATION:

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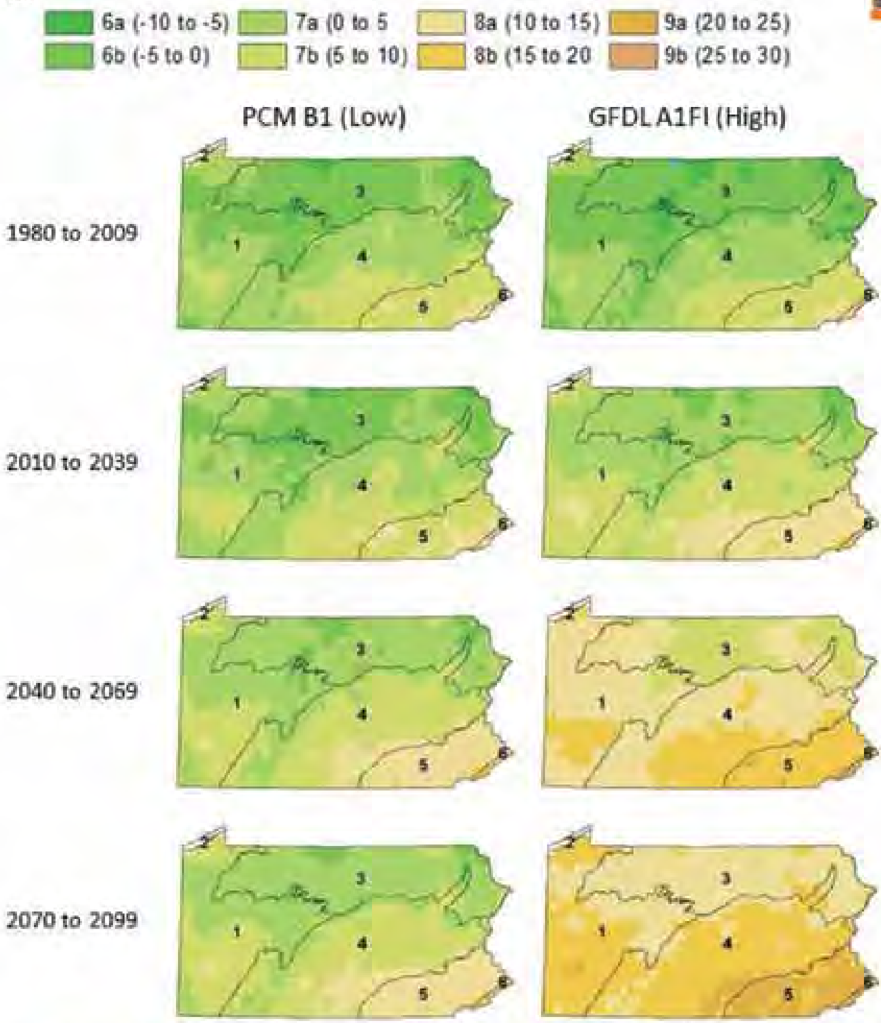
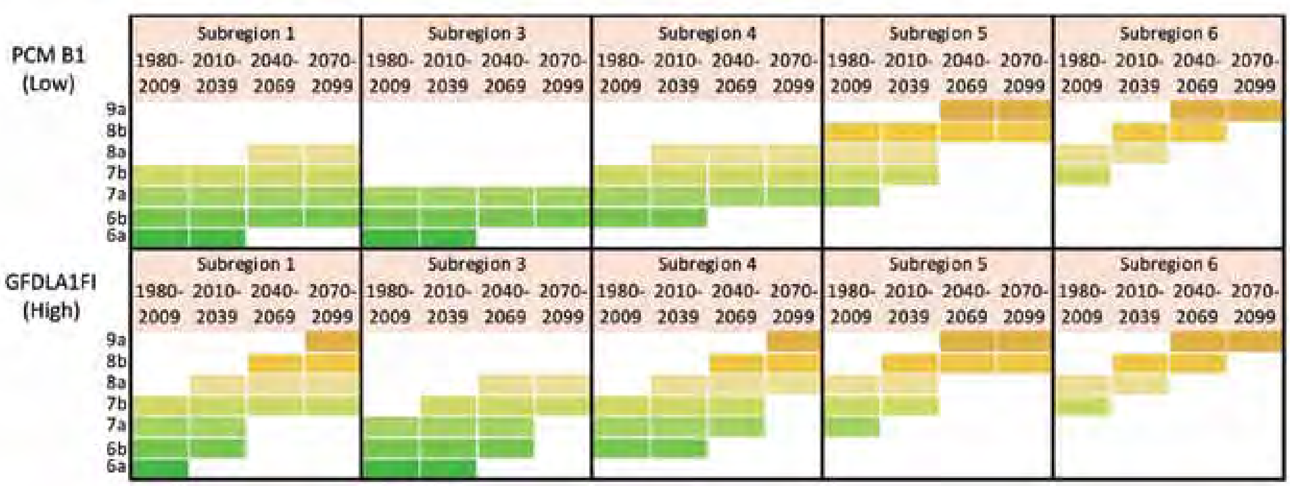
FUTURE HARDINESS ZONES

The plant hardiness zone map is based on minimum annual temperature and can be used as an indicator of cold-tolerance of plants. Average minimum temperatures break subzones into increments of 5°F. Changes in temperature may lead to a shift of one to three higher hardiness zones through the end of the century. The charts below the maps highlight the shifts for each region over time.



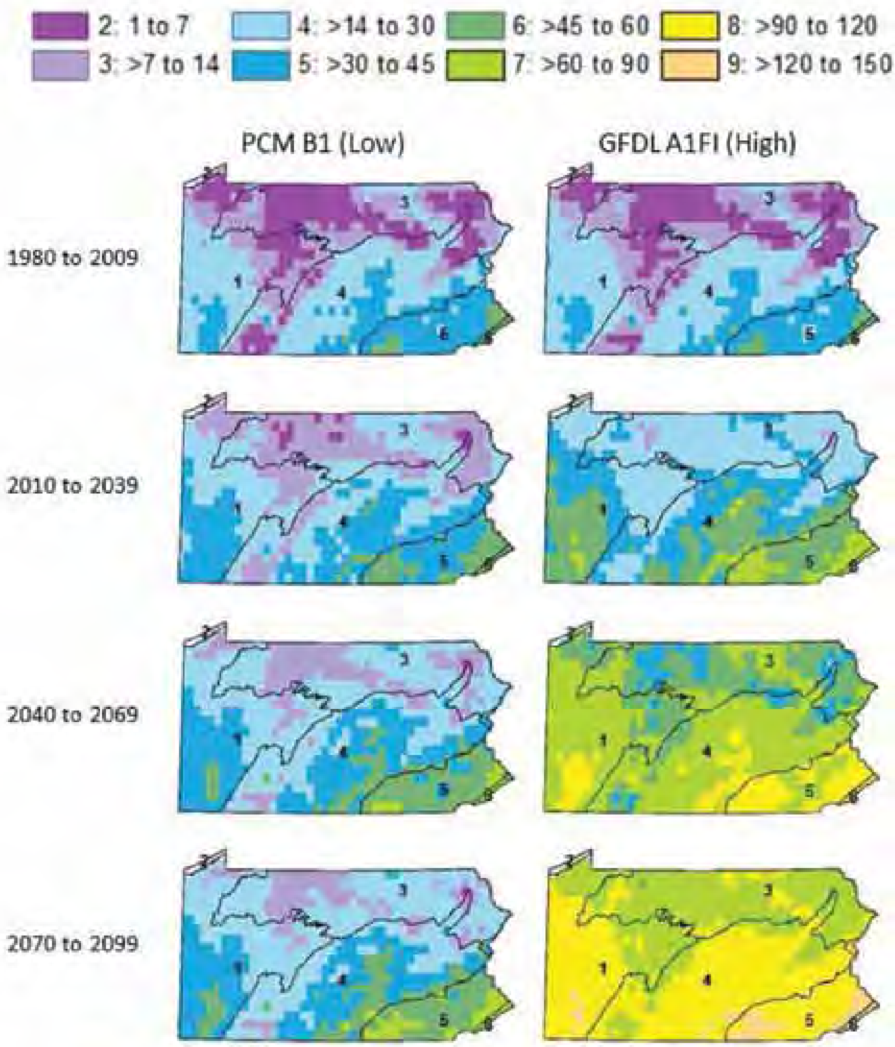
Regions of Pennsylvania

1 – Western Allegheny Plateau
2 – Erie and Ontario Lake Plain
3 – Northern Allegheny Plateau
4 – Ridge and Valley
5 – Piedmont
6 – Coastal Plain



FUTURE HEAT ZONES

The heat zone map is based on number of days exceeding 86 °F (30 °C) and can be used as an indicator of heat stress on organisms. Changes in temperature may lead to a shift of one to five higher heat zones through the end of the century. The charts below the maps highlight the shifts for each region over time.



Regions of Pennsylvania
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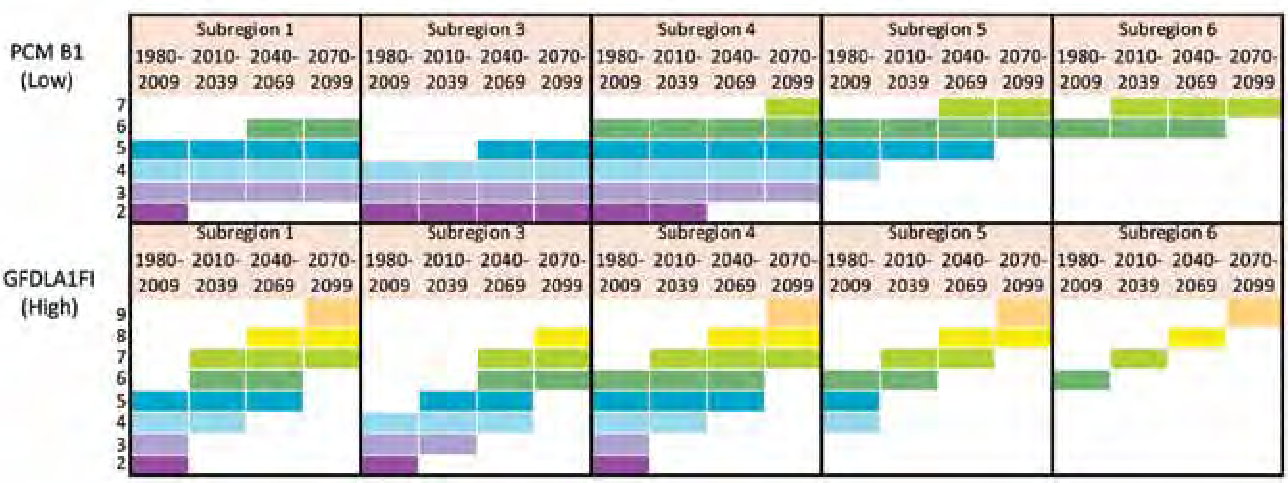

PENNSYLVANIA CLIMATE EFFECTS: FORESTS

SPECIES VULNERABILITY

The climate change effect was calculated by comparing the species' published heat zone tolerance to the map of projected heat zones. Vulnerability was rated by comparing a species' projected climate change effect to its adaptability score (Table 2). For example, Ailanthus (an invasive species) and hawthorn were rated low vulnerability largely due to no change in heat zones and high adaptability score, suggesting these species will do well under a range of future climates. Adaptability scores are calculated from biological and disturbance factors that may make a species more or less able to adapt to future stressors.

Table 1. Potential effects of shifts in hardiness and heat zones for tree species in regions of Pennsylvania that do not have Tree Atlas species distribution modeling. There were no heat or hardiness zone data for subregion 2, which was too small for analysis.

Common Name	Hardiness zone range	Heat zone range	Adapt-ability	Subregion 1 Climate change effect	Subregion 1 Vulner-ability	Subregion 3 Climate change effect	Subregion 3 Vulner-ability	Subregion 4 Climate change effect	Subregion 4 Vulner-ability	Subregion 5 Climate change effect	Subregion 5 Vulner-ability	Subregion 6 Climate change effect	Subregion 6 Vulner-ability
Ailanthus*	5 to 8	8 to 1	high	●	L	●	L	●	L	●	L	●	L
American hazelnut	4 to 8	9 to 1	medium	●	M	●	M	●	M	●	M	●	M
Downy serviceberry	3 to 7	7 to 1	high	●	L	▼	M	▼	M	▼	M	NA	NA
Gray dogwood	3 to 8	8 to 3	medium	▼	H	●	M	●	M	●	M	▼	H
Hawthorn, smooth	5 to 8	8 to 3	high	●	L	●	L	●	L	●	L	●	L
Norway maple*	4 to 7	7 to 1	high	●	L	▼	M	▼	M	▼	M	NA	NA
Norway spruce*	3 to 8	8 to 1	medium	●	M	●	M	●	M	▼	H	▼	H
Redosier dogwood	3 to 8	8 to 1	medium	▼	H	●	M	▼	H	▼	H	NA	NA
Scots pine*	3 to 7	7 to 1	medium	▼	H	●	M	▼	H	▼	H	NA	NA
Serviceberry	4 to 8	9 to 3	high	●	L	●	L	●	L	●	L	▼	M
Smooth sumac	2 to 8	8 to 1	high	●	L	●	L	●	L	●	L	●	L
Southern catalpa	5 to 9	9 to 5	medium	●	M	●	M	●	M	▲	L	●	M
Staghorn sumac	4 to 8	8 to 1	high	▼	M	●	L	●	L	●	L	▼	M
Witchhazel	4 to 8	8 to 1	high	●	L	●	L	●	L	●	L	▼	M

Table 2. Matrix used to determine vulnerability. Vulnerability is based on heat and hardiness zones (L=low; M=moderate; H=high).

Heat/Hardiness Zone Effect	Adaptability Score Low	Adaptability Score Medium	Adaptability Score High
Decrease	High	High	Moderate
No Change	Moderate	Moderate	Low
Increase	Moderate	Low	Low

▲ Climate change was considered to have a positive effect on habitat suitability if the species gained one or more mapped heat zones at the end of the century.

● Climate change was considered to have a neutral effect on habitat suitability if the species did not gain or lose mapped heat zones at the end of the century.

▼ Climate change was considered to have a negative effect on habitat suitability if the species lost one or more mapped heat zones by the end of the century.

*Species marked with an asterisk are nonnative and may be considered invasive or problematic in some locations. Species that are marked NA have not been detected in current inventory data or modeled to be present in the future; however, there may be planted examples of these species in certain locations.

Find a list of tree species with Tree Atlas results at: forestadaptation.org/PA

The general trends derived from these models can be combined with local knowledge and management experience to judge risk on a particular site. Examples of characteristics that make systems more adaptable include high species diversity, landscape connectivity, and the ability to bounce back following a disturbance, such as a drought, flood, windstorm, or fire. Managers can use scientific information from the Mid-Atlantic Forest Ecosystem Vulnerability Assessment and other sources to better understand which places may be most vulnerable. Resources are available to help forest managers and planners incorporate climate change considerations into forest management. A set of Forest Adaptation Resources is available at www.forestadaptation.org.

MORE INFORMATION

Information on heat zone and hardiness zone projections was summarized from Matthews, S.N., Iverson, L., Peters, M., Prasad, A.M., 2018. **Assessing potential climate change pressures throughout this century across the Conterminous United States: mapping plant hardiness zones, heat zones, growing degree days, and cumulative drought severity throughout this century.** U.S. Department of Agriculture, Forest Service. Northern Research Station Research Map NRS-9, Newtown Square, PA, p. 31.

www.forestadaptation.org/PA

pennsylvania
DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES

NIACS
Northern Institute of Applied Climate Science

This technical summary is a result of a collaboration between the Northern Institute of Applied Climate Science and Pennsylvania DCNR. 2018. Available at https://forestadaptation.org/PA. More information on DCNR commitment to address climate change can be found at www.dcnr.pa.gov/Conservation/ClimateChange.

APPENDIX F - RESOURCES

PA DCNR & Climate Change website:
www.dcnr.pa.gov/Conservation/ClimateChange/Pages/default.aspx

Considering Forest and Grassland Carbon in Land Management:
www.fs.usda.gov/treesearch/pubs/54316

PA State Climatologist:
http://climate.psu.edu/

Pennsylvania Flood Maps:
www.floodmaps.pa.gov/Pages/default.aspx

PA DCNR Riparian Buffer website:
www.dcnr.pa.gov/Conservation/Water/RiparianBuffers/Pages/default.aspx

Green and Sustainable Community Parks:
www.dcnr.pa.gov/Communities/GreenCommunityParks/Pages/default.aspx

PA DCNR Invasive Plants website:
www.dcnr.pa.gov/Conservation/WildPlants/InvasivePlants/Pages/default.aspx

PA Topographic and Geologic Survey website:
www.dcnr.pa.gov/about/Pages/Topographic-and-Geologic-Survey.aspx

Northern Institute of Applied Climate Science website:
www.nrs.fs.fed.us/niacs/

CLIMATE CHANGE ADAPTATION AND MITIGATION PLAN

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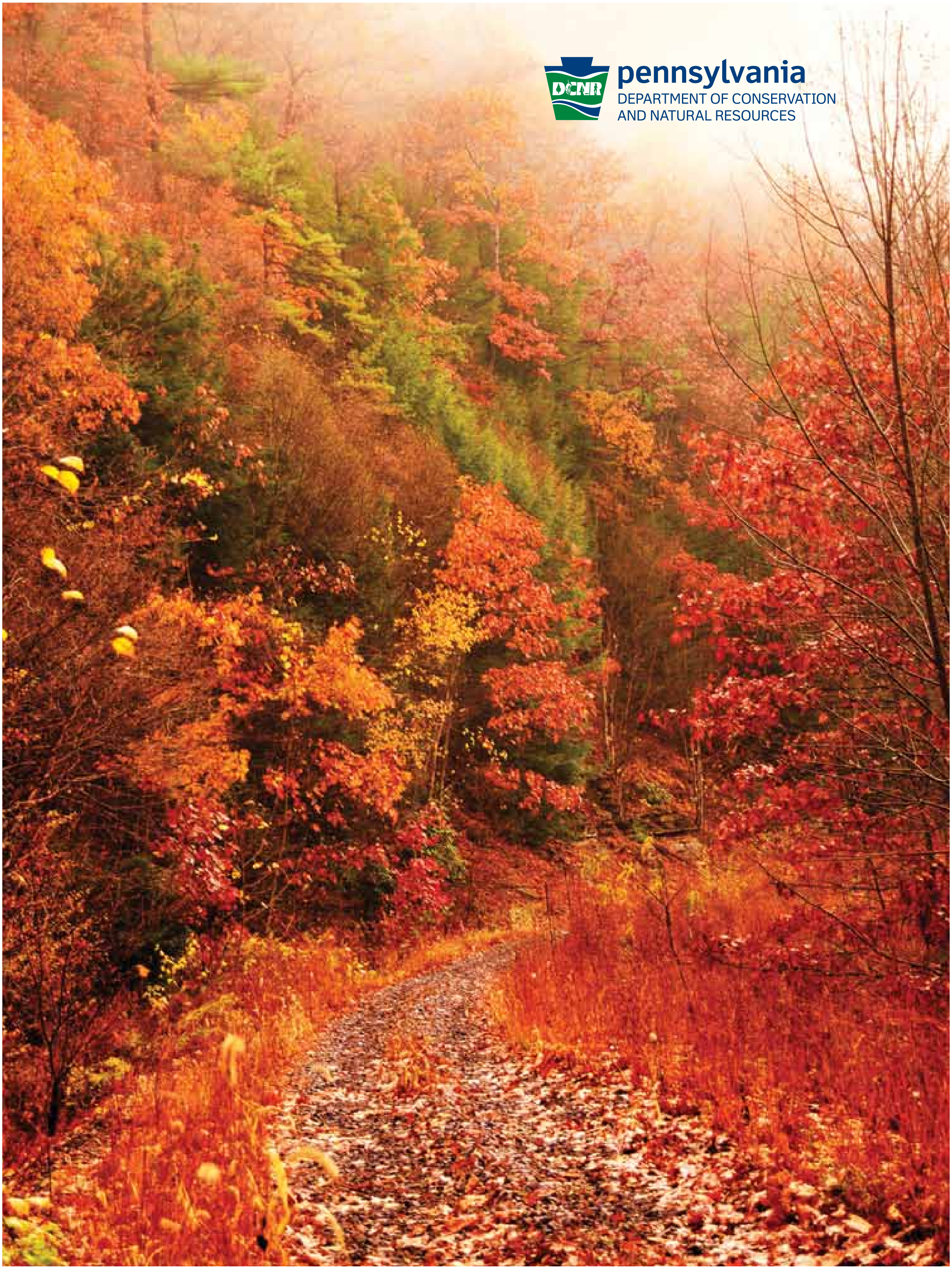

Redbank Valley trails