# DCNR and Climate Change

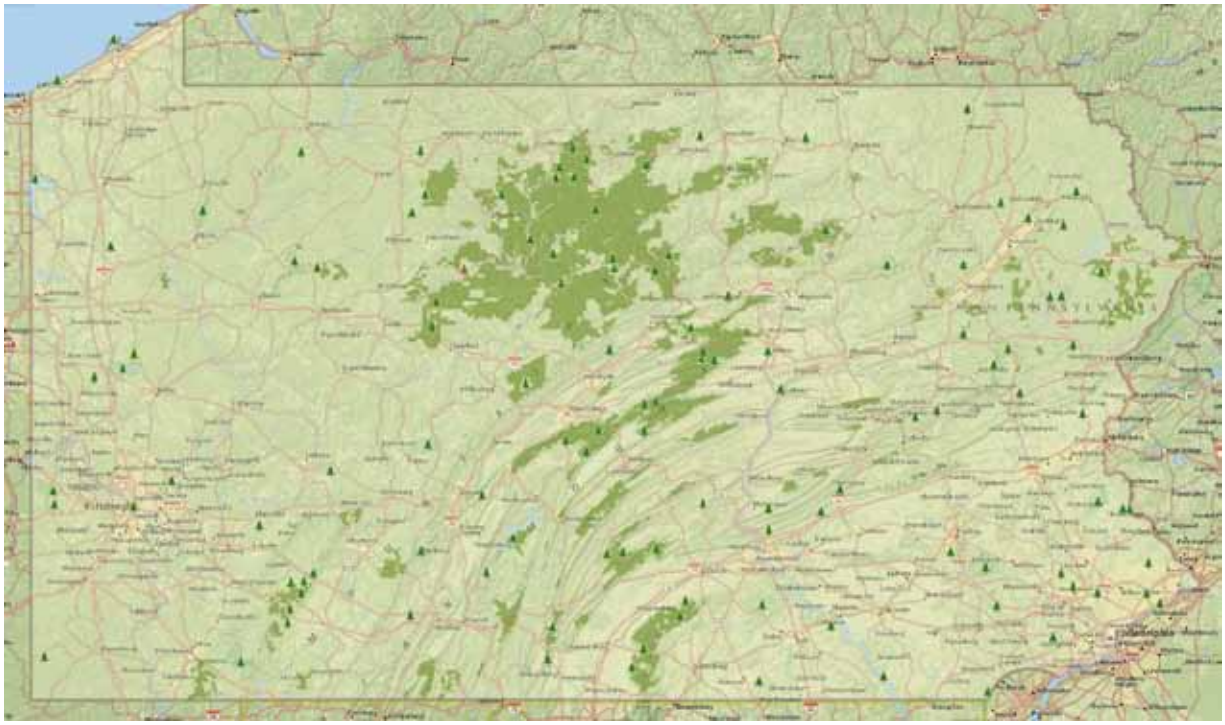
## Planning for the Future

pennsylvania
DEPARTMENT OF CONSERVATION
AND NATURAL RESOURCES

9/9/15

# Table of Contents

# Executive Summary



DCNR-managed lands include state parks, indicated by the tree symbol, and state forests, which are shaded dark green.

The Pennsylvania Department of Conservation and Natural Resources (DCNR) is the caretaker of 2.2 million acres of State Forest land, 120 State Parks, advisor to the owners of 15 million acres of private forest land, a leader in providing outdoor recreation, and is 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.

Climate change has already begun to manifest itself in the Commonwealth in the form of higher temperatures, an increase in annual precipitation, significantly higher numbers of large storm events, changes in peak stream flows, decreased snow cover, 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.

**This report 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 responding to those impacts through mitigation and adaptation.**

While climate change presents some very significant challenges, there is much we can do to both limit its effects and cope with the impacts. 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 new conservation paradigm that facilitates, manages, and copes with change in the natural world, rather than the traditional approach of preserving things as they are or restoring them to some former state.

DCNR's role in this process, as both a land steward and the state's leading conservation agency, can't be overstated. The department's land management practices can directly mitigate atmospheric carbon as well as ensure that our public lands remain resilient and can adapt to climate change. The department can also be a leader, serving as an example of climate-smart land management, green infrastructure development, and providing technical assistance and funding to help its constituents deal with climate change.

# Current & Projected Impacts

When developing a framework to address an issue as complex as climate change, it is essential to understand how it is currently impacting activities or resources and also what the potential or projected effects could be. It's important to note that there may be a significant difference between known current impacts and the actual impacts, since research, monitoring, and baseline studies have been minimal to this point. It's also important to recognize that while climate change on its own may not have a significant direct impact on all species, natural communities, or land uses, it can magnify the impacts of other stressors such as pollution, habitat fragmentation, invasive species, and deer overpopulation.

Regarding future impacts, the terms *low-emissions scenario* and *high-emissions scenario* are often used when discussing the impacts of climate change. While these terms are based on specific General Circulation Models that have been developed to look at future climate change scenarios, they are used here in a more general, non-technical sense. The low-emissions scenario refers to a future in which we significantly and rapidly reduce GHG emissions by the end of the century. The high-emissions scenario refers to business as usual, with little or no reduction in GHG emissions by the end of the century.

## Weather

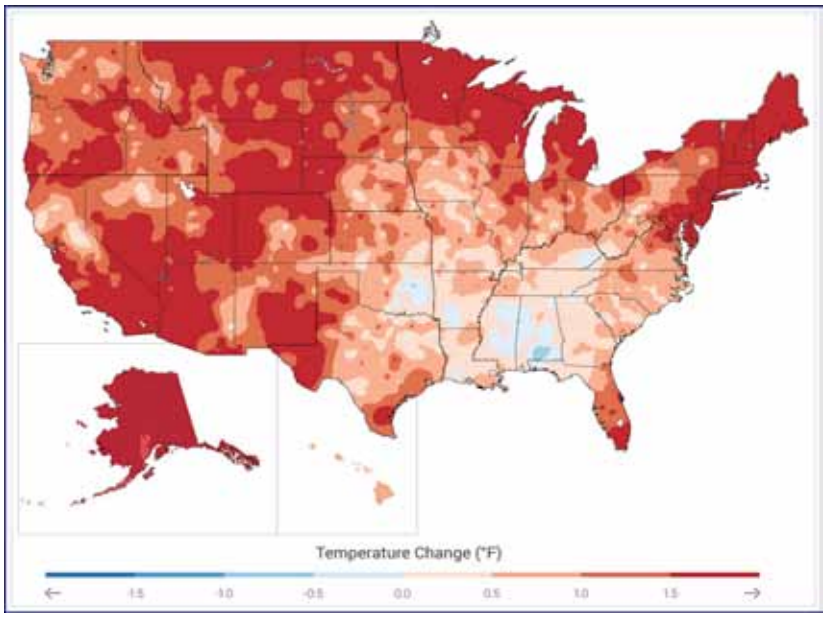
Pennsylvania has seen measureable changes in temperature patterns, precipitation levels, and storm intensity. Since the early 20th century, the Commonwealth has seen a temperature increase of more than 1° C (1.8° F)[1]. Winter temperatures have risen even faster, at a rate of 1.3 °F per decade from 1970 to 2000 in the northeast U.S.[2]

From 2000-2009, the number of record high temperatures were nearly double that of record lows in the contiguous United States. Additionally, the incidence of very hot days (> 90°F) in the northeast U.S. has increased by about two days since the early 1960s. That number is projected to increase an additional 20-30 days per year by mid-century under a lower-emissions scenario.[2]

Annual precipitation has increased about 10% over the past 100 years,[1] with the biggest increase in the fall. The incidence of heavy precipitation events has also increased significantly. According to the 2014 National Climate Assessment,[3] 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% in the Northeast. A further analysis by Climate Central, finds that three of the top 50 U.S. cities seeing the biggest increases since 1950 are in Pennsylvania. Philadelphia is third on the list with a 360% increase, Harrisburg is seventh, with a 283% increase, and Lancaster is 14th, with a 112% increase.

Looking to the future, Pennsylvania is projected to

### Observed U.S. Temperature Change




*U.S. Global Change Research Program*

The colors on the map show temperature changes over the past 22 years (1991-2012) compared to the 1901-1960 average. The period from 2001 to 2012 was warmer than any previous decade in every region. (Figure source: NOAA NCDC / CICS-NC).

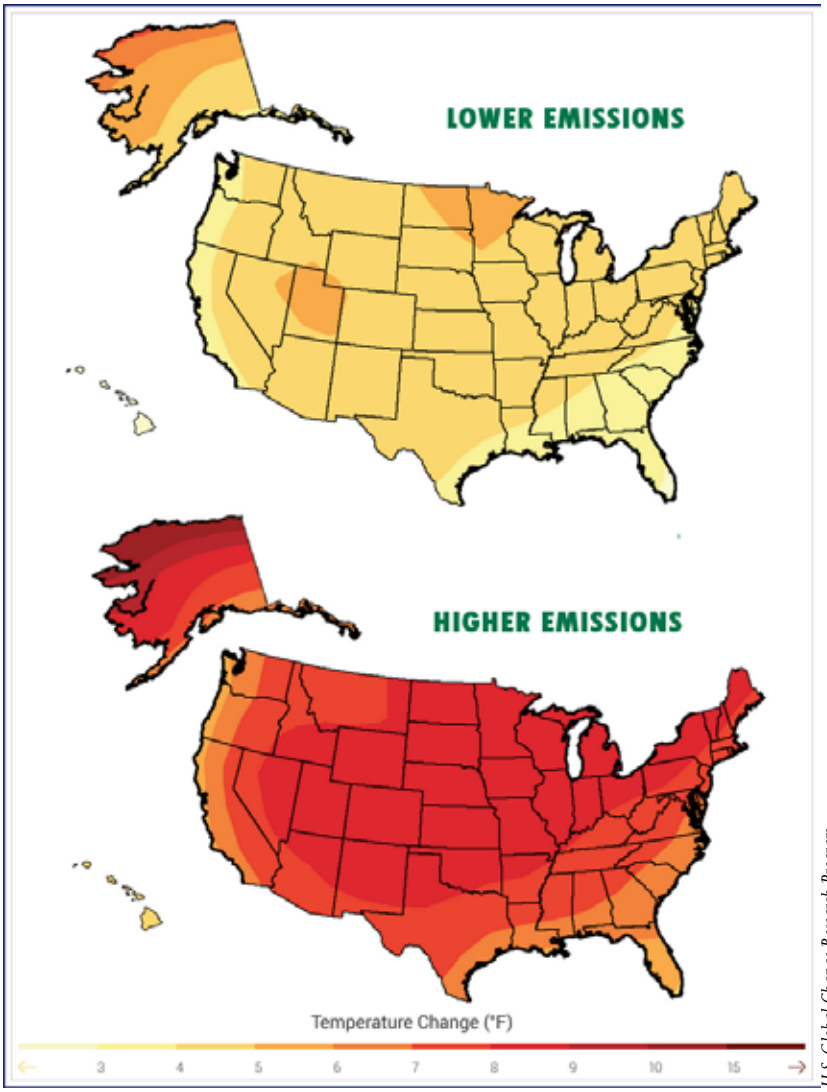
be as much as 3° C (5.4 °F) warmer by the middle of this century than it was at the end of the last century if emissions aren't curtailed significantly. Additionally, annual precipitation is expected to increase by 8%, with a winter increase of 14%.[1]

## Risks and Vulnerabilities

Since temperature and precipitation are fundamental determinants for the composition and function of ecosystems, we can expect to see widespread impacts to natural resources. Warming, precipitation changes, and other alterations associated with climate change also magnify the effects of other environmental stressors, such as invasive species and pathogens, deer over-browsing, and habitat fragmentation, to mention a few.

Current problems, such as the decline in sugar maple and ash, as well as limited forest regeneration, will worsen as the climate continues to change. This coupled with a projected decline in northern hardwoods, especially black cherry, may result in mill closings and job losses and the depression of economic development in some areas. Similarly, increased stress and decline of street trees in urban settings may increase safety hazards, alter the character of towns and neighborhoods, and affect real estate values and a community's sense of place.

Projected Temperature Change




*U.S. Global Change Research Program*

Maps show projected change in average surface air temperature in the later part of this century (2071-2099) relative to the later part of the last century (1970-1999) under a scenario that assumes substantial reductions in heat trapping gases and a higher emissions scenario that assumes continued increases in global emissions. (Figure source: NOAA NCDC / CICS-NC).

The Commonwealth's Climate Change Adaptation Report[4] reviewed the biological and environmental dimensions of climate change and identified specific risks and vulnerabilities for forest systems, freshwater systems, agricultural systems, and wildlife and native plant resources. There was considerable overlap, with the following categories of risks/vulnerabilities shared by all or most of these natural resource areas:

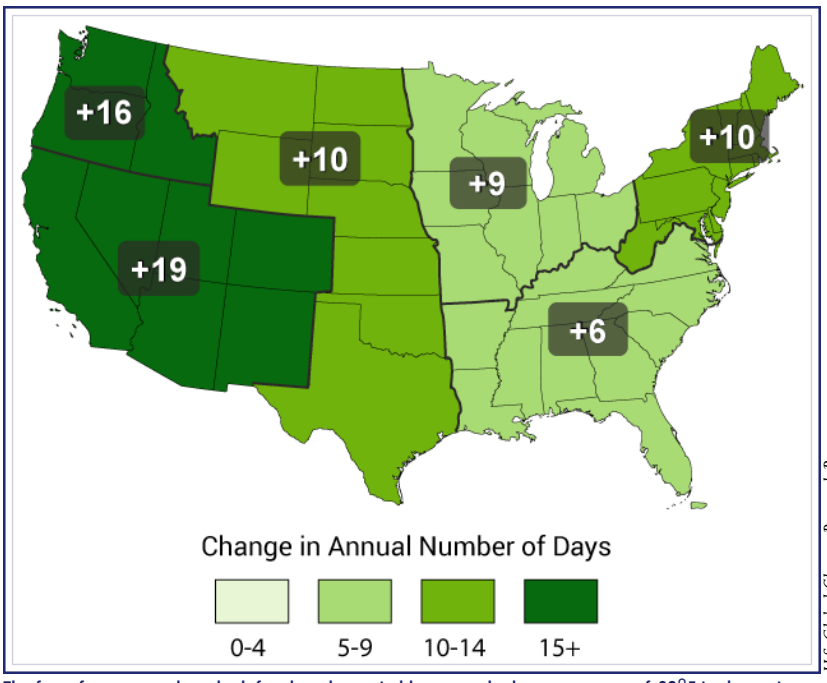
- Shifts in species composition could change ecological function and economic value;
- Interaction of stresses and disturbances, such as fire, storms, pathogens, and invasive species, could have unpredictable impacts on natural and agricultural systems;
- Barriers to connectivity at the landscape and regional scales could restrict the movement of species to new more climatically favorable locations;
- Changes to river and stream flows and shallow groundwater supplies could have adverse impacts on aquatic and wetland species, crop varieties and livestock;

- A lack of genetic diversity in some wild species and agricultural varieties could limit their ability to persist in the face of expected changes in temperature, precipitation, and ecological conditions.

## Forest/Ecosystem Health

Pennsylvania is aptly named for its abundant forests, which have changed dramatically over the past several thousand years as the climate warmed following the glacial retreat at the end of the last ice age. The cold-adapted boreal forests that moved in shortly after the last ice age gradually gave way to the more warm-loving hardwood species we see today. That change was in response to changing climatic conditions, but unlike the current climatic shift, it was slow and gradual.

### Observed Increase in Frost-Free Season Length




*U.S. Global Change Research Program*

The frost-free season length, defined as the period between the last occurrence of 32°F in the spring and the first occurrence of 32°F in the fall, has increased in each U.S. region during 1991-2012 relative to 1901-1960. Increases in frost-free season length correspond to similar increases in growing season length. (Figure source: NOAA NCDC / CICS-NC).

Where and how well a tree grows is based on a complex mix of environmental factors, from topography and climate to soil microorganisms and nutrients. Changes to any of these factors can affect seed germination, tree health, and the types of trees that will grow in an area. This makes planning for the future of the Commonwealth's forests, which are impacted by many different factors in addition to climate change, a challenge for silviculturalists.

Forests cover 58% of the state and are the predominant type of ecosystem found on DCNR-managed lands. These forests have long been subjected to multiple stressors, including pests, disease, invasive species, over-abundant deer populations, pollution, and more. Climate change will exacerbate many of these in addition to adding new stresses. As the U.S. Defense Department said in a recent analysis of the impacts of climate change on national security, climate change is a threat-multiplier.

Climate change is likely to affect forests in several different ways, some positive and some negative, including:

- As habitats become less suitable, some tree species will become stressed, leading to higher mortality and lower regeneration rates. These species will become a smaller component of the forest community, which may have negative ecological and economic impacts. Some species, such as black cherry and sugar maple are already in decline, most likely due to other stressors, but climate change will likely intensify their decline;
- US Forest Service projections suggest limited habitat will remain for many important northern hardwood species in Pennsylvania by the end of the century, including black cherry, sugar maple, yellow birch and others;
- Dry site species (black oak, scarlet oak, chestnut oak, white oak and hickories) may see significant range expansions;
- The combination of higher temperatures, longer growing season, and higher $CO_2$ levels may increase growth rates for some tree species and increase carbon sequestration;
- Phenological changes may result in mismatches

between plants and pollinators and predators and prey, leading to potential negative environmental or economic impacts;

- Increased frost damage due to early spring leaf-out brought on by increasing temperatures;
- Shifts in the distribution of some tree species to the north or to higher elevation. Those at the southern end of their range are likely to become less common or potentially disappear, those at the northern end of their range are likely to expand within the state, and some southern species not yet found here may move into the state;
- Greater insect, disease and invasive species damage;
- Increased heat stress in urban environments due to higher maximum temperatures and the projected number of days above 90°F and 100°F may require removing some tree species from urban street tree planting lists and adding new, more heat tolerant species.

Some of these changes have already begun, but to what extent is not known, because little has been done to assess existing data for baseline information or monitor for climate- related changes. While greater tree mortality is expected, at least for the present it appears that increases in mortality that can be attributed to climate change have been minor. Additionally, the effects of longer growing seasons and $CO_2$ fertilization on tree growth rates has not yet been observed in Pennsylvania's forests, and may be offset by the negative effects of pollutants such as ozone and sulfate deposition. These effects will interact in very complex ways, making highly specific projections of future forest conditions difficult.[1]

## Natural Community Changes

As climate change progresses and temperature and precipitation patterns change, many species will find themselves living outside of or near the limits of their normal tolerance ranges. As a consequence, these species will shift their ranges to more favorable areas, generally to the north or to higher elevations.

For 305 North American bird species, the average center of abundance during the winter shifted to the north more than 40 miles between 1966 and 2013. Of those, 48 species have shifted their wintering grounds more than 200 miles to the north.[5]

An example of one of these range shifts in Pennsylvania is the black-capped chickadee, which is moving north at around one mile per year. As it does, the Carolina Chickadee is moving in from the south and a moving hybridization zone has developed where the two species overlap. As a result, the Carolina chickadee has completely replaced the black-capped chickadee in the southeastern part of the state.

While on their own these range shifts aren't necessarily bad, as the number of species on the move increases, we may see the development of novel ecological communities that have no current analog. We don't know what these new communities may look like, what ecosystem services they will or will not provide, or if there will be an economic impact (i.e. changes in recreational opportunities or timber value). As these shifts occur and natural communities change, conservation goals and management decisions will need to be reassessed.

One potential outcome, which has not been seen in the Commonwealth but that's occurring elsewhere, is ecological transformation, which results in an entirely different ecosystem that supports a different biological community with different ecological and societal

*Photo by: Greg Czarnecki*

Young black-capped/Carolina hybrid chickadees at Hawk Mountain Sanctuary.

functions. An example is the transformation of tens of thousands of acres of Sitka/Lutz spruce forests in Kenai National Wildlife Refuge to savannahs and grasslands due to an increase in invasive species and weather changes due to climate change. This transformation has come with changes in species, fire regime, ecosystem services, and recreational opportunities. Ecological transformation is forecast to affect 5% to 20% of the U.S. land area by 2100.[3]

## Pests, Pathogens, & Invasive Species

It is well documented that climate change leads to an increase in the ecological impact of invasive species, pests (both native and exotic), and pathogens. This may be due to an expansion of the species' range due to warming temperatures, a reduction in the host's defenses due to heat or water stress, reduced winter mortality due to warmer winters, or an increase in the pest's growth rate or number of generations per year due to a longer warm weather season. Overall, climate change may reduce the resilience of ecosystems to resist biological invasions, while biological invasions can also reduce the resiliency of ecosystems to climate change.[6]

Among the pests and pathogens currently in Pennsylvania known to be enhanced by climate change are sudden oak death, anthracnose, beech bark disease, forest tent caterpillar, and hemlock wooly adelgid.[5,6] Some invasive species can also impact the ability of ecosystems to sequester carbon. Japanese stiltgrass, a widespread invasive in Pennsylvania forests, for example, is known to change soil composition and reduce the forest's capacity to store carbon.[5]

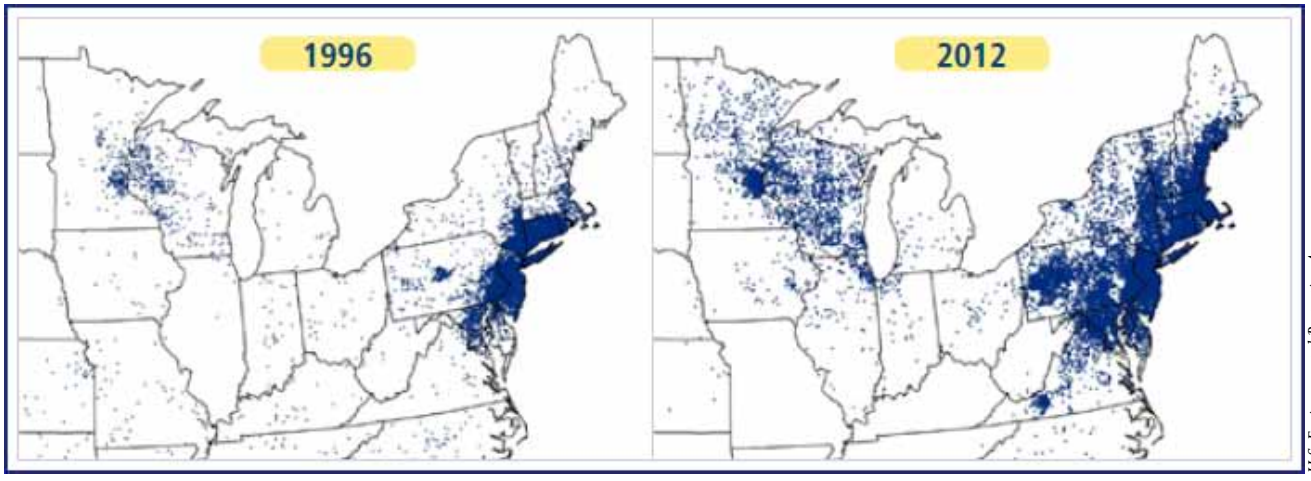
## Employee Health and Safety

Climate change has the potential, and most likely already is, having an impact on DCNR staff, many of whom work outside. Heat-related stress is likely to increase, while cold-related stress may decrease. Airborne allergen (i.e. pollen & mold) levels and potency are likely to increase due to longer growing seasons and $CO_2$ fertilization. The ragweed pollen season, for example, has increased by 13-27 days at latitudes above 44 N.[3] Vector borne diseases, such as Lyme disease and West Nile, are also expected to increase, and there is some evidence that it has already begun.

The number of cases of Lyme disease in the United States has nearly doubled since 1991,[5] and according to the Center for Disease Control is now the most commonly reported vector-borne disease in the United States. In Pennsylvania the number of reported cases of Lyme disease increased by 25% in 2014. The black-legged tick, which is the vector for Lyme disease, is now found in every county in Pennsylvania, and according to researchers at the Cary Institute of Ecosystem Studies, climate change is increasing not only the range of the black-legged tick, but also the time of the year during which the tick feeds.

West Nile disease is expected to increase in prevalence in the higher-elevation areas of the Commonwealth, but

Reported Lyme Disease Cases in 1996 and 2012




*U.S. Environmental Protection Agency*

decrease in in the lower elevation areas. The infection risk is also expected to increase, because the transmission season is projected to increase as temperatures do.[1]

## Infrastructure

DCNR owns, maintains, and designs an extensive variety and number of infrastructure types. The department's buildings, roadways, water and sewage treatment facilities, flood management structures, and communication facilities are all vulnerable to the impacts of climate change.

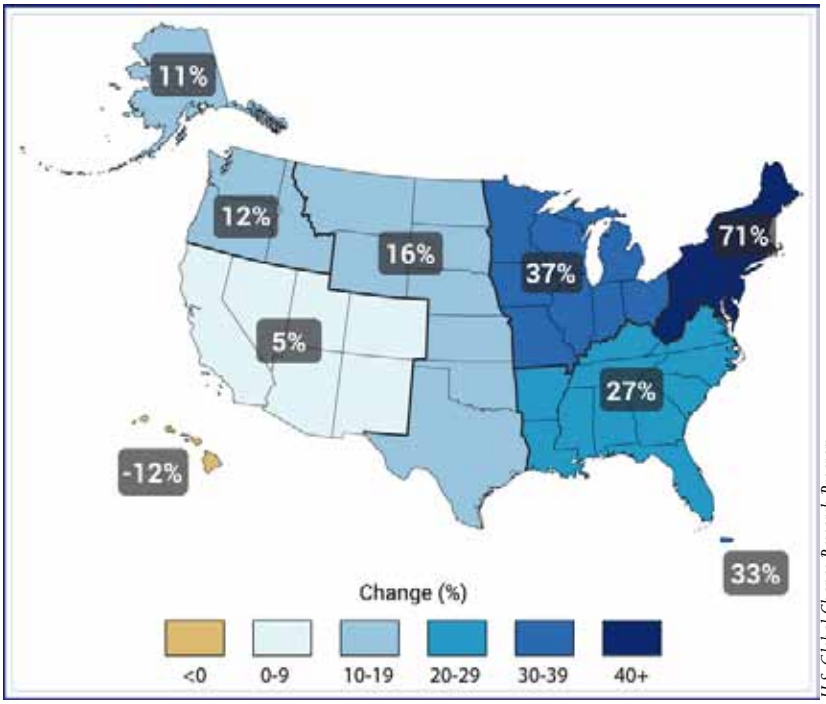
Extreme floods are one of the most costly and damaging climate-related threats to our infrastructure. According to the National Climatic Data Center, Pennsylvania experienced more than 156 storms from 2000 to 2010 that had more than $1 million in property damage each. Total property damage over that same time period is estimated at $1.5 billion.[4]

The department has also experienced significant losses due to flooding since 2000. Delaware Canal State Park, for example, has experienced five major flooding events in the past 11 years that have cost taxpayers more than $32 million in repairs.

Other potential impacts include:

- Increased building cooling costs;
- Damaged asphalt roadways due to extreme heat;
- Bridge and culvert failures, stream bank erosion, and damage to structures in riparian areas due to extreme precipitation events;
- Variability in water supply due to less predictable hydrological and meteorological conditions;
- Interruptions in electrical supply due to extreme heat and storm events.

### Observed Change in Very Heavy Precipitation




U.S. Global Change Research Program

The map shows percent increases in the amount of precipitation falling in very heavy events (defined as the heaviest 1% of all daily events) from 1958 to 2012 for each region of the continental United States. (Figure source: updated from Karl et al. 2009).

## Phenology & Growing Season

The average length of the growing season, which is defined as the period between the last spring frost and the first autumn freeze, in the contiguous U.S. has increased by nearly two weeks since the beginning of the 20th century, with a particularly large and steady increase over the last 30 years. The final spring frosts have also been occurring earlier than at any time since 1895, and the first fall frosts have been occurring later.[5]

A regional analysis of the northeast U.S has shown that the growing season has been increasing by about 2.5 days per decade since 1970. By the end of the century it is forecast to be four to six weeks longer, depending upon which emissions scenario is used.[2]

As the growing season lengthens, the timing of events such as leaf-out, flowering, and leaf drop are changing. Many species of flowers and trees in the northeast, for example, are currently flowering four to eight days earlier than their historical average.[2] Early leaf-out and flowering has led to an increase in frost damage to the

Commonwealth's forests, including one killing-frost in 2013 that damaged more than 213,000 acres in three northern counties. These changes can also lead to mismatches between species whose life cycles are interconnected. Plants may bloom before their pollinators have emerged from dormancy, or trees may see increased insect damage because the insects are emerging before the migratory birds that feed on them return.

## Water

Climate change will impact water resources in several ways, from how much is available and when it's available, to temperature and quality. Overall, precipitation, which supplies the Commonwealth with ground and surface water, has increased, Most of this additional precipitation falls during the winter months, while summers have seen a slight decrease in precipitation.

These changes in precipitation patterns, and a longer growing season due to increasing temperatures, have led to changes in stream flow and soil moisture, and these impacts are predicted to intensify. Peak spring stream flows are expected to occur 10—14 days earlier, and summer low-flows are expected to last about a month longer.[2]

Stream temperature, which is an important measure of ecosystem health, is expected to be altered by future climate change and land use, potentially leading to shifts in habitat and species distributions. The thermal sensitivity of streams (which is defined as the sensitivity of stream temperature to air temperature), however, is based on size and baseflow, so the impact of air temperature will be variable. Coldwater fisheries that depend upon reliable ground water flow may be at risk because extreme precipitation events will lead to more water entering drainages as surface water and less entering the ground water.

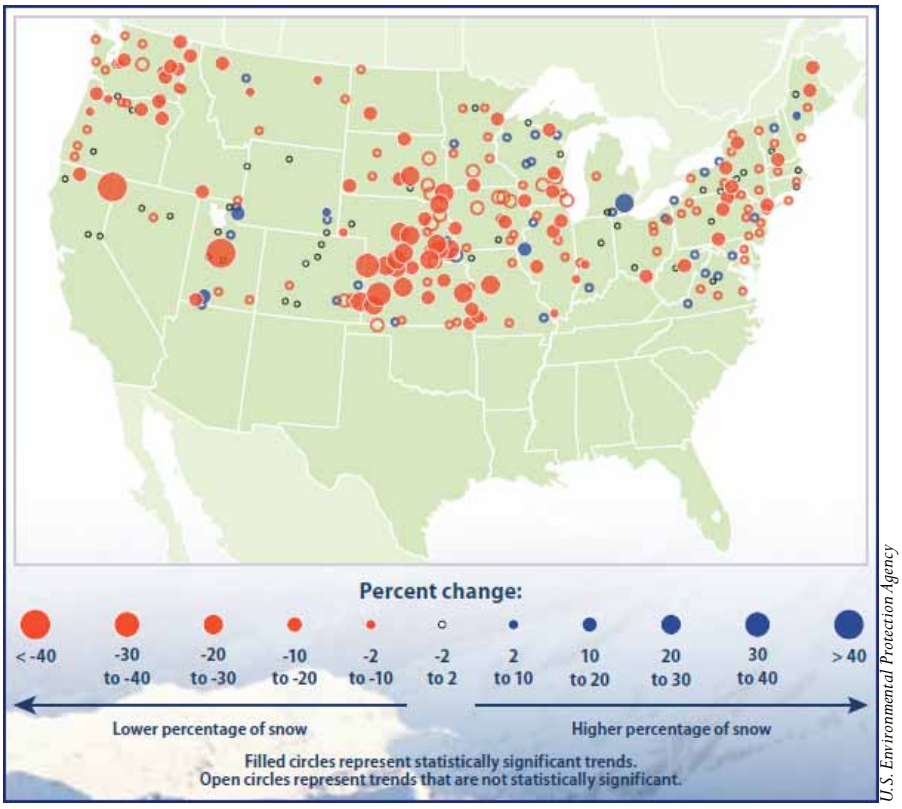
Water quality may also be affected as a result of increasing temperatures and heavy rain events. Surface run-off can carry heavy sediment loads as well as pathogens, and the latter can also result when turbulence in waterways suspends pathogens from bottom sediments. High water temperatures and heavy nutrient-rich runoff can also lead to harmful algal blooms in lakes.[1]

## Recreation

Outdoor recreation is heavily dependent on weather and climatic trends. Not surprisingly, climate change is expected to have a significant impact on the types of outdoor recreation Pennsylvanians enjoy and where they enjoy it.

Higher spring and fall temperatures will lengthen the season for many outdoor recreation activities and may also increase demand for water-related recreation, which could increase pressure to expand or develop

Change in Snow-to-Precipitation Ratio in the Contiguous 48 States, 1949–2014




U.S. Environmental Protection Agency

new pools and beaches. Some of these activities may also be adversely affected by higher maximum summer temperatures and more severe storms. These high summer temperatures may also contribute to increased numbers of harmful algal blooms and an increase in allergens and pollutants resulting in increases in asthma and respiratory issues.

Higher temperatures are also expected to negatively affect sport fish populations, particularly coldwater fisheries. By 2100, all of Pennsylvania is projected to be unsuitable for coldwater fish species, such as brook trout, unless significant reductions in greenhouse gas emissions occur.[1]

Perhaps the greatest impact, however, will be on winter recreation. Winter low temperatures are expected to rise further, with much of Pennsylvania having insufficient snow cover by the end of the century to support skiing or snowmobiling and insufficient ice to support ice fishing. Data collected from 1965-2005 indicated that snow-covered January days declined by 1.5 days per decade in the Northeast and one day per decade in February. Snow totals are expected to further decline 20-30% near the New York border and 50-60% in the Laurel Highlands.[1]

## Economy

Climate change will also have a significant economic impact. Studies show that for every dollar spent in state parks, twelve dollars are raised for the local economy. Consequently, changes in winter recreation and coldwater fisheries could have significant local impacts. Increases in invasive species and pathogens will require increased spending for treatment and eradication and may result in commercial losses of some forest species. Increased storm frequency will result in more money being spent on repair and redesign of infrastructure, and new infrastructure will be needed in response to changing recreational trends. More frequent and extreme wildfires, especially in the western U.S., will require more federal funding to cover the costs of DCNR staff assigned to fight those fires.

The economic impact will be especially significant for our forest resources. In 2012, the state's wood industry had roughly $11.5 billion in sales, an overall total economic impact estimated at $19 billion, and employed approximately 58,000 people.[7] Black cherry, red/soft maple, sugar/hard maple, and mixed hardwoods, which are all predicted to decline due to climate-related stress, collectively account for more than 40% of the total volume of timber harvested in the Commonwealth. These declines could potentially mean significant monetary losses for the department, private landowners, and those employed in the wood products industry.

# DCNR's Strategic Approach to Climate Change

The following section lays out a framework for the department's response to climate change and builds on the work that is already being done. It is in part conceptual, but also provides direction and opportunities for mitigation and adaptation. DCNR's bureaus, divisions and offices will determine next steps on the implementation of these recommendations.

## A New Conservation Paradigm

As the climate changes, so must our approach to conservation and land management. Historically, conservation has focused on maintaining things as they are or returning them to some former state. The conditions under which species, communities, and natural systems evolved, however, are changing, rendering the old conservation paradigm invalid.

Wayne Gretzky, arguably the greatest hockey player of all time, said, "I skate to where the puck is going to be, not where it has been." This is the essence of the new conservation paradigm. We need to base conservation on where the natural world is going, not where it's been.

Rather than manage for persistence, the department should manage for change. As species begin to move in search of more favorable climatic conditions, the plants and animals found in a place will change and consequently so will the natural communities found there. The conservation goal should be to preserve the stage, but allow the actors to change. DCNR should promote and sustain arenas of evolution, not museums of the past.

Exactly how climate change is going to manifest itself in the Commonwealth is unknown, but uncertainty is not the same as knowing nothing. As climate models continue to improve and monitoring begins for climate-related changes, the level of uncertainty will decline. Some argue that this uncertainty is a justification for doing nothing. But instead of inaction, decision-making strategies such as scenario-based planning, structured decision making, and adaptive management should be used to incorporate uncertainty into our planning and management. As Gretzky says, "You miss 100% of the shots you don't take."

The following sections provide some recommendations as to how this new conservation paradigm can be implemented.

## Vulnerability Analysis & Monitoring

The Mid-Atlantic Climate Change Response Framework Project is a collaborative of state (including DCNR) and federal agencies, NGOs, and land owners working to address climate change in Pennsylvania, New York, Maryland, New Jersey, and Delaware. They are in the beginning stages of a regional ecosystem vulnerability assessment, which should be completed by the end of 2015. Several DCNR staff members from the Bureau of Forestry are assisting in writing the assessment. This assessment will evaluate key ecosystem vulnerabilities to a range of future climate scenarios, and will include an evaluation of current conditions, key stressors, past and projected climate trends, and will conclude with a summary of the implications those impacts and vulnerabilities may have on ecosystem management.

Over the past several years the department has also funded numerous projects evaluating the vulnerability of a wide range of plant and animal species to climate change. In combination, these studies will be invaluable in assessing the Commonwealth's vulnerability to climate change.

Monitoring is also an important component of an adaptive management approach to climate change. Without it, we won't know what changes are occurring or how to respond. Based in part on the outcome of the vulnerability analyses, the department should establish a statewide monitoring/research network that includes academia, environmental groups, and citizen scientists. The network could monitor a wide variety

of factors, such as phenological changes, changes in species distribution and abundance, weather and ice conditions, long-term changes in ecological conditions, and more. Additionally, the species, habitat, and natural community inventories conducted by the PA Natural Heritage Program will play an important role in detecting climate-related changes.

Also important is having historical baseline data to compare with ongoing monitoring results. There are many long-term studies and databases produced by universities, other government agencies, and DCNR. Studies such as the Forest Inventory Analysis initiated by the U.S. Forest Service in 1930 and DCNR's monitoring programs should be analyzed for climate-related trends.

## Predictive Modelling

While uncertainty is unavoidable, predictive modelling is still an essential tool for understanding potential future conditions. A number of regional models are already available and will be useful as the department plans its climate change response. Even more useful, however, would be downscaled analyses that look specifically at the state or regions within the state. This analysis would help the department evaluate the potential impacts of climate change, identify monitoring needs, and guide the development of adaptation strategies.

## Adaptation & Resilience

Climate change adaptation can be defined in a number of ways, but put most simply, it refers to those things we can do to limit the impacts of climate change and ultimately increase resilience. It does not include mitigation, which is the reduction of greenhouse gas emissions.

The first step in a well-designed adaptation strategy is to build resilience to other stressors, such as pollution, habitat fragmentation, energy extraction, invasive species, and deer overpopulation. Just as a healthy person is more likely to bounce back from a serious illness than someone who already has health issues, so too is a healthy ecosystem.

Resilience is determined by an ecosystem's adaptive capacity, which is the ability to cope with the effects of climate change with minimal disruption. Generally speaking, unfragmented ecosystems with high biodiversity have a higher adaptive capacity than those that are fragmented, isolated, or contain fewer or more specialized species.

DCNR has a long history of addressing these stressors, but the rapid pace of climate change will require us to reassess these threats and our approach to them. Climate change intensifies the impact of many of these stressors by affecting their timing, spatial extent, and intensity.[8] Consequently, the department needs to assess the additive impact that climate change will have on these threats and how we respond to them.

There are several adaptation approaches, frameworks, and processes that have been developed and are in use by government agencies and environmental NGOs. They include Ecosystem-Based Adaptation, which has been pioneered by the United Nations Environment Program, Climate Smart Conservation, which was developed by the National Wildlife Federation and numerous federal agencies, the Climate Change Response Framework, developed by the US Forest Service, and others.

One example of an approach to adaptation comes from the U.S. Forest Service.[9] It lists the following 10 key components:

1. Sustain fundamental ecological functions.
2. Reduce the impact of existing biological stressors.
3. Protect forests from severe fire, wind, and ice disturbance.
4. Maintain or create refugia.
5. Maintain and enhance species and structural diversity.

6. Increase ecosystem redundancy across the landscape.
7. Promote landscape connectivity.
8. Enhance genetic diversity.
9. Facilitate community adjustments through species transitions.
10. Plan for and respond to disturbance.

The department is already implementing many of these strategies as part of its approach to ecosystem management; however the way we employ them may need to change. It will be necessary to explicitly consider climate impacts, because how, when, and where these strategies should be implemented may change. The National Wildlife Federation refers to this approach as Climate Smart Conservation and defines it as *the intentional and deliberate consideration of climate change in natural resource management, realized through adopting forward-looking goals and explicitly linking strategies to key climate impacts and vulnerabilities*.[10]

The department should evaluate the various approaches and determine which would be most effective in helping design and implement adaptation strategies for DCNR lands. It's quite possible that a hybrid approach incorporating components from each of these might be the best solution.

As managers of one of the largest blocks of public land in the eastern U.S., the department needs to be cognizant of the role DCNR lands play in the movement of species in response to climate change. State parks and state forests will provide refugia and pathways for this movement and thus play a regional and even global role, and our management decisions need to take that into account. This will be a challenge, particularly in areas where land is being converted due to expanding energy infrastructure or growing communities.

An important part of our adaptation strategy should also be identifying and protecting areas that are most resilient to climate change. The Nature Conservancy (TNC) has devised a novel approach to identifying these sites within the northeast. The Northeast Resilience Analysis identifies areas where climate change would be moderated by complex topography, geology, microhabitats, dense wetlands, and permeable natural cover and where there are high levels of biodiversity. DCNR could work with TNC to refine this analysis to help prioritize conservation targets as part of our adaptation strategy.

Another key component of an adaptation strategy is the willingness to consider conservation approaches that heretofore would have been considered unacceptable. These could include evaluating the potential for invasive species to stabilize disturbed habitats when native species succumb to climate change, managing habitat fragmenting features such as pipeline right-of-ways as migratory pathways, or assisted migration for species unable to move to more favorable climates on their own.

Because the projected pace of climatic change is faster than most trees can migrate, assisted migration is a concept that is receiving more consideration. Assisted migration is the movement of species or populations to facilitate natural range expansion in response to climate change. It can have multiple benefits, such as preventing extinction, minimizing economic loss, and sustaining ecosystem services and biodiversity.[11]

As an example, the state of Minnesota is conducting an assisted migration pilot project with TNC, the University of Minnesota, the Minnesota Forest Resources Council and others. Tree species that are found in the southern part of the state, which are more likely to thrive under warmer, drier conditions, are being planted on 2,000 acres of state, county, and federal land in the northern part of the state. They will be managed using a variety of siliviculture practices to determine how well they may do under future climate and management scenarios.

There are a number of other assisted migration trials going on in North America as well, but the process is not without potential drawbacks. It raises scientific, policy, and ethical questions, not to mention the potential pitfalls that accompany the introduction of a species into an area where it has not previously occurred. While assisted migration has the potential to preserve forest health and productivity in a changing climate, and the department should not rule out its use

in the future, it also shouldn't be undertaken without considerable research and forethought. The department has recently developed new genetics guidelines that will help ensure that the movement of any plant or tree species outside of their current range will be done in a thoughtful manner.

These are just some of the adaptation strategies that the department could implement. DCNR should develop a department-wide adaption plan, but given their unique roles and constituencies, each of the department's bureaus should also consider developing individual adaptation plans as well.

## Collaboration

There are many organizations actively studying the impacts of climate change on natural resources and assessing adaptation and mitigation strategies. Collaborating with these entities, many of which the department already works with on other issues, will increase efficiency, reduce costs, save time, and prevent us from reinventing the wheel or attempting failed approaches. The organizations most actively involved in climate change include the U.S Forest Service, U.S. Fish and Wildlife Service, U.S. Geological Survey, Landscape Conservation Cooperatives, National Oceanic and Atmospheric Association, and The Nature Conservancy.

Additionally, it is widely recognized that people are motivated by and behave based on their values much more than by data or scientific evidence. This is particularly true for climate change. Consequently, the department should look for opportunities to collaborate with faith-based groups and community groups, particularly when we work in urban areas, within communities, and as part of the Conservation Landscape Initiatives.

## Education/Communication

There will be an increased need for communicating climate change issues to the public and to DCNR staff. Of particular importance will be showing that climate change is affecting us now and that it's not just an issue we'll have to deal with in the future. Among the key messages should be the impacts of climate change, the consequences of doing nothing, and that most adaptation strategies are no-regret solutions that provide co-benefits beyond climate change. The department's public education programs also offer a great opportunity to both educate the public and engage them in our monitoring efforts as citizen scientists. Similarly, the Bureau of Recreation and Conservation can help educate municipalities about the potential impacts of climate change and adaptation strategies to deal with them.

## Grants and Acquisitions

The department plays an influential role in land conservation and management through its grant and acquisition programs. To maximize the effectiveness of these investments, land acquisitions should contribute to landscape level corridors, habitat connectivity, and the conservation of high-value areas that facilitate species movement and dispersal in response to changing climate. Additionally, changes in climate (i.e., decreased opportunities for "traditional" winter recreation, increased likelihood of intense precipitation events and resulting flooding that may damage infrastructure) should be considered during the grant application review process.

## Recreation

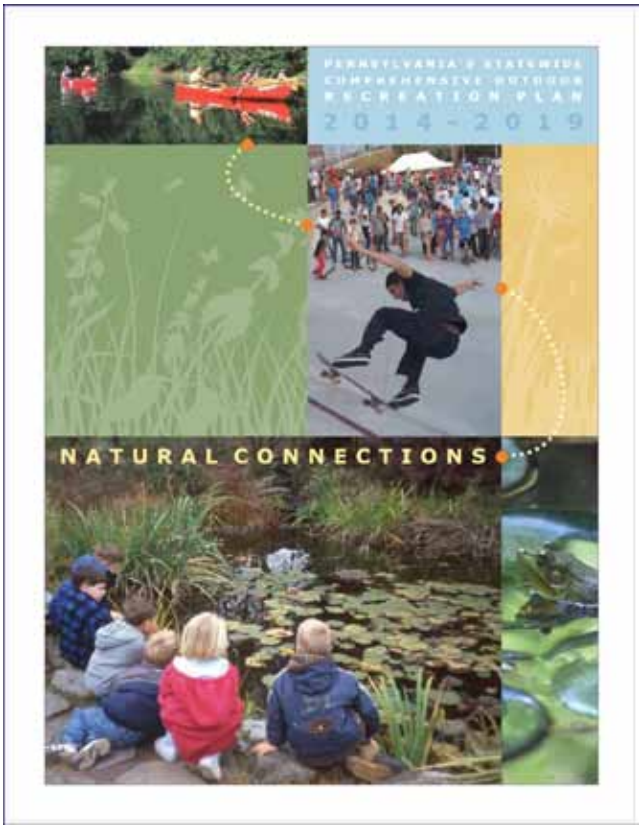
The department is the lead agency for development of the Statewide Comprehensive Outdoor Recreation Plan, which is used by local and state government and private recreation providers to determine where best to make investments in recreation. This five-year plan, which was just revised in late 2014, touches on a broad spectrum of outdoor activities, from hiking and biking to birdwatching and swimming, all of which will be significantly impacted by climate change. Climate change should be considered as the plan's recommendations are implemented.

The Commonwealth's Climate Adaptation Planning Report[4] also contains specific recommendations for

integrating climate change into recreation planning. Among them are:

- Expand trails and greenways to help people escape high summer temperatures; connect the places where they live, work, go to school, and shop; reduce greenhouse gas emissions; and serve as corridors for the movement of wildlife;
- View greenways, trails, and athletic fields as dual purpose facilities that can limit flood damage;
- Develop forested riparian buffers to shade coldwater streams;
- Adjust the time of day and/or length of season that various outdoor recreation activities occur to avoid extreme high temperatures during the summer or take advantage of extended favorable weather conditions during the spring and fall;
- Monitor public beaches and lakes for water quality issues.

As with most climate change adaptation strategies, steps taken to benefit recreation can provide benefits to other areas as well. Many of the solutions are equally applicable to concerns about human health, economics, infrastructure, and wildlife conservation.



Pennsylvania Statewide Comprehensive Outdoor Recreation Plan.

## Forest Carbon Sequestration & Agroforestry

Trees actively sequester carbon in their tissues and in the soil through the process of photosynthesis. As a result, forests play an essential role in removing significant amounts of greenhouse gas from the atmosphere and locking the carbon into both standing wood and wood products. Worldwide, forests absorb and store about 25% of the carbon emitted by burning fossil fuels, while in the U.S. they sequester about 12-15% of the country's annual carbon emissions, with forest products sequestering an additional 1%.[12]

DCNR estimates the amount of carbon being sequestered by our public State Forests during 2015 at nearly 4.7 million tons, with the amount predicted to grow by approximately 3.4% annually. The total amount of carbon currently stored within our public forests is estimated to be a little over 142.5 million tons. Since State Forests account for only 2.2 of the Commonwealth's 17 million acres of forest, it's clear that our forests are critically important to mitigating the impacts of climate change.

Urban trees also play an important part in sequestration. A study of urban trees in Scranton, for example, estimates that they remove 3,000 tons of carbon annually from the atmosphere and collectively have stored 93,000 tons.

In addition to mitigating the impacts of climate change through carbon sequestration, forests also provide co-benefits that help build resilience to climate change, such as improved air quality, clean water, flood and erosion control, and habitat corridors.

The department has a long history of maintaining a healthy, diverse state forest system by utilizing silivicultural practices that promote species diversity and regeneration, while aggressively dealing with invasive species and forest pests. These practices will be increas-

Photo by: Brett Chedzoy

Silvopasture combines trees, which sequester and store carbon, with livestock production.

ingly important in light of climate change, along with preventing the conversion of existing forests to other land uses and expanding forest cover through afforestation. This could be incentivized on both private and state land through a carbon banking and trading system that pays landowners to plant and manage working forests that can both store carbon and supply wood products.

Afforestation should not be limited to traditionally forested parts of the state. As part of the Commonwealth's Climate Change Action Plan, the Bureau of Forestry has developed a plan to increase urban and suburban tree cover over the next 15 years to increase carbon sequestration as well as to reduce energy consumption by providing shade to homes and businesses. The Bureau is also actively promoting agroforestry practices such as planting riparian buffers, forest farming, and silvopasture. These practices not only increase carbon sequestration in agricultural settings but also have the added benefit of serving as adaptation strategies that control flooding, provide wildlife corridors, and more.

## Geologic Sequestration

Carbon can also 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.

DCNR's Bureau of Topographic and Geologic Survey has been involved with research on subsurface carbon storage for over a decade. In 2003, the Federal government organized partnerships across the continental United States and Canada to investigate carbon storage potential, and Pennsylvania joined the Midwest Region Carbon Sequestration Partnership with eight other geographically connected states. Thus far the partnership has developed rough calculations for available carbon storage, assessed the potential for enhanced oil recovery and is progressing from broad, regional studies to more detailed areas, focusing on more favorable geologic formations.[13,14] As part of this effort, the bureau is currently reviewing over 6500 oil and gas wells to correlate rock units across the Commonwealth, mainly in the various Devonian shale formations.

Act 129 of 2008 also required DCNR to investigate $CO_2$ sequestration potential within the Commonwealth, and as a result, *Geologic Carbon Sequestration Opportunities in Pennsylvania* was published in 2009.[15] As part of that legislative mandate, the bureau took a closer look at the subsurface geology of two locations (Indiana and Lancaster/Lebanon Counties) for more localized geologic characterization.[16,17] A series of publications is underway for the Indiana County area, including data collected during the study and subsurface maps of the geology.

In addition, the bureau is one of the partner organizations for the Offshore Storage Resource Assessment through the U.S. Department of Energy. This project will run through October 2018. New work, as well as geologic information previously collected along the East Coast, will be examined to determine the viability of offshore underground $CO_2$ storage. The bureau will be involved mainly in the information sharing and public outreach aspect of this project.

## Infrastructure

According to the U.S. Green Building Council, buildings emit 38% of all greenhouse gases. From an infrastructure standpoint, climate change and its effects can be combated by reducing the carbon emissions that buildings generate (mitigation) and by designing buildings that are resistant and resilient to the effects of climate change (adaptation).


Photo by: Pa. DCNR

Successive Hurricanes Irene and Lee caused massive flooding at Delaware Canal State Park in 2011.

As of today, DCNR has 10 green buildings which are LEED certified. Seven more buildings are in the certification stage and about three are in the planning stage. Many of these buildings utilize geothermal heat pumps to extract and deliver energy for cooling and heating and have high performance building envelopes with high R-values for insulation.

Most of our sustainable buildings have also been designed with storm water best management practices (BMPs) for sustainable sites. Theses BMPs, such as porous pavements and retention and detention basins ensure that storm water infiltrates where it falls, mitigating run-off that may lead to destructive erosion. Other BMPs like rain gardens ensure that run-off is filtered free of pollution before it migrates to receiving waters to preserve the quality of our streams, rivers and the Chesapeake Bay. These storm water best management practices will also help mitigate the overall effect of flooding, which is predicted to continue increasing due to climate change.

DCNR has also deployed demonstration solar arrays in some state parks and is currently exploring the feasibility of mounting solar panels on buildings or pavilions where they might make sense for generating energy for lighting. In the event that extreme weather would incapacitate the grid, these buildings would still be lit without using generators that emit carbon dioxide.

As climate change progresses we also need to reevaluate our recreational infrastructure. Blue Knob, Laurel Mountain, Denton Hill, and Big Pocono State Parks all contain ski resorts. As their infrastructure ages, we should evaluate the investment in these facilities and consider alternate recreational opportunities.

The potential impacts of climate change should be considered when designing any construction project to minimize the impacts and reduce the carbon footprint of the department's infrastructure.

# Conclusion

As this paper clearly shows, Pennsylvania's climate is changing at an unprecedented rate. Average temperatures and annual precipitation are rising, the number of extreme flooding events has increased dramatically, and the growing season is significantly longer than it was just 50 years ago.

Just as clear is that the actions we choose to take or not take today will determine whether our forests, parks, and natural systems will be resilient and adapt as the climate changes. The forests we are planting now won't reach maturity until the end of the century, when the climate will be very different than it is today. The lands we manage will be critical pathways for species moving north as the climate warms. Our grant programs could fund land acquisitions, recreational facilities, and research that help the Commonwealth reduce and adapt to climate change. We can be leaders in green infrastructure and sustainable design, thereby reducing our carbon footprint, helping us adapt to climate change, and serving as examples for others to follow.

For all of these reasons, the time to act is now. As Benjamin Franklin said, "By failing to prepare, you prepare to fail." By viewing everything we do through the lens of climate change, by embracing a new conservation paradigm based on change and adaptation, and by beginning climate change preparedness planning now, we can ensure that we fulfill our mission of stewardship for future generations.

# References


1. *Pennsylvania Climate Impacts Assessment Update* – May, 2015. Penn State University.

2. *Climate Change in the U.S. Northeast. A Report of the Northeast Climate Impacts Assessment*. October, 2006.

3. Melillo, Jerry M., Terese (T.C.) Richmond, and Gary W. Yohe, Eds., 2014: *Climate Change Impacts in the United States: The Third National Climate Assessment*. U.S. Global Change Research Program, 841 pp. doi:10.7930/JOZ31WJ2

4. *Pennsylvania Climate Adaptation Planning Report: Risks and Practical Recommendations*. PA Dept. of Environmental Protection. January 2011. 7000-RE-DEP4303

5. U.S. Environmental Protection Agency. 2014. *Climate Change Indicators in the United States, 2014*. Third edition. EPA 430-R-14-004. www.epa.gov/climatechange/indicators

6. *Bioinvasions in a Changing World: A Resource on Invasive Species - Climate Change Interactions for Conservation and Natural Resource Management*. 2014. A report to the Aquatic Nuisance Species Task Force and The National Invasive Species Council.

7. *Pennsylvania Timber Product Output Survey*. Pennsylvania Department of Conservation and Natural Resources publication. 2015

8. Staudt, Amanda, et al. *The added complications of climate change: understanding and managing biodiversity and ecosystems*. Frontiers in Ecology and the Environment, 11(9):494-501. 2013

9. *Forest Adaptation Resources: Climate Change Tools and Approaches for Land Managers*. General Technical Report NRS-87. 2012. U.S Forest Service

10. Stein, B.A., P. Glick, N. Edelson, and A. Staudt (eds.). 2014. *Climate-Smart Conservation: Putting Adaptation Principles into Practice*. National Wildlife Federation, Washington, D.C.

11. *Effects of climatic variability and change on forest ecosystem: A comprehensive science synthesis for the U.S. forest sector*. U.S. Forest Service, General Technical Report PNW-GTR-870. 2012

12. *Forest Policy Forum - A Forest Carbon Future*, Dovetail Partners, 2015.

13. Battelle. 2005. *The Midwest Regional Carbon Sequestration Partnership (MRCSP): Phase I Final Report*.

14. Battelle. 2011. *The Midwest Regional Carbon Sequestration Partnership (MRCSP): Phase II Final Report*.

15. Department of Conservation and Natural Resources (DCNR), 2009, *Geologic sequestration opportunities in Pennsylvania*, Pennsylvania Department of Conservation and Natural Resources: 150 p.

16. Carter, K. M., Schmid, K. W., Harbert, William, and Parrish, J. B., 2014, *Using geophysical and remote sensing techniques to evaluate deep geologic formations in Indiana County, Pennsylvania: Geologic structure from 2D seismic data*: Pennsylvania Geological Survey, 4th ser., Open-File Report OFOG 14–01.0, 13 p.

17. Schmid, K. W., 2015, *Using geophysical and remote sensing techniques to evaluate deep geologic formations in Indiana County, Pennsylvania–Processed 2D seismic data*: Pennsylvania Geological Survey, 4th ser., Open-File Report OFOG 15–02.0, 5 p.