Afforestation Areas, ChesLen Preserve

Climate Change Vulnerability Assessment for the Natural Lands Climate Adaptation Project

This document represents an evaluation of climate change vulnerability for afforestation areas in the Natural Lands' ChesLen Preserve in Chester County, Pennsylvania. The following information was based on expert input provided in fall 2022 as well as sources from the scientific literature.

Habitat Description

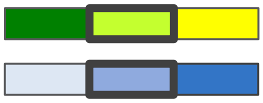
Afforestation is the process of converting non-forested lands into forest, and typically occurs via tree planting and seeding on lands that have been abandoned or degraded (e.g., agricultural or mined lands) (*1*, *2*). Afforestation areas can act as carbon sinks, improve watershed quality, increase canopy cover, and mitigate erosion (*3*). The Natural Lands' ChesLen Preserve spans 1,282 acres in Chester County, Pennsylvania, where afforestation projects are used to strengthen riparian buffers, improve water quality, stabilize creek banks, and filter pollutants. Within the preserve, stream buffer afforestation areas are found along the West Branch Brandywine Creek and its tributaries, covering just over 42 acres. About 11.6 acres of the afforestation areas within the preserve are located along the edge of a wetland complex in the northeastern corner of Unit 3 of the preserve, where they are bounded on two sides by Route 162 and Brandywine Drive (*4*). While most afforestation in ChesLen Preserve is found in riparian areas, some plantings are also located in upland areas (*4*).

The species planted in afforestation areas are generally based on those already present within the area, although other native species may occasionally be added (e.g., hardwoods or smaller trees) (*4*). Within riparian buffer plantings, common tree species include swamp white oak (*Quercus bicolor*), black gum (*Nyssa sylvatica*), sycamore (*Platanus occidentalis*), silver maple (*Acer saccharinum),* and red maple (*Acer rubrum*) (*4*, *5*).

Vulnerability Ranking

Moderate Vulnerability

Moderate Confidence



Vulnerability is evaluated by considering the habitat's sensitivity and exposure to various climate and non-climate stressors as well as the habitat's adaptive capacity or ability to cope with these stressors with minimal disruption. The overall vulnerability of the habitat is ranked on a scale from low vulnerability (dark green) to high vulnerability (yellow). The confidence in the vulnerability ranking's accuracy is similarly ranked on a scale from low (light blue) to high (dark blue).

Afforestation areas of the ChesLen Preserve are sensitive to changes in climate stressors such as precipitation, soil moisture, drought, air temperature, and heat waves. These stressors can impact planted species' growth rate and survival, especially in newly planted and young trees. Some changes, however, may benefit afforestation plantings. Projected increases in temperature and the resulting drier soils may extend the growing season for some planted tree species, supporting their initial establishment and thus contributing to the overall success of afforestation efforts. Once trees are established in this area and begin to mature, they can help with flood management, soil erosion prevention, promote the overall health of soil once degraded, and contribute to forested habitat

Species	Trend
Blackgum (*Nyssa sylvatica*)	▲
Red maple (*Acer rubrum*)	▼ *Reduced climatic suitability but highly adaptable*
Silver maple (*Acer saccharinum*)	▲
Swamp white oak (*Quercus bicolor*)	▼
Sycamore (*Platanus occidentalis*)	▲

Table 1. Likely climate-driven changes in future abundance of individual tree species (see Appendix 1 for more detail).

connectivity within the preserve. Afforestation plantings can also reduce temperatures, both on land and in streams and wetlands, reducing heat stress for plants and wildlife. Due to ongoing planting efforts, the presence of a mix of tree ages within afforestation areas may also help support the adaptive capacity of the habitat by diversifying forest structure and its ability to respond to changes in climate. Strategies that can facilitate the establishment and survival of planted species, such as selecting species with high adaptability, will help to reduce the vulnerability of the habitat. Factors such as discontinuous habitat, barriers to dispersal, threats from invasive species, impacts from surrounding stressors (e.g., roads, agricultural runoff, residential/commercial development), and lack of habitat diversity could affect the ability of the habitat to adapt to future conditions.

Sensitivity and Exposure

Moderate Impact

High Confidence

Sensitivity *is a measure of whether and how a habitat is likely to be affected by a given change in climate and climate-driven factors, changes in disturbance regimes, and non-climate stressors. By contrast,* ***exposure*** *is a measure of how much change in these factors a resource is likely to experience. Sensitivity and exposure are combined here for a score representing climate change impact, with high (yellow) impact scores corresponding to increased vulnerability and low (dark green) scores suggesting a habitat is less vulnerable to climate change.*

Sensitivity and future exposure to climate and climate-driven factors

Climate Stressor	Trend	Projected Future Changes[1]
Precipitation	▲	• 5.7°F increase in average annual temperature in Chester County by 2050; 9.1°F increase by 2100 (*6*) • Most precipitation increases will occur in winter and spring rainfall, with little to no change from historical patterns in the summer and fall (*6*, *7*)
Soil moisture	▲ ▼	• Overall trend towards decreased soil moisture by 2100 (*6*, *8*) • Likely increases in spring soil moisture and decreases in summer and fall soil moisture (*6*, *8*)

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[1] Note that the projections summarized here are based on the RCP 8.5 (high emissions) scenario, which is recommended for planning purposes. Additional details and some projections for the RCP 4.5 (moderate emissions) scenario are provided in the document titled "Overview of Climate Trends and Projections for Natural Lands Preserves", available at https://ecoadapt.org/goto/Natural-Lands.

Drought	▲	• Likely increases in drought frequency and severity due to higher temperatures that increase evaporation and plant transpiration (*6*)
Air temperature	▲	• 5.7°F increase in average annual temperature in Chester County by 2050; 9.1°F increase by 2100 (*6*)
Extreme heat & heat waves	▲	• Increase from 2.3 to 22.5 days per year with high temperatures over 90°F in Luzerne County by 2050, and to 64.1 days per year by 2100 (*9*)

- **Changes in precipitation amount and timing, increased drought, and soil moisture changes** impact hydrologic regimes and the growth and establishment of species planted in afforestation areas. More frequent droughts and warmer temperatures are likely to reduce water availability and soil water retention, resulting in less frequent flooding and decreased soil moisture during summer and fall months (*6*). While reduced water availability can generally lead to soil degradation, impact nutrient availability, negatively affect tree survival rate, and decrease plant growth (*3*, *4*), the drier soils may provide the benefit of a longer growing season for afforestation plantings (+21 days by the end of the century). However, afforestation itself can also affect the exchange of water in an ecosystem (*3*) and, in some cases, has been documented to decrease soil moisture/water retention due to increased rates of plant transpiration (*10*). This could further threaten the survival of species already stressed under drought conditions during the summer and fall months. Additionally, projected trends in increased precipitation during winter and spring months may prove too wet for young trees or saplings, creating possible flood damage and impacting species' survival (*4*).
- **Warmer air temperatures and increased heat waves** may impact soil health (e.g., alter soil pathogens), nutrient availability, plant development, and species distributions (*11*, *12*). As temperatures rise, plant hardiness zones in the region will shift northwards as some species are less able to thrive within their usual home range. This is likely to impact species composition within the preserve; for example, hardwood species like maples may be displaced by oak, pine, and hickory species by the end of the century (*13*). Stress due to increased temperatures as well as changes in species composition may make the habitat vulnerable to invasion by more heat-tolerant species (*14–17*), impacting the establishment and growth of newly planted species in afforestation areas if they are outcompeted or overshadowed by non-native species (e.g., autumn olive [*Elaeagnus umbellate*] in the riparian/wetland afforestation areas of the ChesLen preserve). However, afforestation areas with maturing tree species may also provide a cooling benefit for younger trees by decreasing daytime land surface temperatures during periods of extreme heat, aiding in tree growth and survival (*18*).

Sensitivity and exposure to climate-driven changes in disturbances

Disturbance Regimes	Trend	Projected Future Changes
Extreme flooding & storms	▲	• Increase in magnitude, frequency, and intensity of extreme precipitation events and associated flooding (*6*) • Increase from 0.8 to 1.2 days per year with >2” precipitation (+50%) in Chester County by 2100 (*9*)
Insects & Disease	▲	• Increased occurrence of insect outbreaks and spread of disease (*19*, *20*)

- **Increased severe storms and flooding** may impact afforestation areas where high-velocity runoff uproots new seedlings planted in creek riparian buffer zones. Prolonged instances of flooding will favor species that can adapt to longer periods of inundation, potentially impacting the species composition of the habitat. Flooding can also reduce water quality where increased runoff and contaminants from nearby roads enter streams or wetlands (*21*).
- **Insects (including introduced pests) and diseases (including introduced pathogens)** are likely to damage the forest’s structure and function (*14*) and can weaken the level of defense of the ecosystem against the impacts of climate stressors (*19*, *20*). Insects are temperature sensitive and projected temperature increases could quicken their development and generation time (*22*, *23*). Insects and diseases can alter habitat and ecological processes by reducing tree vitality and can lead to tree mortality events. The resulting impacts of an insect or disease outbreak in a habitat can therefore be detrimental to the habitat’s ability to adequately respond to future disturbances .

Sensitivity and current exposure to non-climate stressors

Non-climate stressors can exacerbate habitat sensitivity to changes in climate factors and disturbance regimes by altering species composition, hydrologic regimes, habitat connectivity, and the ability of planted species to establish and survive. For the afforestation areas of ChesLen Preserve, the non-climate stressors are often the main reason that tree plantings are needed rather than implementing afforestation for the sole purpose of the regeneration of native plants (*4*, *24*).

- **Invasive species** are a significant management concern in afforestation areas, which are vulnerable to invasion when soils are disturbed and native plantings have not yet become well-established (*25*). Young forests, such as those resulting from recent afforestation plantings, have been found to have a higher concentration of invasive species as compared to established forests with intact canopies (*26*). Invasive and problematic species can reduce the abundance and diversity of native species through competition for resources, increased predation risk, and disease spread (*27*). Within ChesLen Preserve riparian buffer afforestation areas, species such as autumn-olive (*Elaeagnus umbellata*), mile-a-minute (*Persicaria perfoliate*), reed canary-grass (*Phalaris arundinacea*), and *Phragmites* spp. are of particular concern (*4*, *5*). Additionally, in the preserve, insects such as the spotted lantern fly (*Lycorma delicatula*) and emerald ash borer (*Agrilus planipennis*) are invasive insects of concern. Invasive species are currently a high priority for management in the ChesLen preserve (*4*).

- **Deer herbivory** limits tree regeneration and impacts habitat species composition due to selective browsing (i.e., oaks are a preferred species by deer) (*28*). Selective browsing of specific immature tree species also impacts the species that depend on them (e.g., birds, insects), and may alter the composition of the afforestation area over time by limiting seedling success and growth (*28–34*). Furthermore, warmer and less intense winter months are likely to prove favorable to deer populations, allowing individuals who would have otherwise not made it through the season to survive and continue browsing in these areas (*28*).
- **Roadways** can act as barriers to dispersal for species seeking refuge from climate impacts and have been connected to changes in species composition, ecosystem function, and altered hydrologic processes (*35*, *36*). The afforestation areas can act as buffers between the roadways and the wetland complex within the ChesLen preserve, possibly minimizing the road's impact on this particular system.
- **Herbicides from adjacent agricultural areas and pollutants** such as pesticides, excess nutrient input, and heavy metals can leech into groundwater and surface runoff and degrade wetland water quality (*37*). The uptake of these pollutants by sensitive non-target species may impact species growth and reproduction (*38*).

Adaptive Capacity

Moderate Adaptive Capacity

Moderate Confidence

***Adaptive capacity** is the ability of a habitat to accommodate or cope with climate change impacts with minimal disruption. High adaptive capacity (dark green) corresponds to lower overall climate change vulnerability, while low adaptive capacity (yellow) means that the habitat will be less likely to cope with the adverse effects of climate change, thus increasing the vulnerability of the habitat.*

Habitat extent, integrity, continuity, and barriers to dispersal

The afforestation areas within the preserve are generally connected to forested land. However, in some sections, afforestation plantings are adjacent to fields, which may leave young trees exposed and susceptible to heat, wind, and flooding (*4*). Barriers to dispersal for this habitat include nearby roads (i.e., Route 162 and Brandywine Drive) and agricultural lands. The preserve is located in a rural, suburban area, with much of the surrounding area occupied by a mix of residential and open space, so dispersal opportunities are likely to be impacted by the future management of these areas (*4*).

Habitat diversity

Species chosen for plantings within the afforestation areas of ChesLen Preserve include blackgum, oaks, and maples (*5*), but the structural diversity among these groups is limited as young trees dominate the area, and there is not yet an established canopy (*4*). Structural diversity (i.e., a mixture of tree ages within a habitat) has been linked to increased resilience because species of various ages have different levels of adaptative capacity to deal with disturbances, and therefore a structurally-diverse habitat could ensure that not every tree would not be wiped out by a single disturbance event (*39*). For example, extreme wind events can cause damage to older trees through breakage and uprooting (*40*), but small trees are less prone to being blown over. Additionally, disturbances such as prolonged flooding could reduce the probability of seed establishment and the survival of young trees with shallow root systems (particularly among species adapted to drier soils such as oaks), but may not have such a drastic impact on older trees with established extensive root systems that can access water retained deep in soils (*41*). Planting young trees in afforestation areas as earlier plantings mature could be an effective strategy to increase structural diversity in the afforestation areas by ensuring that not all trees within the habitat will be impacted at the same severity by the impacts of climate change (*39*, *41*, *42*).

Increasing the species richness and diversity of plantings in afforestation areas could also reduce vulnerability because different tree species have varying resistance to stressors (e.g., drought tolerance [blackgum] and flood tolerance [red maple]) that could prove beneficial in maintaining an overall resilient habitat (*39*, *41*).

Resistance and recovery

Currently, most stands within ChesLen Preserve afforestation areas are under 10 years old, but forest resistance to stressors and disturbances is likely to increase as the trees age. For instance, a recent study found that forests with intact canopies are more resistant to non-native plant invasions (*26*). Native plant regeneration in this area, however, is poor and if the planted species that currently exist within the afforestation areas do not survive, another planting will have to take place to reestablish the tree species (*4*).

Management potential

Overall, the ChesLen Preserve is popular, and the role of afforestation areas in protecting water quality in the region is viewed favorably by the surrounding community. Generally, preserve stewardship has been supported by local townships, county and state governments, and private funders. Educational opportunities provided by Natural Lands about the importance of habitat restoration and afforestation efforts have helped to foster public support for the preserve by reinforcing the surrounding community’s sense of connection to the land.

Regarding preserve management, future changes could strain the organization’s capacity (e.g., staff time, finances) to handle the impacts of climate stressors and disturbances, particularly if they are severe (*4*). For instance, staff capacity may be lessened if intense seasonal droughts necessitate frequent watering of restoration plantings and an increased need to replace trees and shrubs that didn’t survive due to drought and other stressors could become a financial constraint.

Currently, the trees in the afforestation areas are protected by tree tubes and surrounding vegetation is controlled through mowing and herbicide applications (*4*). However, traditional methods of managing habitats, such as burning, mowing, and grazing, may no longer be as effective in preserving certain species in the face of changing future conditions. As climate change places stress on vegetation and potentially hinders the regeneration of some species, continued implementation of these management methods to remove undesirable species could contribute to the stress or loss of desirable species that may not be well adapted to persist or regenerate under changing environmental conditions (*7*). Strategies that support the survival and adaptive capacity of afforestation areas include the selective planting of trees that will increase the structural and species diversity of the habitat, developing early monitoring systems for invasive and problematic species, reducing pollutant runoff from nearby roads and agricultural areas, increasing connectivity in the landscape, removing species that are maladapted, and preserving and planting species that are tolerant to impacts such as flooding (e.g., swamp white oak, red maple, silver maple) and drought (e.g., blackgum) (*42*, *43*).

In the preserve's afforestation areas, the selection of saplings planted is largely dependent on what trees are available to purchase in the area (*4*). However, habitat diversity is strongly connected to the species managers select to plant and when and how they have been planted. Since restoration efforts are ongoing in this area, managers have the opportunity to adapt management strategies as they observe species' resilience to the impacts of climate change (*4*). For instance, species that are projected to have high adaptability and a projected increase in suitable habitat should be prioritized. Of the species currently used in the riparian buffer plantings, blackgum and sycamore species are both projected to expand in the region (*44*). Increasing phenotype diversity and provenance of saplings may also increase resiliency by increasing the likelihood that some individuals will survive environmental changes and disturbance events.

Recommended Citation

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Further information on the Natural Lands Climate Adaptation Project is available on the project page (https://ecoadapt.org/goto/Natural-Lands).

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Appendix 1. Climate Change Projections for Individual Tree Species

Table 1. Adaptability, abundance, habitat change, and capability of tree species in the ChesLen Preserve afforestation areas under RCP 4.5 and 8.5 conditions. *Source: NIACS Climate Change Projections for Individual Tree Species in Pennsylvania* (*44*).

			LOW CLIMATE CHANGE (RCP 4.5)		HIGH CLIMATE CHANGE (RCP 8.5)	
SPECIES	**ADAPTABILITY**	**ABUNDANCE**	**HABITAT CHANGE**	**CAPABILITY**	**HABITAT CHANGE**	**CAPABILITY**
Blackgum	+	○	▲	△	▲	△
Red maple	+	+	▼	△	▼	△
Silver maple	+	–	●	○	▲	△
Swamp white oak	○	–	▼	▽	▼	▽
Sycamore	○	–	▲	△	▲	△

Table 2. Summary of ranking definitions and categories for adaptability, abundance, habitat change, and capability, used to evaluate tree species in Pennsylvania. *Source: NIACS Climate Change Projections for Individual Tree Species in Pennsylvania (44).*

ADAPTABILITY		**ABUNDANCE**	
Life-history factors that are not included in the Tree Atlas model but may impact species ability to adapt (e.g., ability to respond favorably to disturbance)		Based on Forest Inventory Analysis summed Importance Value data, calibrated to a standard geographic area	
+	**High:** Species may perform better than modeled	+	**Abundant**
–	**Low:** Species may perform worse than modeled	–	**Rare**
○	**Medium**	○	**Common**
HABITAT CHANGE		**CAPABILITY**	
Projected change in suitable habitat between current and potential future conditions		Overall rating that describes species' ability to cope or persist with climate change based on suitable habitat change class, adaptability, and abundance in the region	
▲	**Increase:** Projected increase of >20% by 2100	△	**Good: I**ncreasing suitable habitat, medium or high adaptability, and common or abundant
▼	**Decrease:** Projected decrease of >20% by 2100	▽	**Poor:** Decreasing suitable habitat, medium or low adaptability, and uncommon or rare
●	**No change**	○	**Fair:** Mixed combinations, such as a rare species with increasing suitable habitat and medium adaptability