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Chesapeake Forest Lands Climate Change Adaptation and Resilience Planning Guide

Maryland Department of Natural Resources
Chesapeake and Coastal Service
dnr.maryland.gov
580 Taylor Ave, Annapolis, MD, 21401

MARYLAND DEPARTMENT OF NATURAL RESOURCES

MARYLAND FOREST SERVICE

Chesapeake & Coastal Service

Contents

Authors

Justin Arseneault -DNR, Maryland Forest Service-
Nicole Carlozo -DNR, Chesapeake and Coastal Service-
Sara Coleman -DNR, Chesapeake and Coastal Service-
Alex Clark -DNR, Maryland Forest Service-
Rob Feldt -DNR, Maryland Forest Service-
Matt Hurd -DNR, Maryland Forest Service-

Acknowledgements

Over the course of several months, we have worked together to identify climate change impacts and adaptation opportunities on the Chesapeake Forest Lands using many state tools, literature reviews, site visits, and collaborative thinking. We would like to express gratitude to Patricia Leopold of the Northern Institute of Applied Climate Science and Rob Newton and Kate Vogel of the Department of Natural Resources.

Executive Summary

Chesapeake Forest Lands are located on the Eastern Shore of Maryland and contain over 75,000 acres. Dominated by loblolly pine, the forest represents a unique coastal system that is experiencing climate change threats from increasing temperatures, sea level rise, saltwater intrusion, changes in precipitation, and invasive species. Timber and hunting combined bring in just over $1 million on average every year. The Chesapeake Forest Lands are home to many rare, threatened, and endangered species, including Delmarva fox squirrels and bald eagles.

A previously created climate adaptation plan was completed in November 2022 for the Pocomoke State Forest.

Climate Impacts to Forest Resources:

Natural Resources: Increased temperatures, changing precipitation patterns, and sea level rise will alter the species composition of the Chesapeake Forest Lands. Invasive species, forest pests, and pathogens are expected to expand with a changing climate.

Infrastructure: Unpaved roads and water control structures will be stressed as flooding becomes more frequent on the Lower Eastern Shore. Storm events can cause erosion and damage, making certain parts of the forest more difficult to access.

Recreation: Hunting is the major recreational use of the Chesapeake Forest Lands. Climate change may lead to trail washout and decreased access for the public. Additionally, intense heat waves present a public health risk.

Human Resources: Forest staff must respond to problems that may arise from sea level rise, flooding, and invasive species. Climate change may also impact timber harvest, influencing revenue.

Cultural and Historical Resources: There are no known cultural or historical resources located on site, aside from small family cemeteries. If any are identified in the future, the MFS will examine issues and impacts based on climate change.

Key Recommendations

There are many opportunities for climate adaptation and resilience. To protect natural resources, active invasive species management and monitoring should be ongoing. Additionally, increasing vegetative buffers, redirecting water flow to reduce flooding, encouraging regeneration of species that are adapted to future conditions, and maintaining appropriate stand density to address insect pests can help the Forest to be more resilient. Infrastructure improvement options include elevating and reinforcing roads, upgrading culverts to deal with increased water flows, and potentially relocating infrastructure. Overall, increasing climate preparedness and communication will assist staff and the public in mitigating climate change impacts.

Monitoring, cross-agency coordination, and data-driven forest management are needed to keep healthy, native forests on the Eastern Shore. Improving and maintaining infrastructure, including increasing culvert sizes to allow for increasing storm flow, will allow for normal operations to continue at the Chesapeake Forest Lands despite changing climate conditions. Additional adaptation opportunities include updating timber harvesting policies or focusing on tree species with a wider ecological tolerance.

Introduction/Overview

The Maryland Forest Service (MFS) has partnered with Chesapeake and Coastal Service to prepare a climate change adaptation and resilience planning guide for the Chesapeake Forest Lands that evaluates climate hazards, impacts from climate change, and potential adaptation strategies and implementation opportunities. It is intended that this guidance document will support forest staff in decision making and resilience planning and will be used in coordination with the already existing Sustainable Forestry Management Plan to achieve the goals of continued forestry operations, recreational access, and infrastructure maintenance.

Objective and Resilience Statement

The Maryland Forest Service is guided by the mission to restore, manage, and protect Maryland's trees, forests, and forested ecosystems to sustain our natural resources and connect people to the land. This document will provide recommendations and solutions that support Chesapeake Forest Lands' resilience to climate change and ensure the goals of the forest service can continue to be met.

Document Organization

Throughout this document climate change impacts to the Chesapeake Forest Lands (CFL) will be separated into five categories including impacts to: natural resources, infrastructure, recreation, human resources, and cultural resources. Each category is described below.

Natural resources: flora and fauna of the forest

Infrastructure: physical and organizational structures and facilities located at Chesapeake, such as roads and trails

Recreation: opportunities for visitor engagement

Human resources: number of employees, staff time, and financial resources

Cultural resources: historical information and archaeological sites

For each category described above, two scenarios are described in detail: no climate action (a summary of anticipated impacts under 'business as usual') and adaptation options and opportunities.

Background

There is now robust evidence that climate change will lead to increased temperatures, altered precipitation patterns, rising sea levels, and longer growing seasons by the end of the century in the Mid-Atlantic region. The Maryland Forest Service is acutely aware of the impending effects of climate change and is taking action to prepare state forests for future conditions. In February 2023, a workshop was held with forestry managers, CCS staff, and a representative from the Northern Institute of Applied Climate Science (NIACS) to conduct a climate change risk analysis. The goal of the workshop was to develop a list of climate change impacts that are most crucial to understand and plan for with respect to Maryland forests (Appendix B). Prior to meeting, participants were asked to complete a survey detailing their climate-related concerns related to the health and sustainability of certified forests in Maryland. For the Eastern Region, foresters identified

a host of climate impacts and then prioritized the list based on likelihood of occurrence and severity. This led to the following list of key climate change threats: extreme events, rising sea levels, increases in pests and forest pathogens, increases in invasive plant species, and multiple or interacting impacts. The workshop participants also identified potential adaptation actions for the major threats, considering the urgency of response, benefits, drawbacks or barriers, and capacity for implementation. It's important to note that adaptations recommended and implemented will vary based on the timeframe being considered. Additionally, for several of the proposed adaptations, such as conducting more frequent maintenance on dirt/gravel roads to deal with storm damage, additional funding or staff may be required. This document provides a more in-depth look at some of the climate change impacts expected to influence the Chesapeake Forest Lands.

Unlike Pocomoke State Forest, the other state-owned forest located on the Eastern Shore, the Chesapeake Forest Lands have a long history of heavy management and timber production. The forest includes most of the former land holdings of the Chesapeake Forest Product Company. In 2004, 29,000 acres on the Chesapeake Forest Lands (CFL) were the first public property in Maryland to be dual certified as a Sustainable Forest under the Sustainable Forestry Initiative (SFI) and the Forest Stewardship Council (FSC). The Vision for Chesapeake Forest Lands is that it will become an active, working model of certified sustainable forestry on the Eastern Shore that: supports abundant and diverse plant and animal life, contributes to improved water quality, supports natural resource based economic benefits, and provides diverse opportunities for recreation (MDNR Forest Service 2021).

Physical Description

The Chesapeake Forest currently contains 75,559 acres distributed across six counties: Caroline, Dorchester, Somerset, Talbot, Wicomico, and Worcester. This large expanse of forest lands is divided into 187 management units and includes some of the last large segments of unbroken forest in a largely agricultural region of the state. The majority of Chesapeake Forest Lands consists of young loblolly pine forests, and there are no identified old-growth forest stands. Non-forested lands make up roughly 4% of the total area and there are approximately 6000 acres of wetlands. Ecologically Significant Areas that have been specifically delineated comprise 30% of the forest lands. Additionally, there are 29 Irreplaceable Natural Areas (INA) located within the Chesapeake Forest.

While loblolly pine is the most prevalent commercial species, other common tree species on the landscape include red maple, sweetgum, oaks (white, southern red, black, willow, swamp white/chestnut, water), pond pine, shortleaf pine, American beech, hickories, yellow poplar, and black gum. Native shrubs present include mountain laurel, flowering dogwood, witch-hazel, American holly, wax myrtle, sweetbay magnolia, blackberry, and blueberry. Abundant populations of deer, turkey, and waterfowl make for considerable hunting opportunities. The soils of the eastern shore are poorly drained and seasonally wet conditions affect the timing and type of management activities conducted.

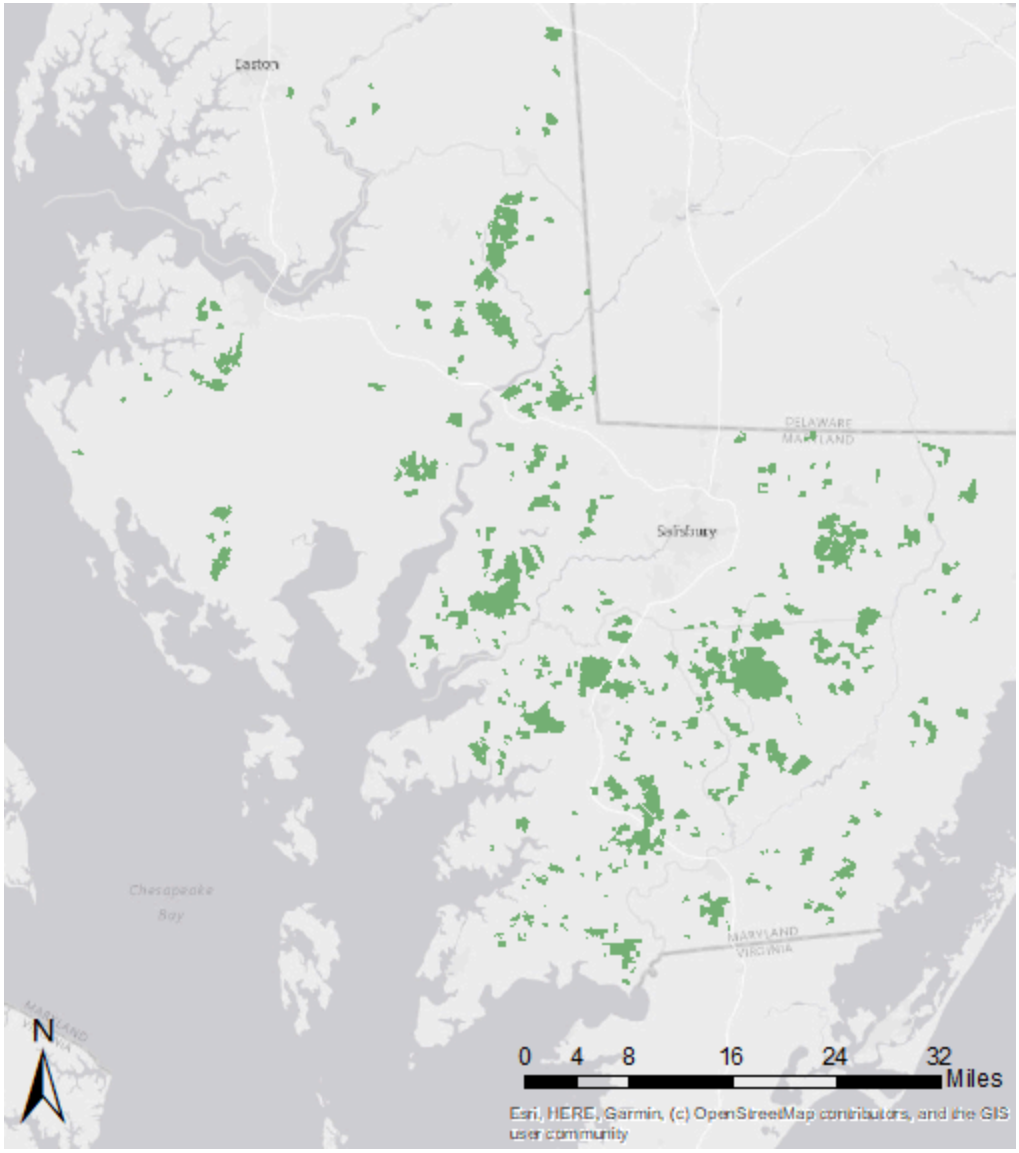

Figure 1. Map of the Chesapeake Forest Lands on Maryland's Eastern Shore.

State Forest Assets and Resources

The primary goal of Chesapeake Forest Lands is to demonstrate that an environmentally sound, sustainable managed forest can contribute to local and regional economies. The dominant commercial species present is loblolly pine. In addition to timber, the CFL provides important benefits for water quality and contributes to 23 watersheds draining into the Chesapeake Bay. The Delmarva fox squirrel, bald eagle, and 101 other species considered rare, threatened, or endangered are currently found on or near CFL tracts.

As one of two state forests in the Eastern Region, Chesapeake Forest Lands is managed by seven MFS staff: five full-time and two contractual employees. In recent years, the revenue generated by hunting has surpassed that of timber harvest.

Unique Areas

The Little Mill Run natural area in Worcester County is a 177 acre INA designated as Tier 1 in BioNet, a data layer that prioritizes conservation needs based on the rarest habitats and species in the state. This mesic bottomland forest contains a blackwater

stream which flows into an old millpond. The wetlands and adjacent 100 foot upland buffer at this site are regulated as Wetlands of Special State Concern (WSSC) by the Maryland Department of the Environment. Tree species include loblolly pine, sweetgum, black gum, and red maple.

Centennial Ponds INA located in Dorchester County is a Tier 2 BioNet habitat. This natural area contains a mix of Delmarva bay, mesic mixed hardwood forest, coastal plain flatwood swamp, and coastal plain oak-pine forest. Some of the rare species present here include coppery St. John's-wort (*Hypericum denticulatum*, state-listed as Threatened), two-formed pink (*Sabatia difformis*, state-listed as Endangered), black-fruited spikerush (*Eleocharis malanocarpa*, state-listed as Endangered), capitate beakrush (*Rhynchospora cephalantha*, state-listed as Endangered), and Harper's beakrush (*Rhynchospora harperi*, state-listed as Endangered). Natural Heritage Program staff are working with MFS to reintroduce fire to this Delmarva Bay complex. Additionally, the control of invasive species will be key to the habitat restoration efforts.

Fishing Bay Wetlands INA is a large expanse of tidal and nontidal wetlands habitat located adjacent to Fishing Bay in southern Dorchester County. This nearly 8,000 acre area begins at the Lewis Complex (D26) and stretches southwest to Fishing Bay. This area contains some of the best examples of marsh and other wetland communities in Maryland, from salt and brackish tidal flats and marshes to tidal forest. Some important bird species found here include black rail (*Laterallus jamaicensis*, state-listed as Endangered), saltmarsh sparrow (*Ammospiza caudacuta*, state-listed as In Need of Conservation), Coastal Plain swamp sparrow (*Melospiza georgiana nigrescens*, state-listed as In Need of Conservation), and bald eagle.

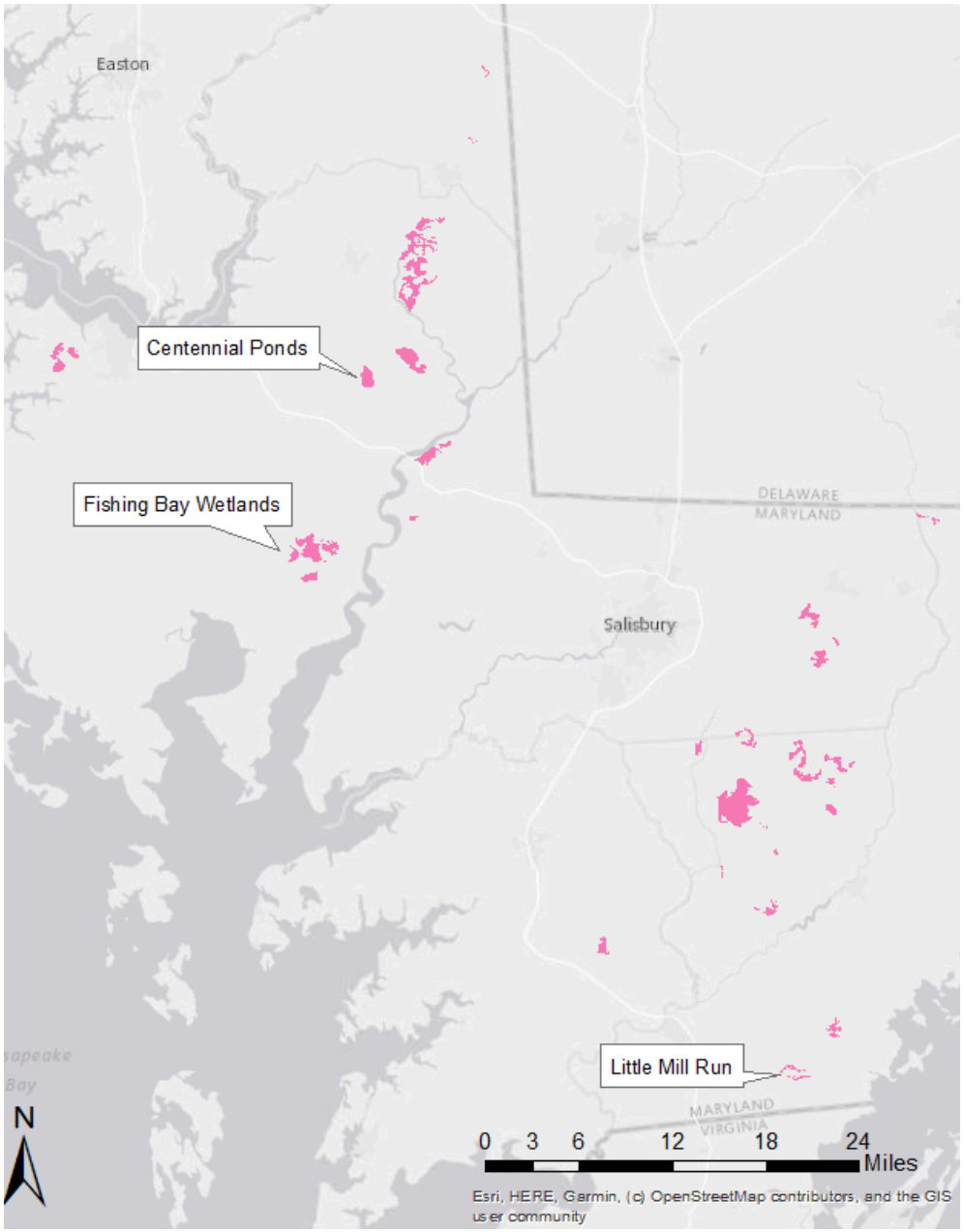

Figure 2. Irreplaceable natural areas of the Chesapeake Forest Lands, with above areas referenced labeled.

Categorizing Climate Change Impacts and Threats to Resources

In 2019, Chesapeake and Coastal Service partnered with Salisbury University's Eastern Shore Regional GIS Cooperative to highlight areas of Maryland that are vulnerable to climate change. Ranking ecological value (EV) and climate vulnerability (CV) using factors such as precipitation rates, sea level rise, rare, threatened and endangered species, and habitats, the study scored habitats on a scale of 0-100, with a higher score representing greater vulnerability. Appendix A includes a map for each county with scores for the Chesapeake Forest Lands tracts (some parcels acquired after 2018 are not shown). Some areas that scored high for both ecological value and climate vulnerability value include the Fred Besley Demonstration Forest (D30), the Lewis tract

(D26), the Insley tract (D06), the Lathrop tract (W06), and the Hoernicke-Oliphant complex (D25).

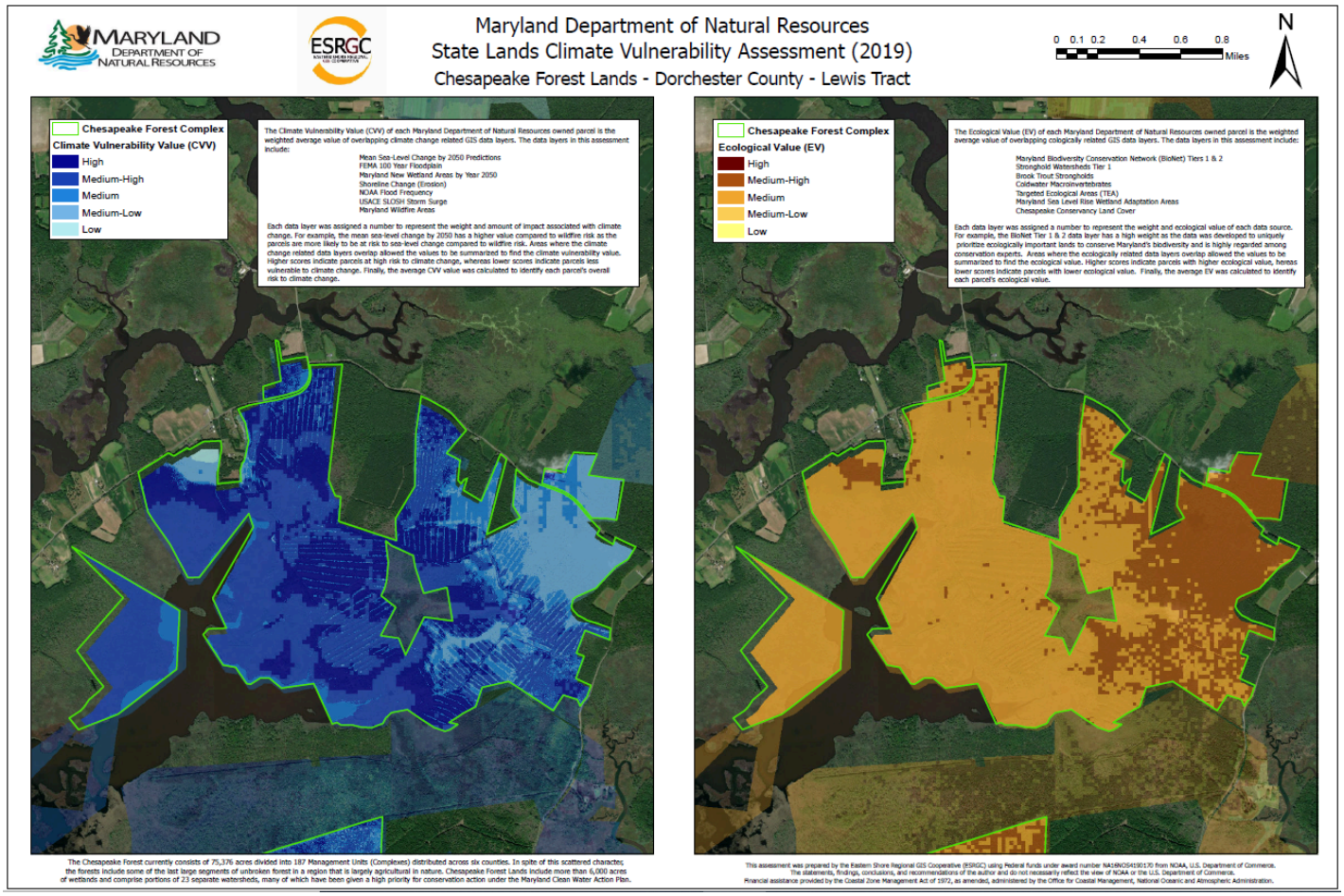

Figure 3. Climate Vulnerability Value on the left and Ecological Value on the right for the Lewis Tract (D26) of the Chesapeake Forest Lands. Analysis completed by the Eastern Shore Regional GIS Cooperative (ESRGC).

The following sections describe observed impacts of climate change, compiled via literature review and conservations with natural resource professionals.

Temperature

Since the beginning of the 20th century, temperatures in Maryland have increased 2.5°F (Runkle et al. 2022). Regionally, the eastern part of Maryland typically has temperatures moderated by the Chesapeake Bay and Atlantic Ocean. The annual number of very hot days (maximum temperature of 95°F or higher) varies from three to eight days on the Lower Eastern Shore (Runkle et al. 2022). Annual average temperature in Maryland is projected to increase by about 3°F by mid-century, and by as much as 9°F by the end of the century if current trends continue (USGCRP, 2018). Such rising temperatures mean milder and shorter winters, and prolonged growing seasons. According to the Mid-Atlantic Forest Ecosystem Vulnerability Assessment and Synthesis, warmer temperatures could lead to increases in invasive plants, pests, and pathogens. More mild winters can also cause the phenomenon of “false spring”, when the weather in February is warm enough for trees and perennial plants to break dormancy. These plants can then suffer freeze damage if temperatures in March drop (Via 2023). The earlier blooming of some species and earlier arrival of migratory birds can lead to

asynchronies, mismatches between key food source availability and migration patterns (USGCRP 2018).

Forest die-off from heat stress, as well as drought, has been observed globally (Anderegg et al. 2015). Trees that are not acclimated to intense heat may incur the most damage, as well as in areas such as along highways or on steep slopes with greater exposure (Ahrens 2021).

In 50 large US Cities, the EPA has collected data that show the average heat wave season across is about 49 days longer now than it was in the 1960s. Maryland is also very likely to experience a greater incidence of heat waves (2022 Annual report from MCCC). Higher temperatures are linked to respiratory problems in humans and can trigger heat stroke, indicating increased risks for MFS staff and recreational users of the Chesapeake Forest (CDC).

Sea Level Rise, Nuisance Flooding and Saltwater Intrusion

The Likely range (66% probability) of the relative rise of mean sea level expected in Maryland between 2000 and 2050 is 0.8 to 1.6 feet. Global greenhouse gas emissions during the next 60 years will largely determine the rates of sea level rise in the latter part of this century (Boesch et al. 2018). The Chesapeake Bay is the third most vulnerable area of the country to sea level rise, in part due to the additive impact of land subsidence (Runkle et al. 2022). Coastal communities in Maryland will see increases in nuisance flooding as sea levels rise. Nuisance flooding, also known as high tide flooding, is when tides reach anywhere from 1.75 to 2ft above the daily average high tide and cause issues by spilling onto streets or overwhelming storm drains (MyCoast). Such flooding is disruptive and has the capacity to damage infrastructure. As stated in the Worcester County Nuisance Flooding Plan, flood water may carry debris and stress culverts in low-lying areas (causing ponding on low-lying roadways). At the February Maryland DNR Forest Service Climate Change Workshop, participants assessed sea level rise as already happening, with an overall medium risk.

Saltwater intrusion can occur as sea levels rise and water moves onto the land, often caused by high tides or storm surge in low-lying areas. Another mechanism is when saltwater infiltrates shallow freshwater aquifers and raises the groundwater table below the soil surface, sometimes by excessive withdrawals of freshwater (Maryland Department of Planning 2019). In a summer 2020 saltwater intrusion delineation flight on the Lower Eastern Shore, more than 50,000 acres of forest were found to be affected. Dorchester County exhibited the most acres of damage (US Forest Service 2020). Saltwater intrusion and rising sea levels can lead to marsh encroachment and ‘ghost forests,’ a phenomenon acutely felt at Blackwater National Wildlife Refuge (Reynolds 2019). This large scale die-off of trees is also observed on the Lewis tract, adjacent to Island Pond. Lewis Complex has undergone major changes in the last 10-15 years, and although many pine stands here are more than 30 years old, the trees remain stunted. Even after dry periods, this is a portion of the forest that routinely has standing water.

Using data derived from the Cambridge, Maryland NOAA tide gauge, and following the Guidance for Using Maryland’s 2018 Sea Level Rise Projections, relative sea level rise in the CFL is predicted to be near 2ft by 2050 and 4.3ft for 2100. The flood risk tolerance for the forest is determined to be medium, meaning there is the intent to adapt

and ability to tolerate some inundation. The Maryland SLR projections are legislatively mandated to be updated every 5 years with the next update to occur in 2023. At that time it is advisable to review the RSLR predictions for 2050 and 2100 to see if amendments need to be made.

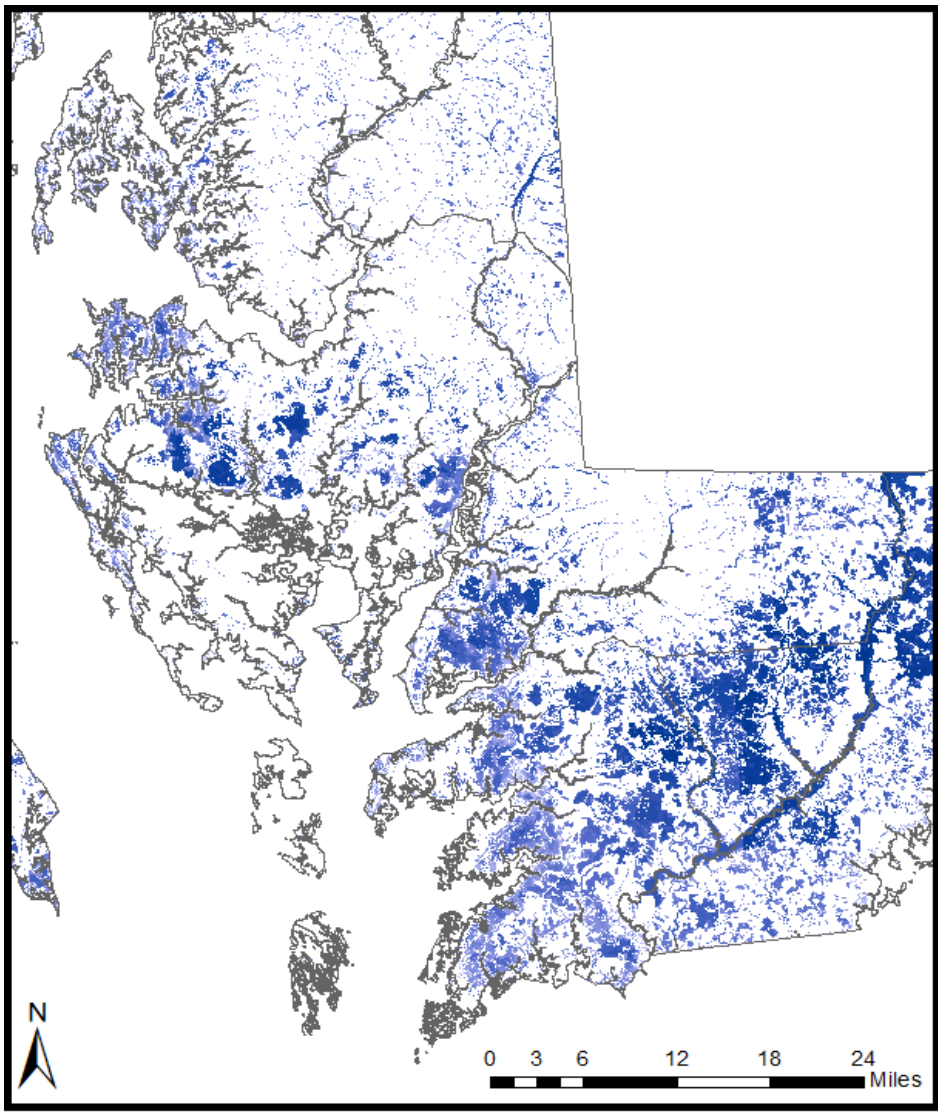

Figure 4. Predicted wetlands for the lower Eastern Shore in 2100. Darker blue represents higher scoring regions based on projected wetland size and key habitats for rare species.

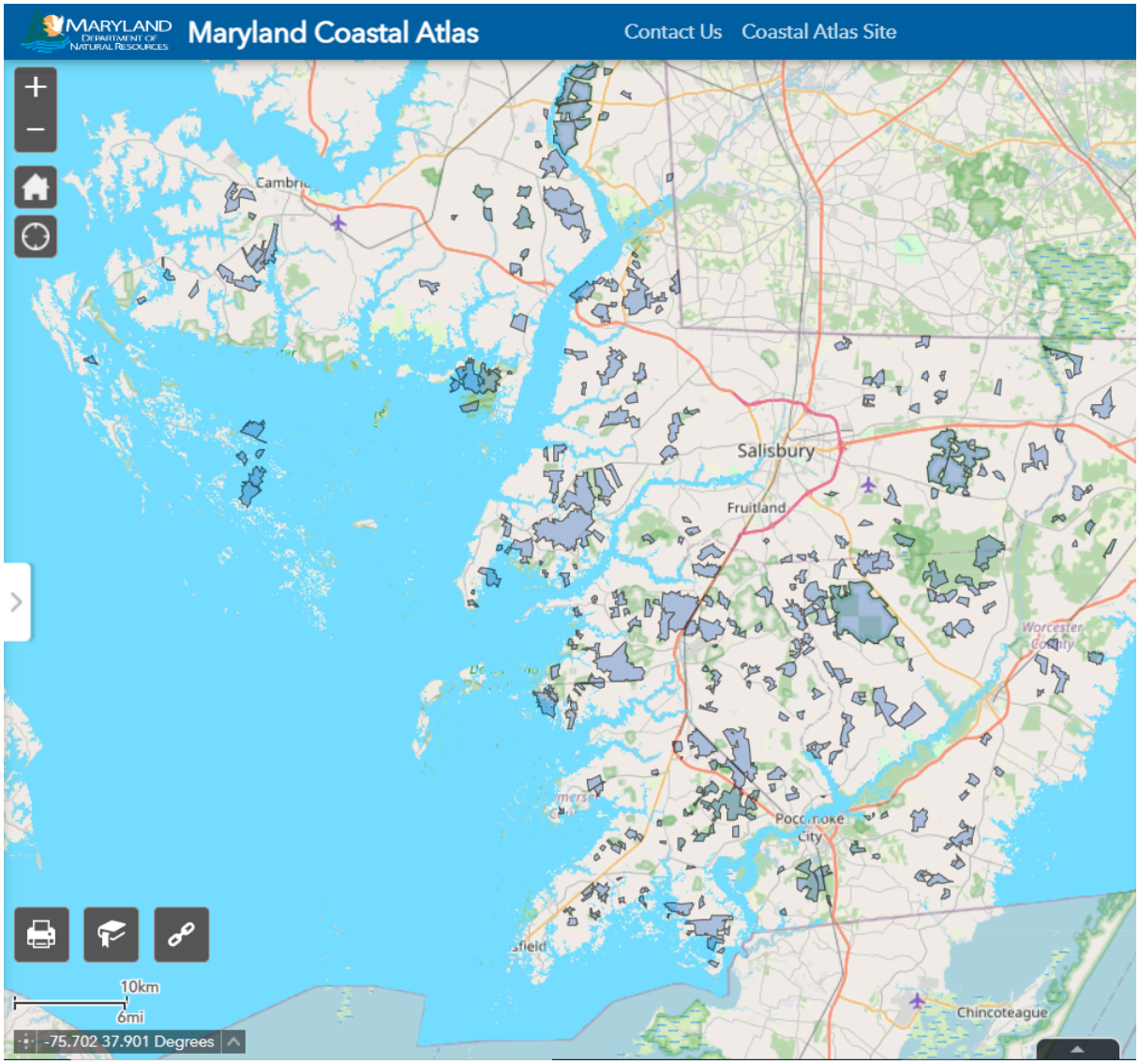

Figure 5. Predicted sea level rise of 0-2 ft on the Lower Eastern shore, expected by 2050. Darker blue polygons are the Chesapeake Forest Lands. Western tracts are particularly vulnerable, including Fair Meadow, Insley, Fred Besley Demonstration Forest, Travers, Lewis, and Lathrop.

Changing Precipitation Patterns

Total annual precipitation has been above the long-term average for the last 26 years (1995–2020) (Runkle et al. 2022) and we are likely to see average annual precipitation and the frequency of heavy downpours increase over the next 100 years. While projections of precipitation are much less certain than projections for temperature, the Atlantic coast will likely experience increases in the number, intensity, and inter-annual variability of extreme precipitation events (Runkle et al. 2022). Greater precipitation is projected for winter and spring for the Northeastern US (2014 National Climate Assessment). Increases in precipitation are expected to be offset by warmer temperatures resulting in greater evapotranspiration and decreased soil moisture, especially during the growing season (Swanston et al. 2018).

Increased precipitation may lead to greater nutrient runoff, erosion, and sedimentation (EPA). These factors negatively impact ecosystem health and may threaten water

quality. Additionally, increased flooding and erosion can damage roads and make accessing sections of the CFL difficult or impossible.

Storm Frequency

It is likely that the frequency of heavy precipitation will increase during the 21st century in many areas of the planet (USGCRP 2018). It is thought that increasing global surface temperatures will lead to more moisture in the atmosphere, which in turn leads to more rainfall, and in the Mid-Atlantic and New England, Nor'easters are expected to increase in frequency and intensity (Via 2023). Heavy rainfall can cause flash flooding and soil erosion (Via 2023).

Scientists have also predicted that wind speeds will increase in a warming climate and that the proportion of storms that intensify into powerful Category 4 or 5 storms will increase (Barlow and Camargo, 2022). In 2020, the hurricane season broke records with 30 named storms, 12 of which made landfall. The following year was the fourth-costliest hurricane season on record, with 21 named storms, including 7 that made landfall (Via 2023). Storm surge is often the largest threat to life and property from a hurricane. A number of factors can impact storm surge, including storm intensity, size, angle of approach to the coast, and the shape and characteristic of coastal features like estuaries (NWS). Storm surge and strong winds place natural resources and infrastructure at risk. After Hurricane Sandy, MFS staff noticed changes in the community along Muddy Hole Road in Wicomico County (M. Hurd, personal communication). Portions of the forest here have become too wet to be harvested and have been heavily colonized by *Phragmites*.

Interacting Impacts

It is not yet clear how these combined stressors may impact forests, as many models and experiments tend to focus on one factor in isolation. Extreme weather events may increase susceptibility to forest pests and pathogens, as evidenced in Europe following an unusually severe and long-lasting heat wave that began in 2018. After many large deciduous and conifer trees declined and eventually died, legacy effects were seen the following year when remaining trees were highly vulnerable to bark beetle colonization (Pureswaran et al. 2022). Increased precipitation may benefit pathogens which spread through water, but some evidence suggests that pathogens reach epidemic levels within a small range of climate conditions, so increasing temperatures may not necessarily signify increased infection rates (Dukes et al. 2009). While climate change can shift the distributions and boundaries of forest pests and pathogens, it may also modify tree physiology and defenses (Kirilenko and Sedjo 2007). Trees already stressed by heat and inundation could be more vulnerable to pathogens (Frankel et al. 2012). All of these factors can influence timber supply and will affect the market.

Moreover, changing land use patterns and expanding human development are expected to strain ecosystems in concert with changing climate conditions.

Figure 6. Standing water in a tract of the CFL in Wicomico County.

Climate Impacts on Forest Resources

The Chesapeake Forest Lands were purchased by the MDNR in a piecemeal fashion, beginning with nearly 60,000 acres acquired from the Chesapeake Forest Products Corporation in 1999. Most of this area was intensively managed for timber products. Further, the forest has been fragmented over time by construction of roads and conversions of native hardwoods to pine plantations (MDNR Forest Service 2021). Given the expansive nature of the CFL and the diverse habitats present, climate change impacts may vary based on location and elevation of stands.

No Climate Action: Natural Resources

Depending on the scenario and species, changing climate conditions could result in a change in rotation length of timber stands. Increased average temperatures may result in the increased incidence of pests, disease, and fire, which will affect the composition of the forest and complicate management. An increase in severe weather events with high winds and precipitation will impact operations, forest structure, and biology. The dominant tree species in the CFL, loblolly pine, has needles that are highly adapted to conserving moisture, and has a high photosynthetic rate, indicating it will endure through future conditions (Virginia Tech). Models have shown that loblolly pine is expected to fare well under a range of future climate projections (Iverson et al. 2019).

Wildlife Habitat and Impacts: As temperatures warm, many invasive species have the ability to expand their range and disrupt natural ecosystems. It's also thought that globally, biological invasions are among the top drivers of biodiversity loss and species extinctions (IUCN). Simultaneously, warmer and drier conditions could exceed the ecological tolerances of some oak and cherry species in the region (Swanston et al. 2018). An assessment that describes the vulnerability of forests in the mid-atlantic region, can be further broken down into subregions. For the purposes of this plan, the coastal plain subregion is most appropriate. Shortleaf pine, red maple, and yellow-poplar are shown to have good capability, while white oak is determined to have fair capability. Several species present in the CFL are listed as having poor capability to cope or persist with climate change, including American beech and Atlantic white-cedar (Iverson et al. 2019). This assessment illustrates the complex factors that all play a role in predicting future species assemblages, such as species migration potential and future habitat suitability.

Marsh habitat exists on several CFL tracts and will likely expand given sea level rise. The following tracts contain a great deal of palustrine wetlands: Hamlet, Wells, Haislip Greenhill, Cullen, Haislip Savannah, Handy, Marumsco, Lynnwood Duncan, Colona, Hoernicke Oliphant, Strickland, Lankford, Jesse Johnson, Thomas, and W.T. Wills. Additionally, the Lewis complex, Insley tract, Fair Meadow complex, northern edge of the King's Misfortune tracts, and some areas within Muddy Hole complex contain estuarine wetlands and brackish water. The blackbanded sunfish and banded sunfish, two Species of Greatest Conservation Need (SGCN), are perfectly adapted to the naturally low oxygen, acidic blackwater swamps that characterize these forested lowlands of the Eastern Shore. Within the Lewis Complex is the Fishing Bay Wetlands, a 7,922 acre INA with various communities that provide habitat, food, and nesting material for animals. A host of at-risk bird species are present here, including the least bittern, northern harrier, common gallinule, red-headed woodpecker, brown headed nuthatch, and worm-eating warbler. The Wildlife and Heritage Service acknowledges sea-level rise and land subsidence leading to habitat loss as a major threat to the Fishing Bay Wetlands. Prolonged flooding is not suitable for loblolly pines; complete inundation for more than 2 weeks during the growing season often results in significant mortality for seedlings and saplings (Baker and Langdon).

The State Wildlife Action Plan acknowledges that remaining forested areas in the Upper and Lower Coastal Plain, especially those dominated by hardwoods, provide places for migrating songbirds to rest and refuel on their long journeys to the north or south of Maryland. A large-scale study by the National Audubon Society determined that heat, heavy rain, and sea level rise are the biggest threats facing birds on the Eastern Shore of Maryland. Chesapeake Forest Lands are known to contain several rare, endangered, and threatened (RTE) species of birds, including the sedge wren, Henslow's sparrow, and bald eagle. Without monitoring or habitat conservation, these species may face changes in ranges or other threats. In addition to avian species, the CFL also provides habitat for the Delmarva fox squirrel. Listed as an endangered species in 1967, this tree squirrel was once found throughout the Delmarva Peninsula (CBP). Today, they are known to occur in portions of Queen Anne's, Talbot, Dorchester, and Caroline counties in Maryland and have since been delisted (USFWS). Delmarva fox squirrels rely on mature forests of mixed hardwoods and pines for food and den sites. Changes in forest composition and age structure could disrupt this recovering species.

Forest Fires: On average, over 5,000 wildfires occur per year in Maryland (MSA). On state lands, roughly 200 acres of forests per year are burned, and there are efforts within MFS to increase the capacity for prescribed burns. Historically, the CFL were shaped by a regime of frequent, low-intensity wildfires, often conducted by Native Americans (MDNR Forest Service 2021). Typically, loblolly pines less than 5ft tall suffer mortality from light fires. But mature loblolly pine survives low- to moderate-severity fires because of relatively thick bark and tall crowns (Carey 1992). Yellow-poplars are similarly resistant to fire when mature with thick bark, but seedlings and saplings can be susceptible (Griffith 1991). Conversely, red maple is generally intolerant of fire but exhibits rapid regrowth following fires. Late spring or early summer burns are most damaging to the red maple (Tirmenstein 1991).

Figure 7. A low-intensity prescribed burn is used to eliminate high fuel loads and undesirable species competition.

While fires burn more land in the Western part of the US than in the East, climate change threatens to increase the frequency, extent, and severity of wildfires (Environmental Protection Agency 2023). Currently, the Maryland Forest Service responds to an average of 122 wildland fires per year (MD DNR 2022). A goal stated in the 2020-2025 MDNR Forest Action Plan is to 'manage forest health and fire.' This will be accomplished through objectives II.A- Provide emergency response to natural resource threats and II.B- Develop approaches to reduce threats from long-term stressors to forests.

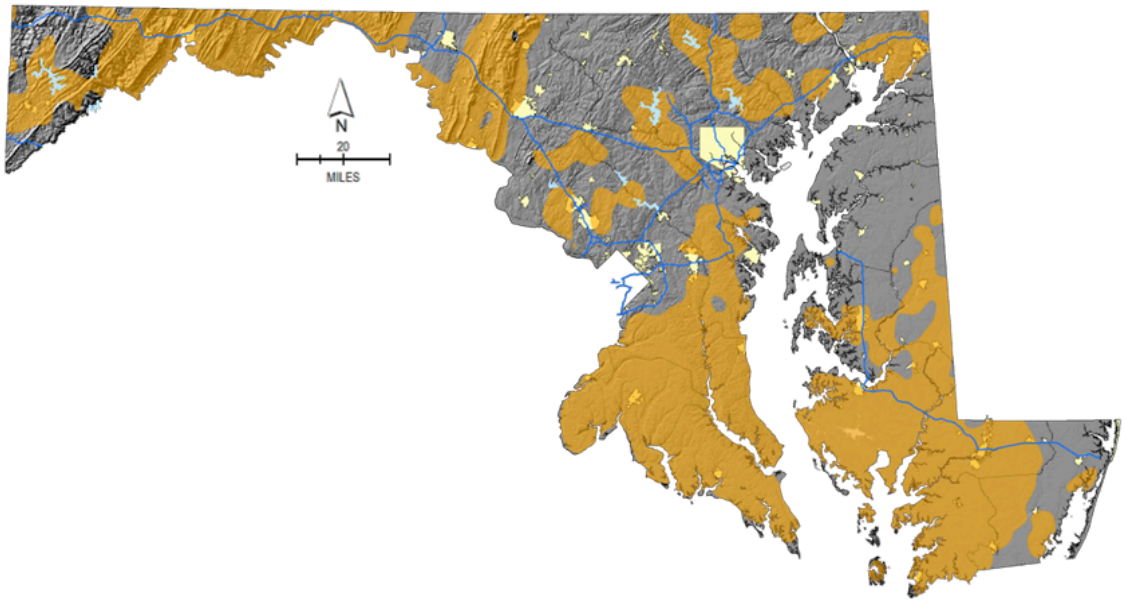

Figure 8. Priority areas for wildfire suppression and risk reduction, taken from the 2020-2025 MDNR Forest Action Plan.

Ecosystem Services: Changes in season length, rainfall patterns, and temperature will undoubtedly affect ecosystem services. One of the most important ecosystem services provided by forests is carbon storage. Soil carbon is usually the largest and most stable carbon pool, but heavy rainfall events can cause flood-related tree mortality which leads to soil erosion and losses of carbon from forest ecosystems. Accounting for land-use change, disturbance, forest aging, and management, US forests are expected to continue to store carbon, but at declining rates (USGCRP 2018). Additionally, invasive plant species can enhance carbon sequestration, storage, and cycling, and influence rates of nitrogen cycling in forests and grasslands (Miniat et al 2021).

Forest pests and pathogens that impact ecosystem services may also be influenced by climate change. In the recent past, Maryland State Forests have dealt with spongy moth, southern pine bark beetle, hemlock wooly adelgid, and emerald ash borer (MDNR Forest Service 2021). In the past year in particular, staff have seen high abundance of the spongy moth, which typically targets hardwoods like oak, maple, and gum (M. Hurd, personal communication, Center for Invasive Species and Ecosystem Health). The southern pine beetle is one of the most destructive insect pests of pines and Maryland falls in the northern range of this bark beetle (US Forest Service 2020). Loblolly pine is a preferred host and the insect tends to attack large mature stands of pine. Major outbreaks often occur after a mild winter or a hot, dry spring. Bark beetles have increased in intensity in recent years, mainly because rising temperatures are preventing the widespread winter die-off of beetle larvae, while also enhancing the beetles' destructive power. Individuals are hatching earlier and reproducing more frequently (Katz 2017). In 2020, the MD Department of Agriculture recorded the first positive emerald ash borer trap in Somerset County. Traps in Wicomico and Worcester Counties were negative (US Forest Service 2020). Managing this pest can be especially difficult given the proximity of privately owned forests surrounding the CFL.

Adaptation Options and Opportunities: Natural Resources

Wildlife Habitat and Impacts: To maintain species and structural diversity within the Chesapeake Forest, managers can support adequate regeneration and maintain a variety of age classes across the landscape (Swanston et al. 2016). Additionally, protecting vulnerable habitats and identifying areas with high diversity will allow for wildlife to persist. The 2023 Eastern Region Annual Work Plan states that sites containing rare plant and or animal communities, also known as Ecologically Significant Areas (ESA), will be identified and managed for their special qualities. Various ecosystem restoration projects continue to proceed, including the Brookview Ponds ESA restoration at Indiantown Complex. This wetland area contains rare and endangered species and was ranked by the Natural Heritage Program as the highest restoration priority site in the CFL. Removal of loblolly pine within 200 ft of each Carolina bay wetland or wetland complex and restoration of the hydrology at the site have been completed. Prescribed burns are ongoing to limit the reinvasion of woody plants.

Low-lying areas of Chesapeake Forest that continue to be inundated and may be destined to become ghost forests could be considered for preemptive marsh migration management strategies. In such ecosystems assessed as highly vulnerable across a range of plausible future climates, transition actions might be appropriate for long-term effectiveness. When the risk associated with resistance and resilience actions is judged to be too great, facilitation of a new ecosystem is preferred (Swanston et al. 2018). As discussed in the February 2023 workshop, transitioning to wildlife habitat/hunting opportunities where land is becoming too wet or salty to grow trees or salvage harvest might be an option (Handler et al. 2022). Further, if opportunities arise for land acquisition, MFS could target upland with more potential for timber growing.

Monitoring of key habitats is also crucial to understanding how climate change impacts will be felt on the ground. The 2021 Maryland Coastal Adaptation Report Card cites a lack of data for scoring certain indicators, which reflects a lack of adequate data for planning. Data gaps must be filled in order to adapt to climate change, such as mapping visualizations to better understand how storm surge, flooding, and other impacts will occur under projected sea level rise scenarios (Laumann et al. 2022).

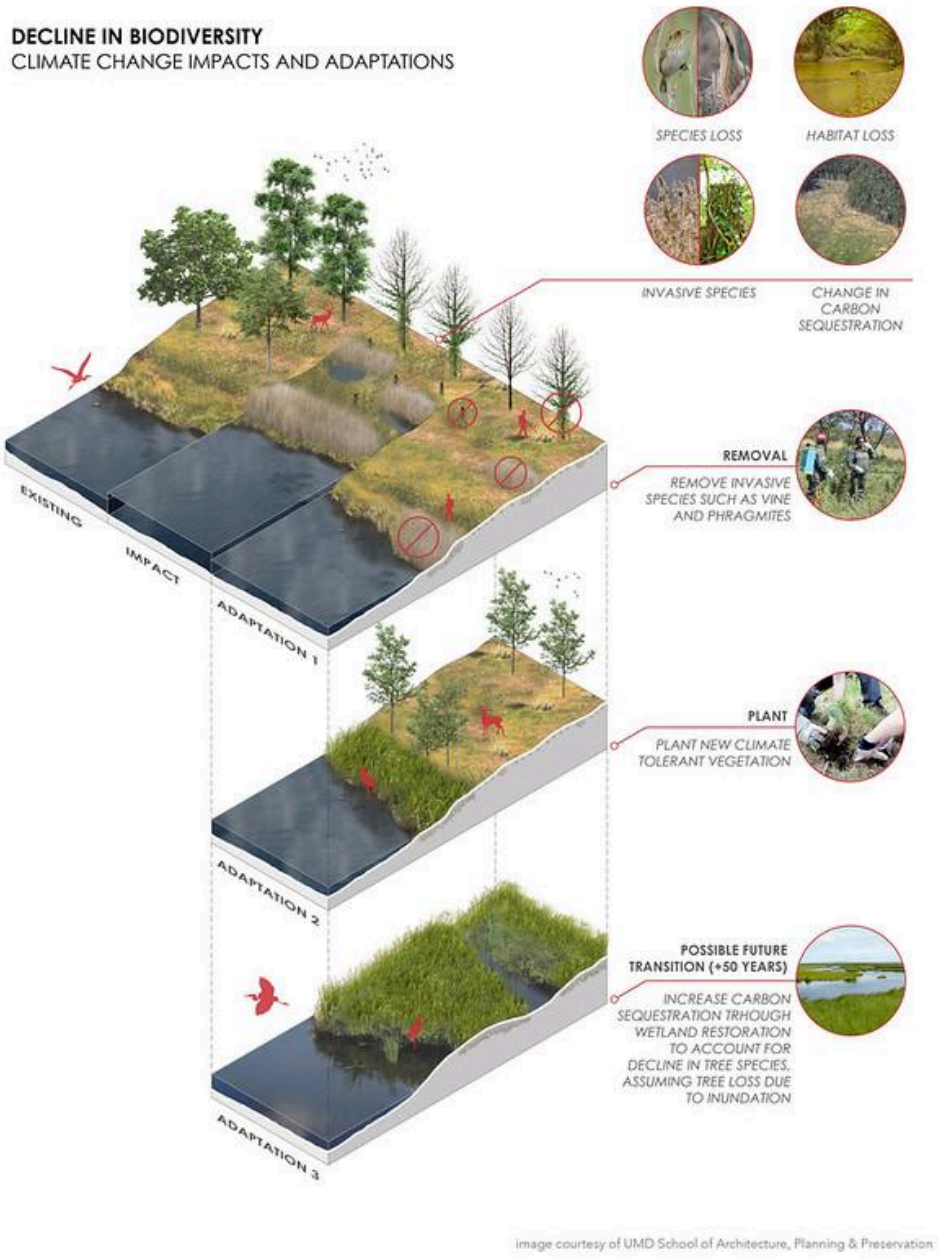

Figure 9. Potential adaptation options to address habitat change and biodiversity loss. Image created by UMD School of Architecture, Planning, and Preservation.

Forest Fires: Becoming more resilient to forest fires requires advanced preparedness and strategic planning. The placement of water pumps should be analyzed and assessed so that staff know where to locate pumps and how to use them in a fire emergency. Additionally, roads should be maintained as much as possible to allow access to fire roads. Other adaptations include establishing or maintaining fuel breaks to stop the spread of fires, removing and preventing establishment of non-native species that may alter fuel regimes, and promoting diversity within and among forest communities (Sample et al. 2022). Promoting fire- and drought-adapted species and ecosystems in areas that may see an increased fire risk is another adaptation strategy (Swanston et al. 2016). The MFS is undertaking this technique through management zones that assist the conversion of pine to hardwood stands on the Eastern Shore.

Ecosystem Services: To prevent outbreaks of pests like the southern pine beetle, managing stand density is critical. Thinning is the preferred forest management tool used to attain desired stand densities. Once an outbreak of southern pine beetle has occurred, a combination of insecticides sprayed directly on tree boles and sanitation harvests (removal of infested trees) are some management options (Clarke and Nowak 2009).

Further, controlling invasive species, through herbicides and mechanical thinning, is a critical way to reduce competition for moisture, nutrients, and light. Prioritizing and maintaining unique sites can allow for the development of refugia of native plant communities. This may be achieved by limiting harvest or management-related disturbance in areas that may be buffered from climate change (Swanston et al. 2016). Through the State Climate Vulnerability Assessment and the WHS effort of cataloging Irreplaceable Natural Areas, the state has been able to identify and prioritize ecologically valuable and climate sensitive areas. Increasing monitoring to facilitate early detection of invasive species is also important. MFS staff can prioritize areas that are more likely to be colonized and quickly halt the spread of invasives.

Extending rotations, particularly on highly productive sites, to optimize tree growth can increase forest carbon stocks (Swanston et al. 2016). Additionally, managers can promote long-lived species with wide ecological tolerances, which may mean importing genetic stock from a variety of locations within a species' range. Understanding subtle variations in microclimate will aid managers if they choose to establish heat- and drought-tolerant species in sites that will become hotter and drier, protecting from potential carbon loss. Favoring southern-adapted species like oaks and hickories can also create more climate-resilient forests and increase carbon storage (Swanston et al. 2016).

To protect water quality, there are several options to address excess water and decrease erosion. A regenerative step pool storm conveyance system can attenuate and treat the quality of storm water flow by using shallow aquatic pools, an underlying sand or woodchip filter bed media, and native vegetation (AA County Department of Public Works). Maintaining and restoring floodplain connectivity, for example with stream restoration, is another method of slowing water velocity (NIACS).

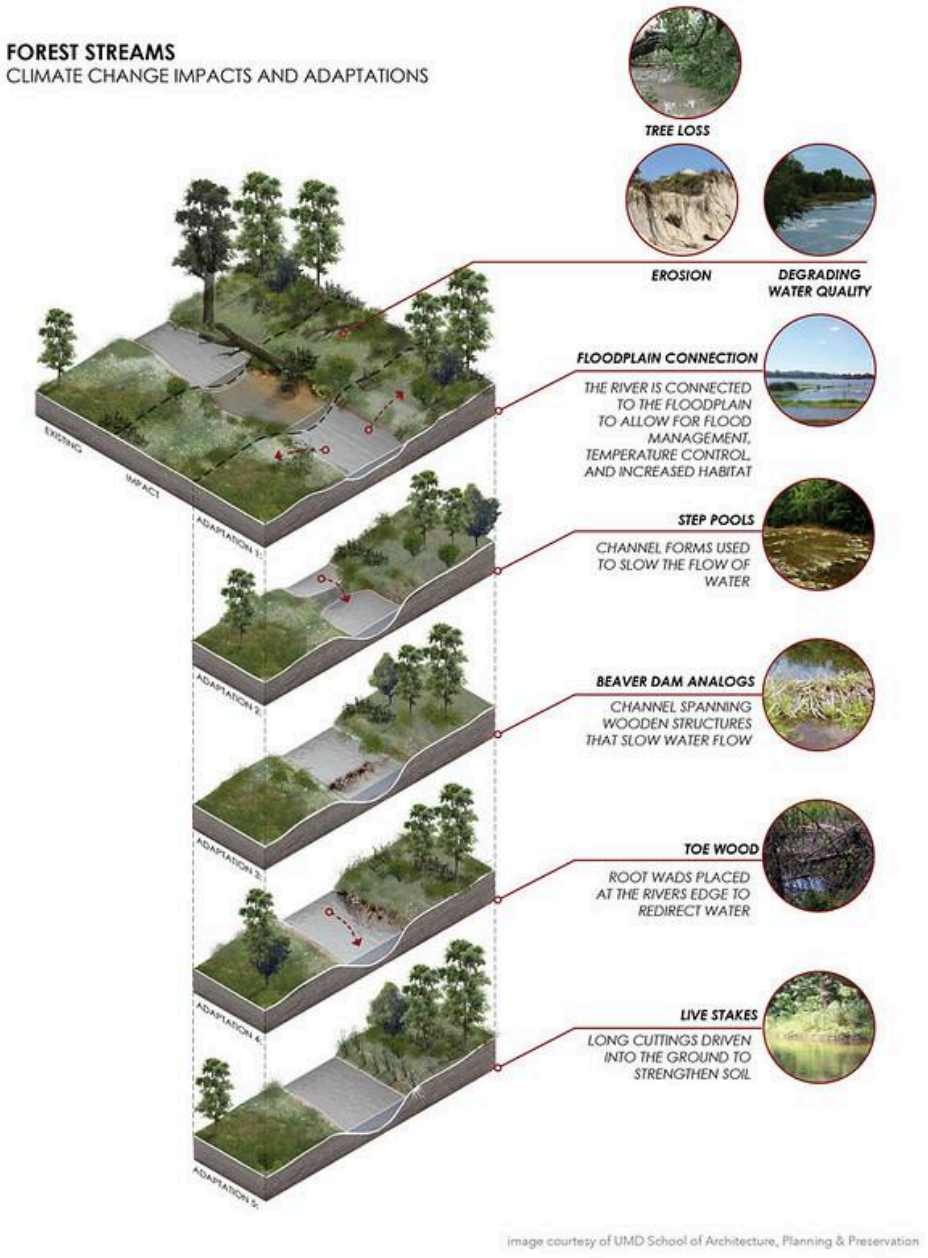

Figure 10. The impact of increased precipitation and flooding on forest streams, along with several adaptation options. Graphic created by UMD School of Architecture, Planning, and Preservation.

Climate Impacts on Infrastructure

While there are no buildings or structures on the CFL, there are 410 miles of roads and three bridges that the state maintains. Additionally, there are 174 culverts that allow water to flow through, facilitating the movement of wildlife and reducing erosive forces on roads.

No Climate Action: Infrastructure

Roads and Access: Maintenance of roads is a major task for forestry staff. An increase in flooding and worsening storms have compromised water control structures, culverts, and roads, leading to washout, erosion, pipe failures, and unsafe road conditions. Decreased site access impacts fire control, invasive species management, and timber harvesting. Using Maryland's Coastal Atlas, it is clear that multiple CFL tracts are highly vulnerable to storm surge. When considering category 1 hurricane storm surge, the Oriole, Lank Anderson, Mt. Vernon, Insley, Baumgarthner-Southam, Elmwood, Marumsco, Travers, White, and Cox complexes, as well as the Besley Demonstration Forest are likely to be inundated. Nuisance tidal flooding is also an issue for road access, as demonstrated by the Maryland Department of Transportation data. Areas of Dorchester and Somerset Counties may be unsafe to access in a tidal flooding scenario for year 2020, with slightly more inland areas at risk of flooding in a scenario for year 2050.

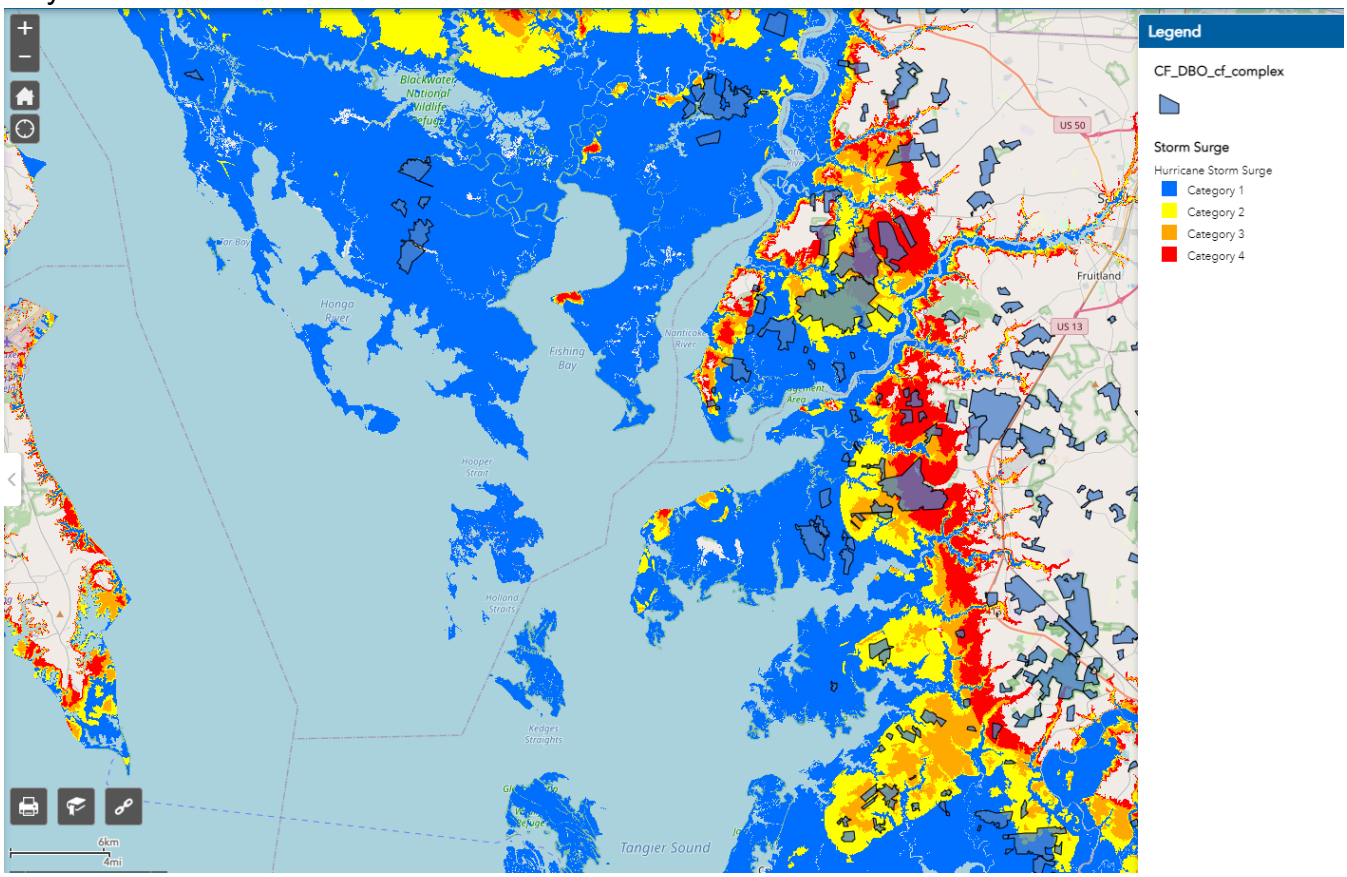

Figure 11. Hurricane storm surge predicted for the Lower Eastern Shore of Maryland. The blue polygons are CFL tracts.

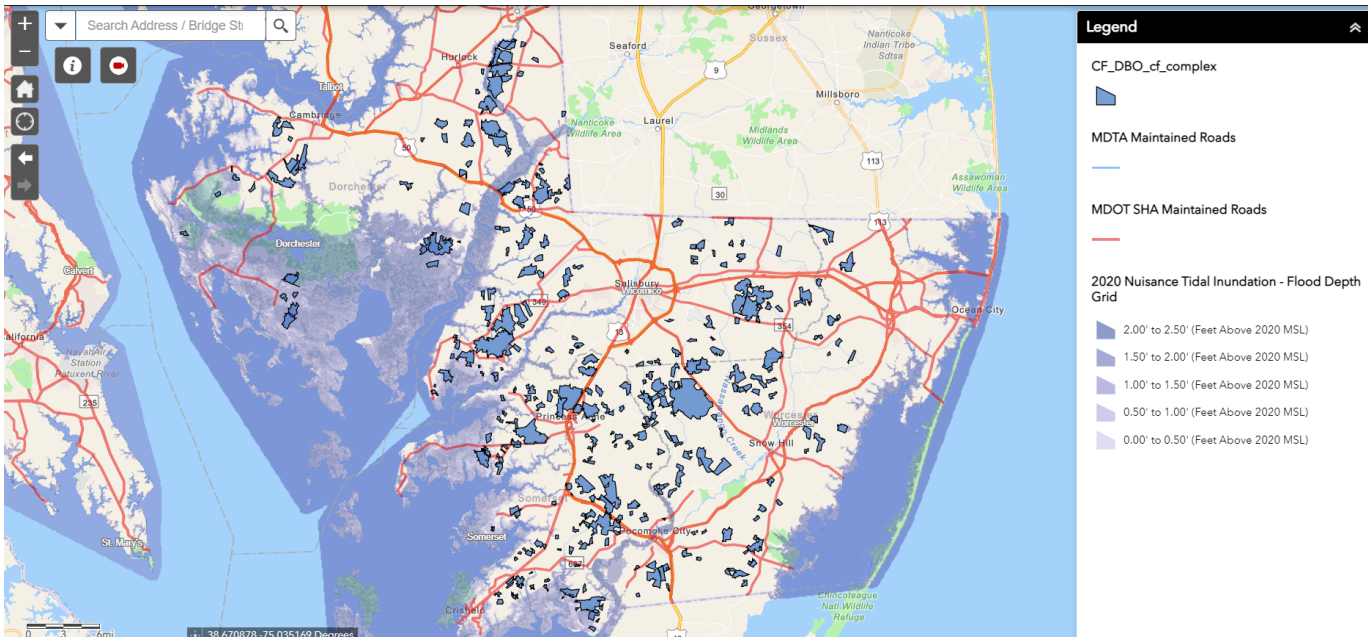

Figure 12. Nuisance tidal flood inundation as shown by the Maryland Department of Transportation Climate Vulnerability Viewer. The blue polygons are CFL tracts and major roads are shown in red.

Additionally, encroaching *Phragmites* and other invasive plants can quickly lead to overgrown and difficult to access roads.

Figure 13. Exposed culvert pipes in the Athol Complex after extreme flooding washed out the road in 2013.

Fire pumps and placements: In 2003 the Maryland Forest Service was awarded a State Fire Assistance Hazard Mitigation grant by the USDA Forest Service to implement a multi-year statewide dry hydrant installation program. Dry hydrants are a pipe system permanently installed into a water source that permits the withdrawal of water by drafting to provide an available water source for fire suppression (MDNR Forest Service, 2008). It is possible that dry hydrants located in low-lying areas, such as near tracts in Dorchester County, will be inaccessible given flooding and sea level rise.

Adaptation Options and Opportunities: Infrastructure

Roads and Access: Updating and upsizing culverts is an obvious solution to address increased precipitation and erosion. The above section of road in Athol complex had a new culvert installed several years ago that allows for a greater volume of water to pass through. Additionally, MFS worked with Engineering and Construction to move from two pipes to a single opening, which reduces the amount of debris that gets caught during high flows. More intensive adaptation strategies to restore hydrology include removal of dams, decommissioning roads to reduce erosion and sedimentation, and installing berms or dikes to divert surface waters. Alternatively, low-volume roads or trails could be modified to have a low-water crossing structure, such as a low-water bridge or ford, that is designed to be overtopped during heavy precipitation (Shannon et al. 2019).

Fire pumps and placements: The placement of water pumps should be analyzed and assessed, so that in case of a fire emergency all staff know where to locate pumps and how to use them. Maintaining roads in good condition to allow access to fire roads is also critical. Additionally, forest management techniques such as thinning and fuels removal to reduce the risk of fire can be implemented.

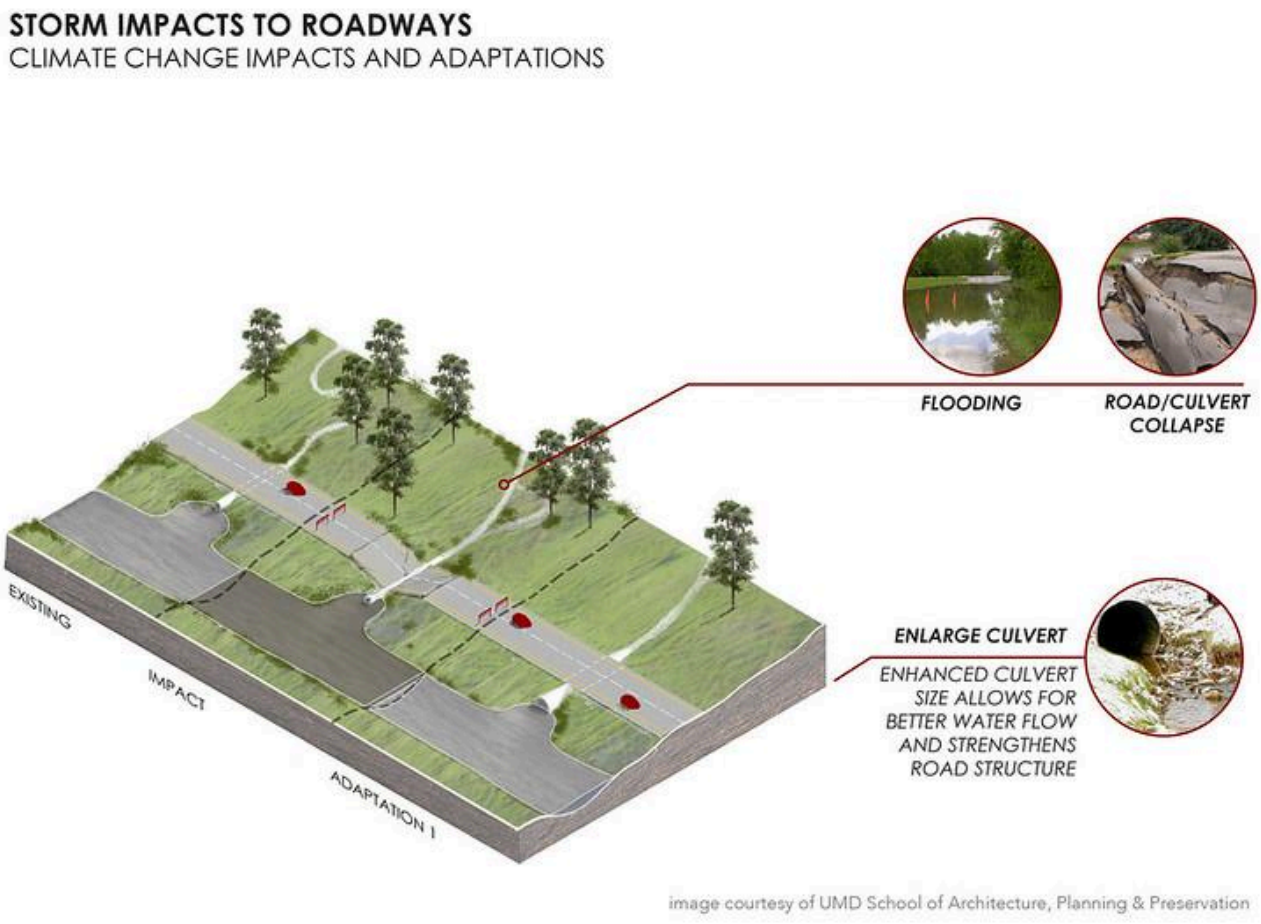

Figure 14. Potential adaptation for a road vulnerable to flooding and washout.

Climate Impacts to Recreation

Chesapeake Forest Lands contain 36 miles of trails for hiking/horseback riding and two soft launches for kayaks. Camping is not permitted. MFS staff estimate an annual attendance by 20,000 recreational users. The draft FY 2024 Eastern Region Annual Workplan lists “Continue to explore additional Resource Based Recreational (RBR) opportunities on the forest. This may include hunting, horseback riding; water trails, hiking trails, bird watching opportunities, geocaching, etc.” under Recreation Projects. Hunting is a major source of revenue for the Forest and traditionally over 200 organized hunt clubs have used the property, mostly targeting deer and turkey. Currently about 2,500 members of hunt clubs utilize roughly half the area of the forest. Only 1022 acres of the CFL do not allow hunting.

No Climate Action: Recreation

Access: With increased extreme weather and likelihood of sea level rise, many roads and trails in the Chesapeake Forest Lands may become unusable, at least during certain times of the year. There is also potential for flooding and damage to boardwalks and the two soft kayak launches.

Figure 15. Boardwalk at the soft kayak launch at Island Pond in Dorchester County.

Hunting: Hunting opportunities should remain constant, though access to areas might be impacted by storms and sea level rise. With changes in habitat type, hunters may shift their target species in the CFL over time. As discussed in the February 2023 workshop, forestry staff have noticed some hunters beginning to target Sika deer as more marsh habitat expands into low-lying forested areas.

Adaptation Options and Opportunities: Recreation

Access: One way to ensure safety of the public is to limit access to certain parts of the CFL during exceedingly wet conditions. This also limits the impacts to roads and trails that may be vulnerable to erosion (O'Toole et al. 2019). Additionally, hardening road and trail surfacing with gravel or rocks, especially at approaches to water crossings, and constructing elevated boardwalks can decrease the expense of maintenance costs and keep visitors safe.

Providing clear signage on why some areas are not open and updating the DNR website and social media pages with real-time weather data can keep visitors safe and allows an opportunity to further educate the public on effects of climate change. Given the limited staff capacity of foresters at CFL, these are less intensive options that can reach a wide audience.

Hunting: Improving communication to hunters about potentially reduced access and dangerous conditions is one way to ensure this activity can still occur in the forest. The NIACS recommends educating the public on the true extent of environmental change, for example, encouraging recreational users to have personal protection against heat-related illness, noxious plants, and disease-bearing insects. Further, allowing for shifts in the timing of opportunities to align with changing conditions may be necessary. For instance, re-evaluating the hunting seasons of prime target species (Swanston et al. 2016).

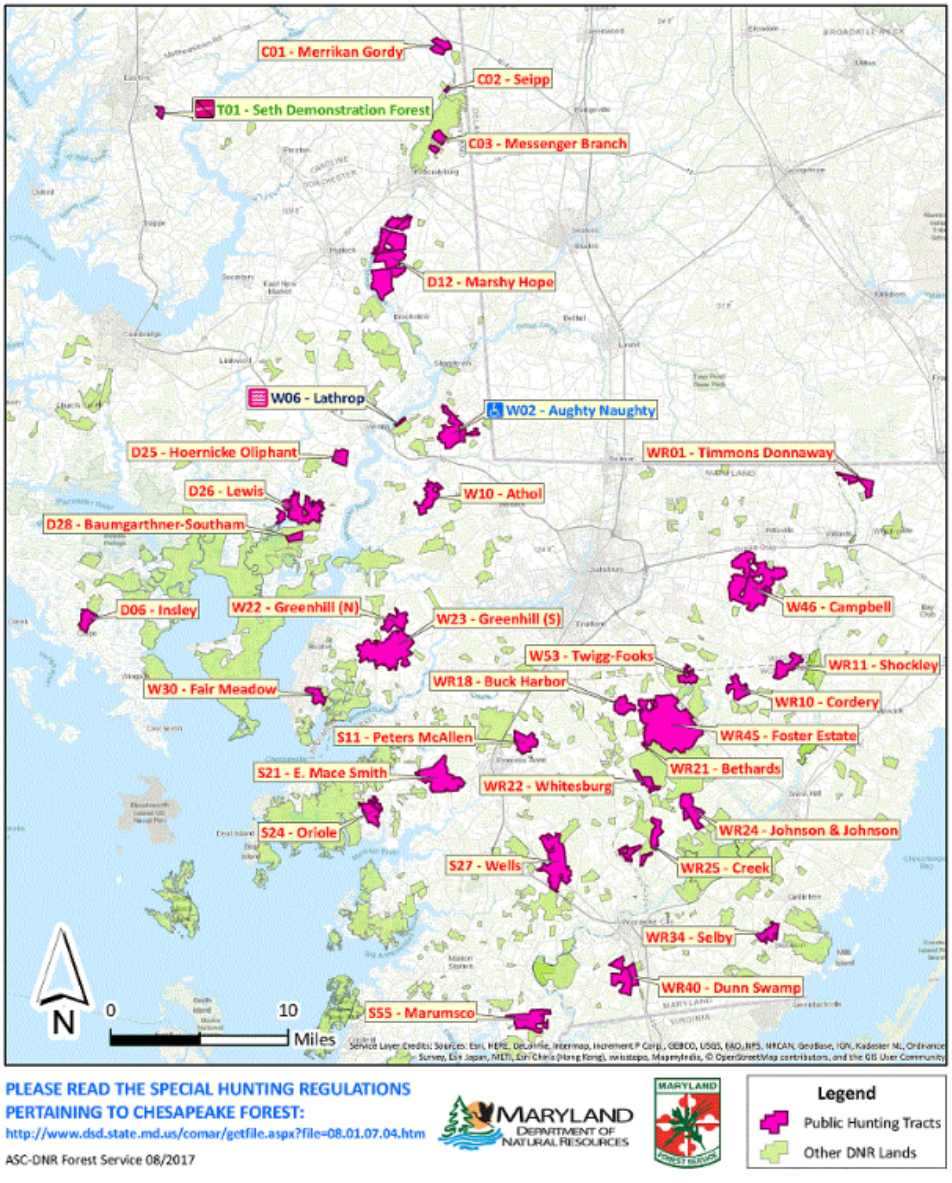

Figure 16. DNR map depicting the public hunting areas within the Chesapeake Forest Lands. Some areas currently only allow bow hunting or waterfowl hunting from the shoreline.

Climate Impacts to Cultural Resources

There are no known cultural or historical resources located on site, with the exception of a few small, family grave sites. These are protected to the extent possible. If any other cultural or historic resources are identified in the future, MFS staff will look at issues and impacts to forest management and timber sales.

Figure 17. Overgrown cemetery headstones located within Chesapeake Forest.

Climate Impacts to Human Resources/Economy

On average, the annual timber harvest from the CFL produces $470,000 in revenue. With the closure of saw and paper mills in the state, there has been a decrease in revenue from timber harvesting over the last decade. Loblolly pine sawtimber remains the most valuable commercial product from forests on the Eastern Shore, as nearly 90% of the wood used on the Lower Shore is loblolly pine (MDNR Forest Service 2021). Hunting revenue averages approximately $585,000 per year for Chesapeake Forest.

No Climate Action: Human Resources and Economy

Invasive Species: Several invasive species are found in the forest, including *Phragmites*, Japanese knotweed, Japanese stiltgrass, Chinese lespedeza, Callery pear, bamboo, mile-a-minute, mimosa, and wisteria. One invasive species that has been difficult to eradicate in the Chesapeake Forest Lands is mile-a-minute (*Persicaria perfoliata*). This weed prefers sites with moderate to high soil moisture and full sunlight, is able to quickly establish itself in forest edges, wetlands, roadsides, and streambanks (Templeton et al. 2020). Forming dense mats and growing rapidly, mile-a-minute can crowd out native species (USDA). MFS staff have tried spraying and introducing weevils to various tracts to target mile-a-minute, with little to no success (A. Clark, personal communication). Similarly, multiflora rose (*Rosa multiflora*) is present in some forest

tracts of Wicomico County, and can form dense thickets that invade pastures and crowd out native species (USDA). One of the most successful invasive species to colonize the CFL is *Phragmites australis*. This reed grows in fresh and brackish wetlands and along river banks and shorelines, and is commonly found in ditches and roadsides (CBP). In the Chesapeake Forest, *Phragmites* can outcompete young loblolly pines and stunt growth (A. Clark, personal communication). As the pines grow and establish crowns, they can effectively shade out the *Phragmites*.

Figure 18. Thick *Phragmites* stand at the Lewis Tract of CFL, in Dorchester County.

Figure 19. Recent forest harvest colonized by mile-a-minute weed.

Timber harvesting: Several tracts of the CFL are no longer able to be harvested. Low-lying areas with routine flooding and standing water are not suitable for the heavy machinery needed to log. Additionally, some areas with encroaching marsh and high water table have produced pines with stunted growth. The trees are of a smaller diameter than what is expected based on the age of stands, and yellow needles indicate signs of stress (A. Clark, personal communication; Hodges and Lorio Jr, 1975).

Human Health and Planning: Climate change can have direct and indirect impacts on human health. Extreme heat most acutely impacts children, the elderly, those with existing health problems, and people that are active outdoors. Another direct impact is injuries or even death associated with flooding. Indirect impacts may be seen as increases in respiratory problems with changes in air pollution and allergen production. Vector-borne diseases, in particular Lyme disease, are expected to worsen with climate change (MDH). Without action, it's possible that MFS staff could be at greater risk of health problems. Loss of productivity or changes to scheduled forestry activities could occur.

Further, by not including changing climatic conditions into management decisions, disasters such as wildfires will put a greater demand on forest staff as they will have to reprioritize management decisions and address the consequences of wildfires, such as erosion, increased flooding, and greater operational costs.

Adaptation Options and Opportunities: Human Resources and Economy

Invasive Species: Increasing monitoring, particularly at trailheads and along roadways, of invasive species can allow for early detection (Swanston et al. 2016). Most MFS staff are already familiar with current and potential invasive species in the region through MDA training, but recruiting recreational users could also aid in the fight against invasive plants. Smartphone apps such as MAEDN allow for citizen scientists to make reports when they observe invasive species in the field. Another mitigation strategy is to thoroughly clean equipment prior to forest operations, to prevent facilitating the spread of invasives during harvesting or other activities (Swanston et al. 2016).

Timber harvesting: Introducing species that are adapted to future conditions is one way to ensure timber harvesting can continue at CFL. These could include longleaf pine or winged elm, or other species expected to have new potential habitat under climate change in the coastal plain. Many oak species are also predicted to have good capability to adapt in this region (Butler-Leopold et al. 2018). Additionally, MFS staff can manage herbivory to protect or promote regeneration following disturbance (U.S. Forest Service Transportation Resiliency Guidebook).

Human Health and Planning: In the short term, educating staff and providing first-aid training is an adaptive strategy that will prepare CFL for the increased health risks associated with extreme heat, reduced air quality, and major storms. Preparing for emergencies will also require redundancy, for instance having more than one access point and multiple communications systems.

Prioritizing maintenance tasks for MFS staff will also be critical. Incorporating future conditions into repairs and updates to infrastructure will ensure funds are spent wisely and new projects will be appropriate for years to come. Opting for highly cost effective treatments to address risk, such as vegetating barren areas to reduce erosion and removing debris from stream crossings, is preferred (U.S. Forest Service Transportation Resiliency Guidebook).

Recommendations for Future Planning

Existing Efforts

The 2020-2025 Forest Action Plan calls out many strategies to respond to climate change in the state's forests. These include efforts to expand tree planting, managing forests for drinking water reservoirs, identifying sensitive species and planning for continuity of habitat, and incorporating climate change adaptation into management strategies while coordinating with restoration partners.

Additionally, the Sustainable Forest Management Plan for CFL (updated in April 2021) lists several tactics for forest management that indirectly address climate resilience. MFS sets goals to establish native riparian communities along streams to improve in-stream habitat, to stabilize stream banks, and to increase surface roughness to encourage sedimentation. The plan also states that invasive species will be controlled aggressively and in a timely fashion when discovered in the field. GIS records will be updated to maintain up-to-date maps of invasive colonization.

Long Term Goals

Five years: The 2020-2025 Maryland Forest Action Plan includes several efforts to help the state adapt to a changing climate. To build resilience and continue carbon sequestration, the plan highlights efforts to expand tree planting, retain existing forests, and manage for diverse, well-stocked, vigorous forests. Over the next five years, priority should be identifying the most vulnerable areas of the CFL and developing appropriate annual workplans. Another recommendation is to update the State Lands Climate Vulnerability Assessment completed by the ESRGC to incorporate new data sources and parcels that were acquired after 2018. This will allow forestry staff to better target at-risk tracts.

Ten years: Over the next ten years, educating the public about how climate change will affect forests is paramount. Preparing recreational users for the health and safety risks associated with increased storms, dangerous heat waves, and more pests will allow for continued enjoyment of the outdoors. Additionally, making necessary changes to infrastructure will be necessary to maintain operations. Roads that are already experiencing flooding and inhibiting access to timber harvesting and management areas should be the first to be reconstructed. Culvert sizes should be increased to account for precipitation changes. Updates should be made to the Sustainable Forest Management Plan for Chesapeake Forest Lands within the next ten years.

Fifteen years: In the next 15 years it is expected that invasive species management will be a priority in the Chesapeake State Forest. Moreover, control of insect pests should be ramped up to ensure that higher elevation stands where trees are not threatened by sea level rise and flooding can remain productive.

Fifty years: Using the Cambridge tide gauge, 2ft of seal level rise is projected for the majority of the Chesapeake Forest Lands by 2050. This will mean increased marsh habitat and likely die-off of stands in lower elevations as the trees are more frequently inundated. Allowing for marsh migration and increasing riparian buffers can aid in the continuation of wildlife habitat.

One hundred years: Given that sea level rise in 2100 is predicted to reach more than 4ft, operations at the Chesapeake Forest Lands will undoubtedly change. Low-lying tracts like Lewis, Muddy Hole, Elmwood, Handy, Marumsco, and White will likely be fully submerged. The MFS should prioritize acquisition of upland parcels to continue timber operations on the Lower Eastern Shore.

Identifying Projects and Partners

Collaborating both with partners within DNR and with other state agencies, nonprofits, universities and academic institutions, as well as private landowners will allow the MFS to enact more of the adaptation options outlined here. Continued and future partnerships could include:

- Working with MD DNR's Trust Fund to address forest and wetland restoration
- Local watershed organizations to increase capacity for monitoring
- Land Acquisition and Planning to identify potential upland parcels that could be purchased

- Continuing to work with the Northeast Institute of Applied Climate Science to identify adaptation options
- Ducks Unlimited to protect wetland habitats
- Working with MDA to further investigate the extent of ghost forests and evaluate insect susceptibility

Overall Conclusions

The State of Maryland is well aware of the challenges associated with climate change. In coming years, forestry management practices will have to change to manage for the increased stress on state resources. Maintaining fundamental ecological function, timber harvesting, and recreational use of the Chesapeake Forest Lands will require innovative approaches. Reducing the impacts of biological stressors like pests and invasive species, protecting species with wide ecological tolerances, and encouraging regeneration after severe disturbances can aid the forest in becoming more resilient. As for the impacts of climate change on humans, training staff and providing clear information to the public are key adaptation strategies.

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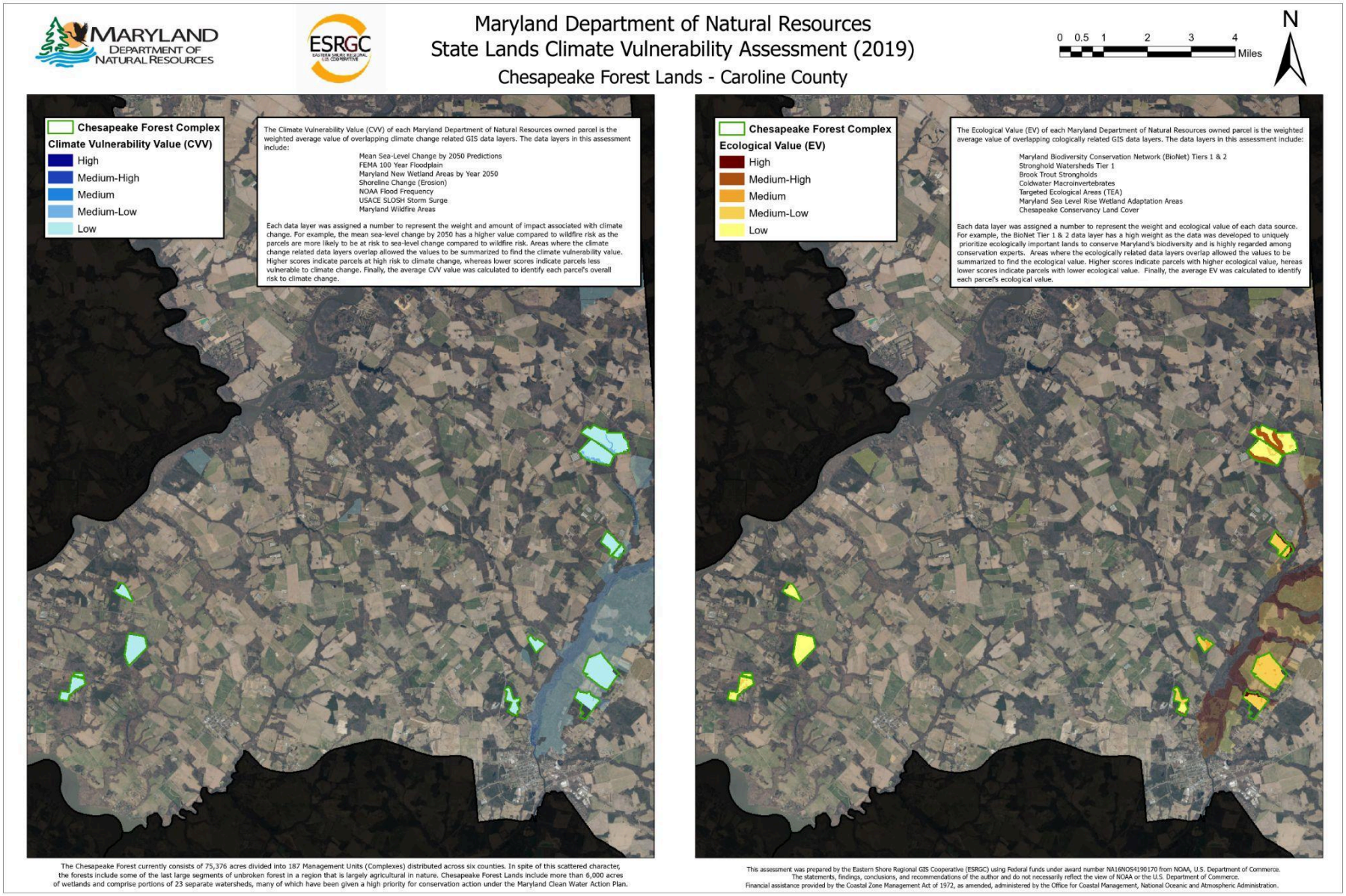
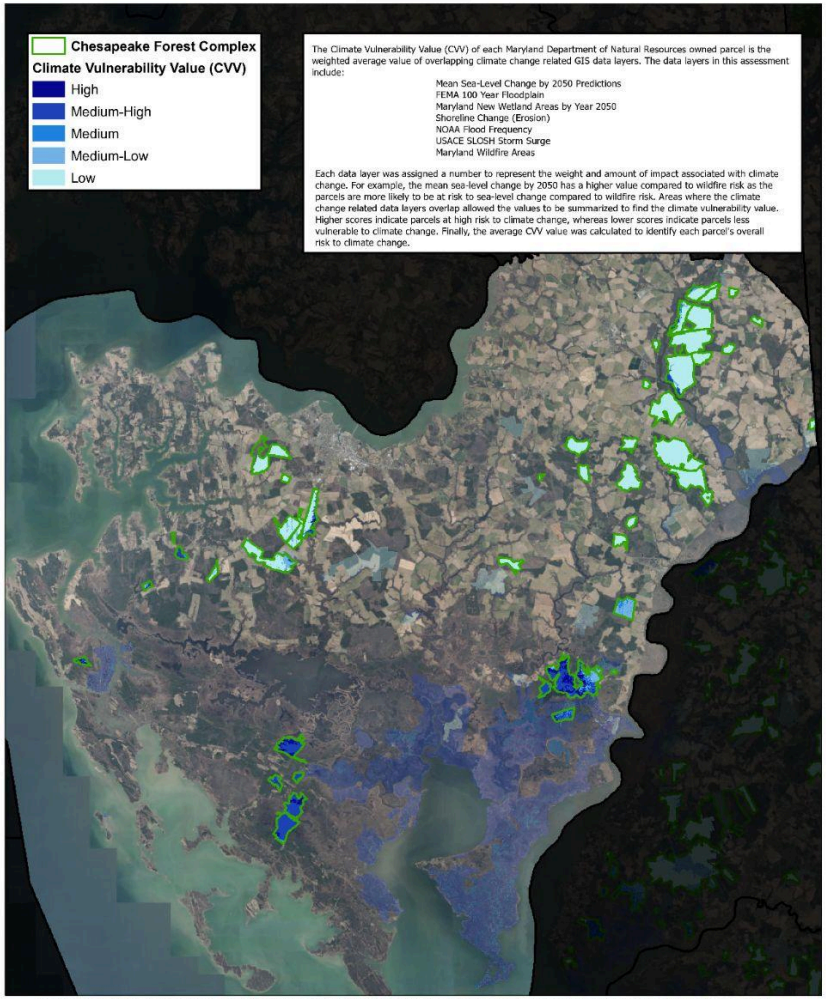
Appendix A. County level maps of ecological value and climate vulnerability value across the Chesapeake Forest Lands

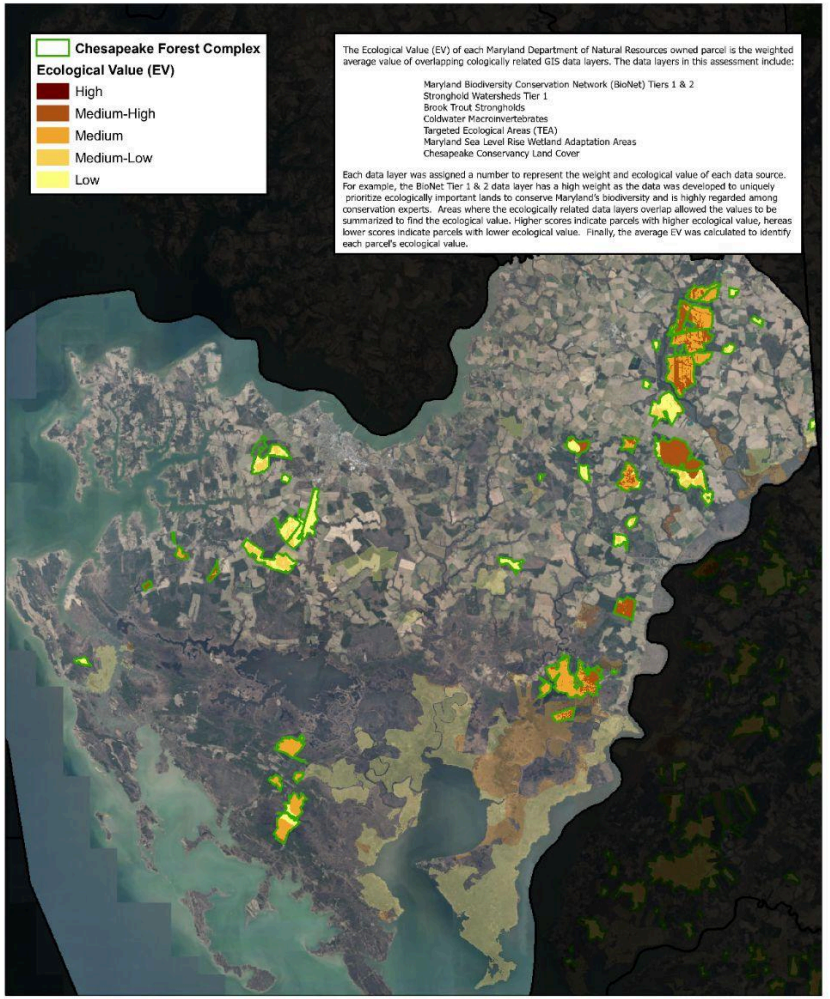


Maryland Department of Natural Resources
State Lands Climate Vulnerability Assessment (2019)
Chesapeake Forest Lands - Dorchester County

0 1.25 2.5 5 7.5 10 Miles

N





The Chesapeake Forest currently consists of 75,376 acres divided into 187 Management Units (Complexes) distributed across six counties. In spite of this scattered character, the forests include some of the last large segments of unbroken forest in a region that is largely agricultural in nature. Chesapeake Forest Lands include more than 6,000 acres of wetlands and comprise portions of 23 separate watersheds, many of which have been given a high priority for conservation action under the Maryland Clean Water Action Plan.

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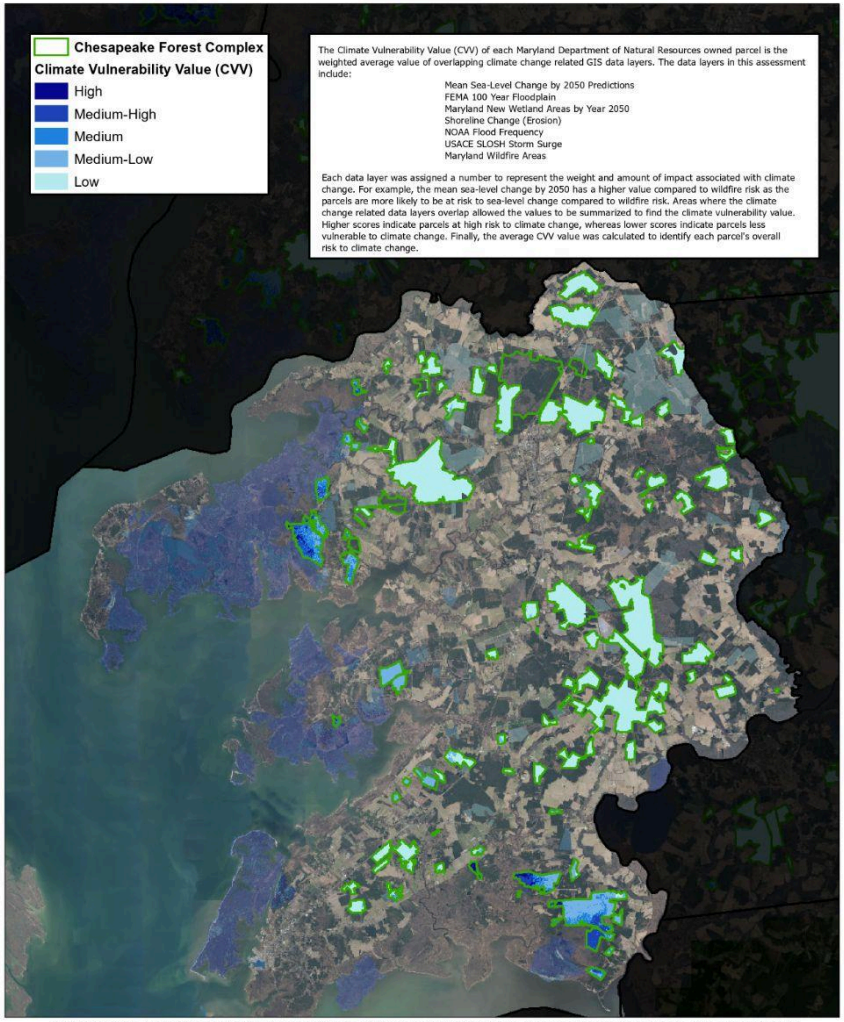
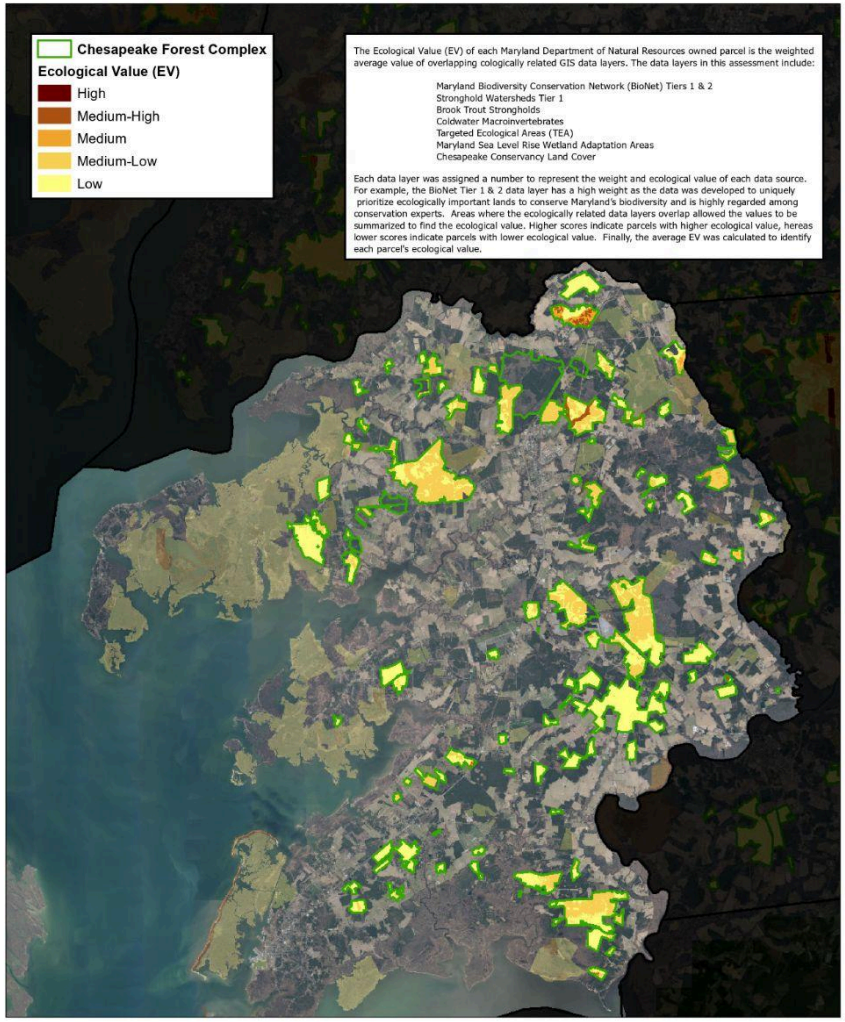
Maryland Department of Natural Resources
State Lands Climate Vulnerability Assessment (2019)
Chesapeake Forest Lands - Somerset County

0 0.751.5 3 4.5 6 Miles

N





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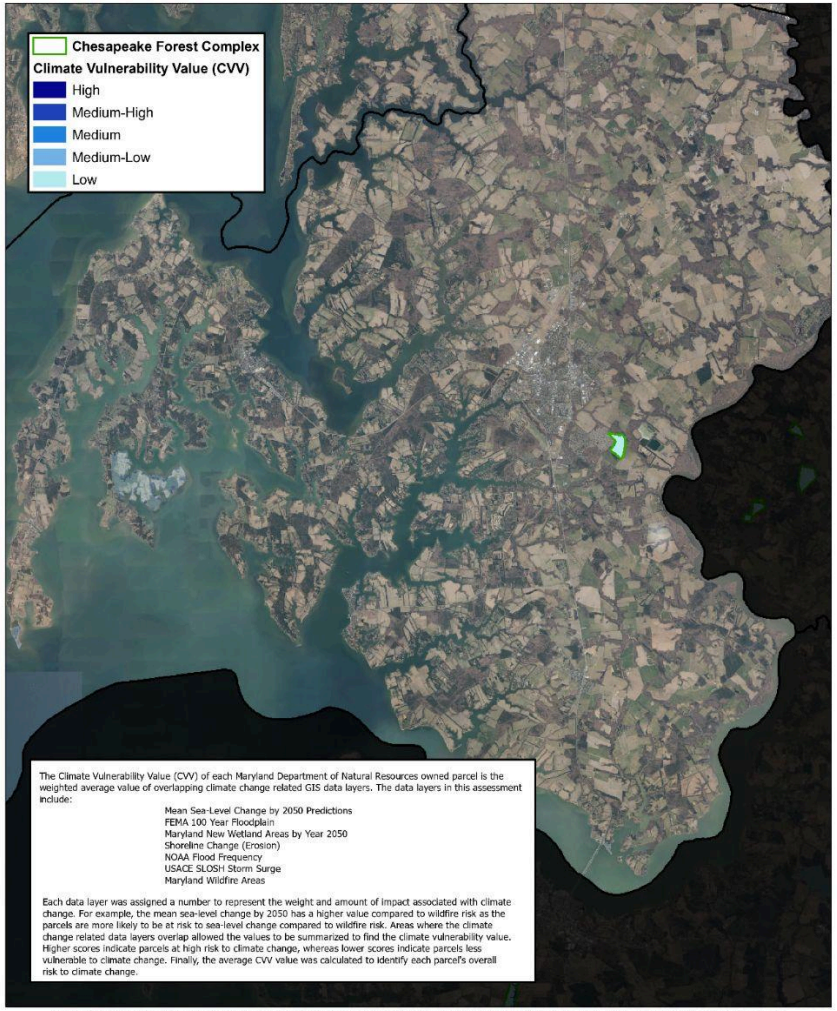
Maryland Department of Natural Resources
State Lands Climate Vulnerability Assessment (2019)
Chesapeake Forest Lands - Talbot County

0 0.75 1.5 3 4.5 6 Miles

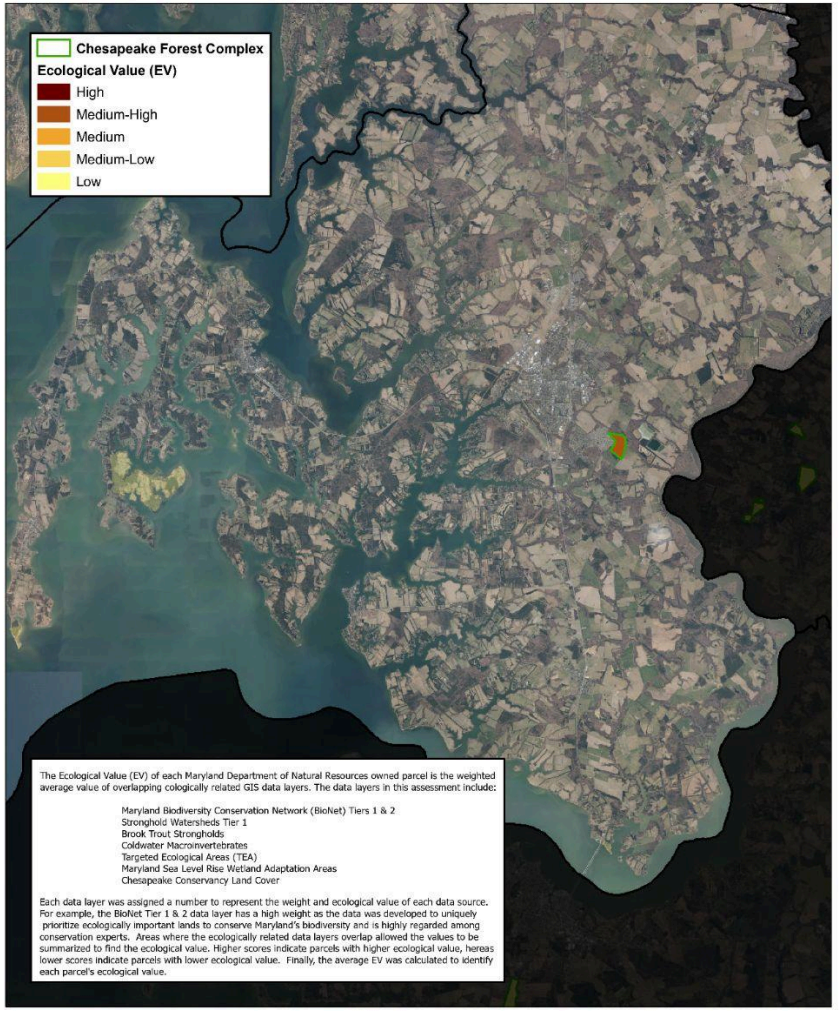
N



The Climate Vulnerability Value (CVV) of each Maryland Department of Natural Resources owned parcel is the weighted average value of overlapping climate change related GIS data layers. The data layers in this assessment include:

Mean Sea-Level Change by 2050 Predictions
FEMA 100 Year Floodplain
Maryland New Wetland Areas by Year 2050
Shoreline Change (Erosion)
NOAA Flood Frequency
USACE SLOSH Storm Surge
Maryland Wildfire Areas

Each data layer was assigned a number to represent the weight and amount of impact associated with climate change. For example, the mean sea-level change by 2050 has a higher value compared to wildfire risk as the parcels are more likely to be at risk to sea-level change compared to wildfire risk. Areas where the climate change related data layers overlap allowed the values to be summarized to find the climate vulnerability value. Higher scores indicate parcels at high risk to climate change, whereas lower scores indicate parcels less vulnerable to climate change. Finally, the average CVV value was calculated to identify each parcel's overall risk to climate change.



The Ecological Value (EV) of each Maryland Department of Natural Resources owned parcel is the weighted average value of overlapping cologically related GIS data layers. The data layers in this assessment include:

Maryland Biodiversity Conservation Network (BioNet) Tiers 1 & 2
Stronghold Watersheds Tier 1
Brook Trout Strongholds
Coldwater Macroinvertebrates
Targeted Ecological Areas (TEA)
Maryland Sea Level Rise Wetland Adaptation Areas
Chesapeake Conservancy Land Cover

Each data layer was assigned a number to represent the weight and ecological value of each data source. For example, the BioNet Tier 1 & 2 data layer has a high weight as the data was developed to uniquely prioritize ecologically important lands to conserve Maryland's biodiversity and is highly regarded among conservation experts. Areas where the ecologically related data layers overlap allowed the values to be summarized to find the ecological value. Higher scores indicate parcels with higher ecological value, hereas lower scores indicate parcels with lower ecological value. Finally, the average EV was calculated to identify each parcel's ecological value.

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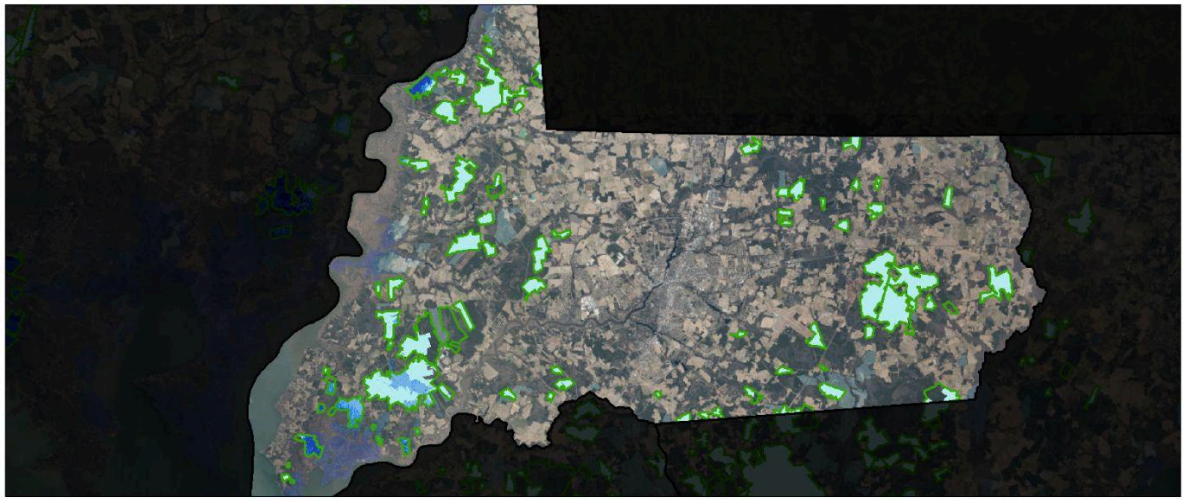
Maryland Department of Natural Resources
State Lands Climate Vulnerability Assessment (2019)
Chesapeake Forest Lands - Wicomico County

0 1.25 2.5 5 7.5 10 Miles

N



Chesapeake Forest Complex
Climate Vulnerability Value (CVV)
- High
- Medium-High
- Medium
- Medium-Low
- Low

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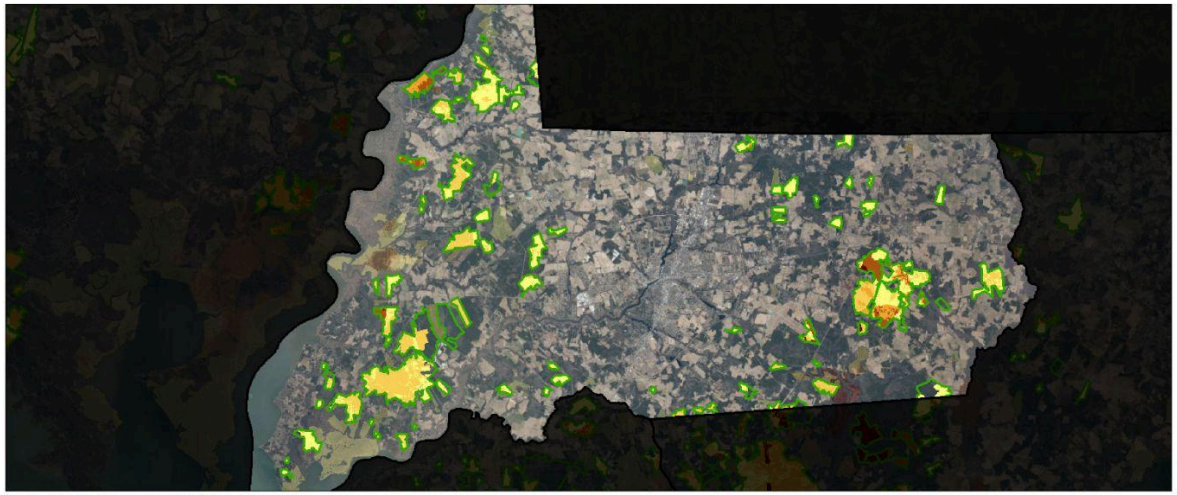
Chesapeake Forest Complex
Ecological Value (EV)
- High
- Medium-High
- Medium
- Medium-Low
- Low



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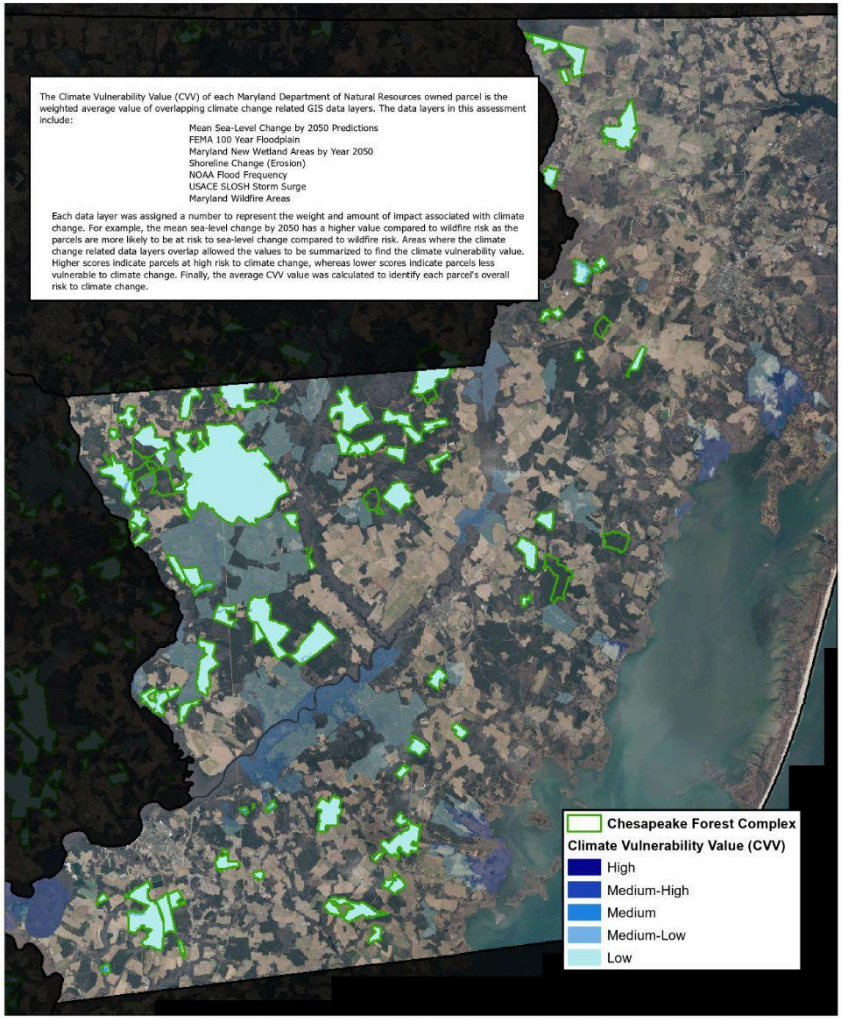
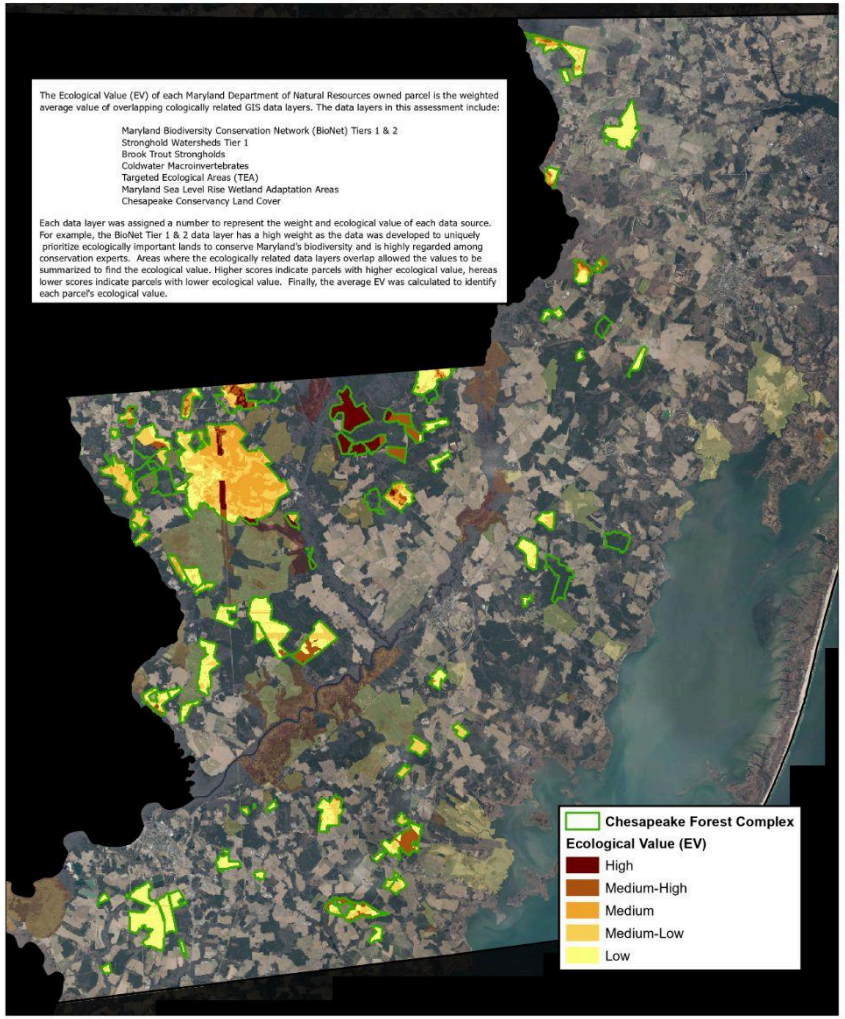
Maryland Department of Natural Resources
State Lands Climate Vulnerability Assessment (2019)
Chesapeake Forest Lands - Worcester County

0 0.751.5 3 4.5 6 Miles

N





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Appendix B. Risk assessment results from February 2023 workshop with Maryland Forest Service

Risk Assessment				
Climate Change Impacts and Vulnerabilities	**Likelihood**	**Severity**	**Overall risk**	**Prioritize?**
From Step 2 worksheet	*What is the likelihood of this impact/vulnerability occurring in the next 20 years? (Very Likely-Very Unlikely)*	*What is the severity of the impact if it does happen? (Negligible-Severe)*	*Use the diagram to determine the risk rating. (Low-High)*	*Select impacts that are high risk or require an immediate response*
Rising sea levels. Sea levels along the Atlantic coast expected to rise by 7 to 23 inches by the end of the century. Saltwater Intrusion.	Already happening	Minor	Medium	3
Extreme events. Intense precipitation events will continue to become more frequent. Storm Surge Impacts	Already happening	Moderate	Medium-High	2
Increases in insect pests and forest pathogens. Certain insect pests and pathogens will increase in occurrence or become more damaging.	Possible	Minor	Medium-Low	4
Increases in invasive plant species. Many invasive plants will increase in extent or abundance.	Possible	Minor	Medium-Low	5
Multiple or interacting impacts: Regulatory or Policy	Already happening	Major	High	1