

Maryland Department of Natural Resources Climate Adaptation, Mitigation and Education 2019 Report

Prepared as required in the State Environment Article § 2-1305(c), HB 514, Chapter 429 in 2015 and in accordance with § 2-1257 of the State Government Article, for the Governor and Commission

Introduction

Climate change is an important consideration given the mission and operations of the Maryland Department of Natural Resources (department). The department uses science, data, monitoring and modeling to inform investment decisions, determine impacts to habitat, and understand the potential effects on our waterways and our communities. The department also leads the Maryland Commission on Climate Change Adaptation and Resiliency Working Group (ARWG), which supports the commission by developing a comprehensive strategy for reducing Maryland's climate change vulnerability, providing state and local governments with tools to plan for and adapt to the more extreme weather and rise in sea levels anticipated as a consequence of climate change.

The Maryland Greenhouse Gas Reduction Act (GGRA), requires a 25 percent reduction in greenhouse gas (GHG) emissions from 2006 levels by 2020. The law, re-authorized during the 2016 legislative session, further extended the goal to a 40 percent reduction by 2030 (the 40 by 30 Plan). The department contributes to mitigating greenhouse gases through managing public and private forests, planting trees, and restoring streams and wetlands. Carbon removed from the atmosphere through growth of forests is considered in Maryland's Greenhouse Gas Inventory, managed by the Department of the Environment¹. Only the actions Maryland takes to increase this carbon sink relative to the 2006 emissions baseline are reported here and considered as contributing towards the greenhouse gas reduction goals.

This document details what the department has done in the past year to contribute to greenhouse gas mitigation and our progress towards the goals laid out in the GGRA plan. It also includes information on our work providing guidance for climate adaptation and response and what we have done to educate the public on how climate change will impact them.

Highlight Facts/Figures

- 49,170 Forest Acres Managed in 2018 - 164% percent of yearly goal
- 2,170 Forest Acres Planted in 2018 - 137% percent of yearly goal
- Both Planting and Managing Forests on Track for 2020 Goal
- The Chesapeake and Atlantic Coastal Bays Trust Fund restored 2,245 acres of wetlands in state fiscal year 2018 and 4,982 acres of wetlands since 2010
- Created the nation's first state-led Climate Leadership Academy for state and local government officials, infrastructure executives, and business leaders

¹ <https://mde.maryland.gov/programs/Air/ClimateChange/Pages/GreenhouseGasInventory.aspx>

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Greenhouse Gas Mitigation Programs

1. Managing More Forests to Capture Carbon

Program Description

Managing more forests to capture carbon will promote sustainable forestry management practices in existing Maryland forests on both public and private lands. Enrolling unmanaged forests into management regimes enhances forest productivity which increases rates of carbon sequestration in forest biomass and the amount of carbon stored in harvested durable wood products. This translates to economic benefits and increased availability of renewable biomass for energy production. This increased forestry management in Maryland is estimated to result in a 1.80 million metric tons of carbon dioxide equivalent (MMtCO₂e) cumulative reduction in the state's greenhouse gas (GHG) emissions by 2020. The 2020 goals of this program are to improve sustainable forest management on 30,000 acres of private land annually and ensure 50 percent of state-owned forest lands will be third-party certified as sustainably managed. This program is performing as designed.

Program Objectives

The potential emission reductions from the program by 2020 are estimated to be 1.80 MMtCO₂e. This number represents a conservative estimate of the cumulative carbon sequestered through the program. Appendix C of the 2015 GGRA Update provides a more detailed description of the process used to quantify greenhouse gas reductions.

Implementation Milestones

Public Lands:

- Since 2006, 211,000 acres of state forests have been certified with dual third party certification for Forest Sustainability to the Sustainable Forestry Initiative and Forest Sustainability Certification standards.
- The department is developing similar sustainable forest management practices on state park and wildlife land.
- Department of Natural Resources Wildlife and Heritage Service is developing Forest Stewardship Plans on several Wildlife Management Areas
- The department has accelerated pace of silvicultural activity:
 - Savage River State Forest will increase the number of timber sales from 14 to 20. The Maryland Forest Service is continuing to work to decrease the backlog of timber sales.
 - State Forest Annual Workplans included 2,324 acres of timber harvests for FY19, that will be naturally regenerated.

Private Lands:

- Since 2006 we have implemented-
 - 274,138 acres of stewardship plans
 - 168,310 acres of sediment control

- 104,607 acres of forest stand improvements (eg., tree planting, timber stand improvements, wildlife habitat)
- Total of 547,055 acres of forest management plans on private lands
- The department is currently on track to meet our goal by 2020

Technical Assistance Provided:

- Forest Stewardship Plan preparation
- Forest Stewardship Plan implementation – expanded special rivers project
- Financial assistance – state and federal cost sharing
 - Woodland Incentive Program
 - Healthy Forests/Healthy Waters
 - Working on the next round of projects
 - Backyard Buffer Program
 - Environmental Quality Incentive Program (EQIP)
 - Conservation Reserve Enhancement Program (CREP)
 - Income Tax Modification (TAXMOD)
 - Expanded eligibility of forestry practices in 2014
 - Forest Conservation and Management Program
 - Woodland Assessment Program
- Completed the development and application of the University of Maryland remote sensing capability for forest carbon assessment.
- Launch of National Aeronautics and Space Administration, U.S. Department of Agriculture and U.S. Department of Energy climate science project for remote sensing, modeling and field-based measurements to quantify the carbon consequences of alternate development and management plans across rapidly changing forests in Maryland. Pending funding approval.
- Forest Management Study

The department identified a forest management site that utilizes three forest management plans:

Low Management (100 percent hardwoods), Moderate Management (50-70 percent pines: 30-50 percent oaks) and High Management (100 percent pine). The department's Resource Assessment Service has and continues to evaluate the below ground carbon sequestration on these management plots to complement the determination of carbon sequestration in the above-ground forest. Baseline data was collected annually in 2011 thru 2014. After analysis of the 2014 data, this project was changed to a 5 year sampling interval. Expected project completion: 2030.

Estimated Emission Reductions for CY18

- Forest management on private land in Maryland reduced carbon emissions by 0.26 MMtCO₂e.
- Forest management on public land in Maryland reduced carbon emissions by 0.21 MMtCO₂e.
- Both exceed yearly reduction goals.

Table 1 Forest Management Programs

Calendar Year	Stewardship Plan ⁽¹⁾	Sediment Control ⁽¹⁾	State Forest Regeneration ⁽²⁾	Timber Stand Improvement ⁽¹⁾	Wildlife Habitat ⁽¹⁾	Total Acres
2006	13,834.1	9,113.1	2,417.0	3,092.9	2,172.6	30,629.7
2007	14,135.0	11,204.8	1,731.0	5,925.6	3,331.4	36,327.8
2008	26,787.3	11,692.2	1,823.5	5,611.2	4,146.4	50,060.7
2009	17,936.9	11,044.4	2,234.1	3,789.2	3,212.8	38,217.4
2010	14,921.2	9,539.8	2,158.2	3,178.0	2,070.6	31,867.8
2011	22,012.1	11,585.8	1,891.8	4,496.0	3,302.1	43,287.8
2012	19,486.4	12,177.6	1,723.6	3,910.0	2,705.8	40,003.4
2013	18,945.0	12,235.9	1,524.9	5,054.9	1,062.5	38,823.1
2014	16,580.0	13,100.6	1,249.2	3,072.9	434.0	34,436.6
2015	23,111.6	13,973.8	1,803.7	5,373.8	279.0	44,541.9
2016	35,224.3	18,022.1	1,866.6	3,802.1	696.2	59,611.3
2017	24,795.1	18,048.6	2,504.7	3,506.3	1,223.4	50,078.0
2018	26,369.1	16,571.8	2,469.6	3,233.8	525.6	49,170.0
2019	18,000.0	11,000.0	1,500.0	4,500.0	2,800.0	37,800.0
2020	18,000.0	11,000.0	1,500.0	4,500.0	2,800.0	37,800.0
Total	310,138.1	190,310.5	28,397.9	63,046.6	30,762.4	622,655.4
Average Annual	20,675.9	12,687.4	1,893.2	4,203.1	2,050.8	41,510.4

15 Year Target Goal	270,000.0	165,000.0	22,500.0	67,500.0	42,000.0	567,000.0
Percent of Goal Obtained	115%	115%	126%	93%	73%	110%
Estimated 2030 Target Annual Goal	21,000.0	13,000.0	1,600.0	4,000.0	2,000.0	41,600.0

(1). From the Maryland Forest Service PMAS report where a calendar year is defined as Quarters 3 & 4 of the preceding year, and Quarters 1 & 2 of the current Fiscal Year. For example, the number for 2006 represents the reported values from PMAS for Q3 & Q4 of FY2006 and Q1 & Q2 of FY2007.

(2). State Forest harvest acres are only tracked by FY. Number reported from the annual State Forest Harvest Report and harvest data from WMAs and demonstration forests for the same fiscal year.

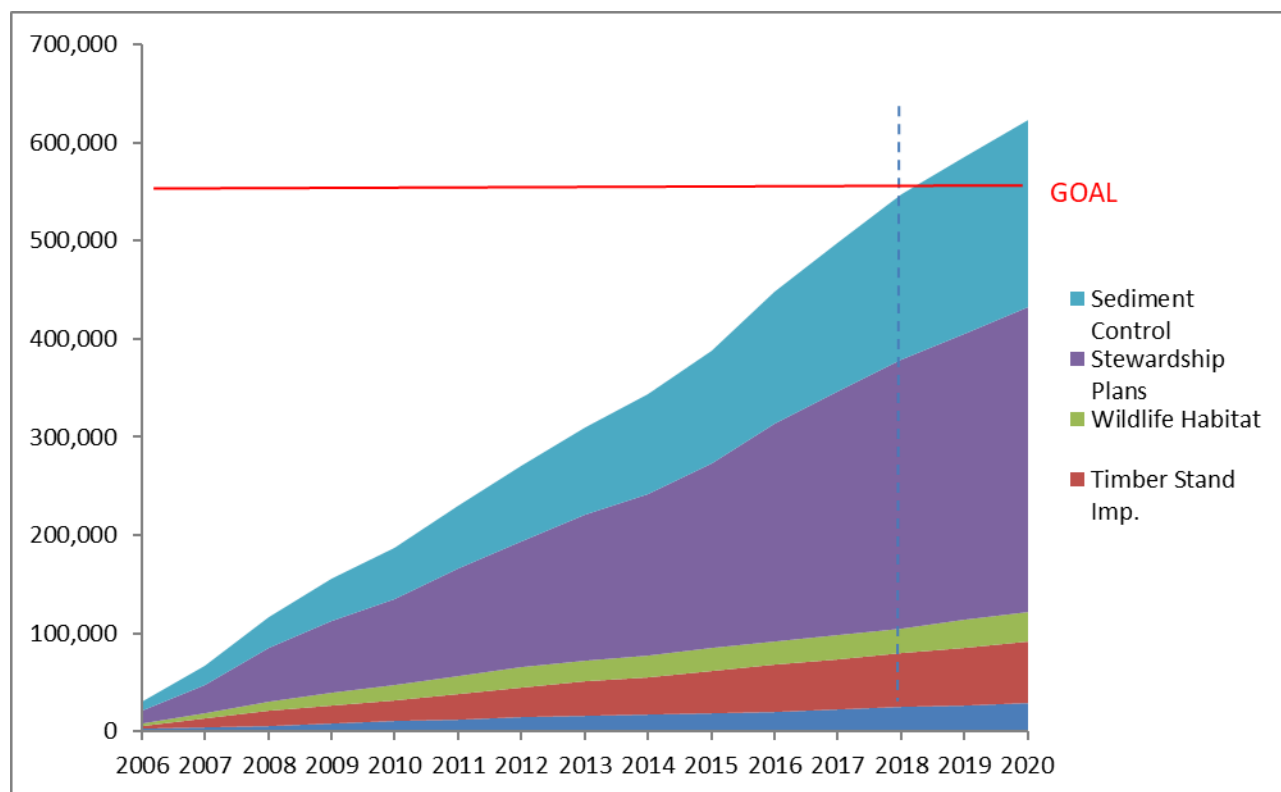


Figure 1: Managing Forests to Capture Carbon. The Maryland Department of Natural Resources is promoting sustainable forestry management practices in existing forests on public and private land through a suite of efforts, policies and programs.

Enhancement Opportunities

Current programming appears to be meeting targeted goals.

Funding

The Woodland Incentive Fund is the progenitor of much of the activity on private lands. This fund receives revenues from a number of sources including fees for service and assistance in implementation of an approved practice, funding from the Chesapeake and Atlantic Coastal Bays Trust Fund (under § 8-2A-04 of § 5-307), and subject to approval by the secretary and the Board of Public Works, a portion of the revenues derived from the forestry practices on designated lands owned and managed by the department. Another important revenue source is property tax from the transfer of forest lands (up to \$200,000 per year). However, the property tax transfer allocation for the Woodland Incentive Fund has been variable for the last several years and a new source needs to be identified to make up this gap to provide more uniform program funding.

Challenges

See Funding section above.

Relevant Information

Towson University's Regional Economic Studies Institute (RESI) 2015 study estimated that the Managing Forests to Capture Carbon program, once fully operational, would support a total of 268 jobs by 2020, \$28,564,453 in net economic output and \$28,137,209 in wages over the lifetime of the program. Chapter 6 and Appendix K of the 2015 GGRA Update report provides more detail on the RESI studies and the job creation and economic benefits associated with this program.

2. Planting Forests in Maryland

Program Description

Planting trees expands forest cover and associated carbon stocks by regenerating or establishing healthy, functional forests through practices such as soil preparation, erosion control and supplemental planting. These actions help to ensure optimum conditions to support forest growth. By 2020, the implementation goal of this program is to achieve the afforestation and/or reforestation of 43,030 acres in Maryland. Achieving the 43,030 acre target should cumulatively reduce greenhouse gas (GHG) emissions in the State by 1.79 MMtCO₂e by 2020. This program is performing as designed.

Program Objectives

The potential emission reductions from the Planting Forests in Maryland program by 2020 are estimated to be 1.79 MMtCO₂e. This represents a conservative estimate of the cumulative sequestration achieved through this program. Appendix C of the 2015 Greenhouse Gas Reduction Act Update provides a more detailed description of the process used to quantify GHG reductions.

Implementation Milestones

The department is implementing this program through a suite of efforts, policies and programs, including:

Public Lands:

- State forest system annual work plan implementation

Private Lands:

- Technical Assistance
 - Forest Stewardship Plan implementation
 - Forest Conservation Act (FCA) implementation

Financial Assistance – Rural Lands: State and Federal Cost Sharing:

- Woodland Incentive Program (WIP –MD Forest Service)
- Income Tax Modification (TAXMOD)- expanded eligibility of forestry practices in 2014
- Environmental Quality Incentive Program (EQIP – Federal/NRCS)
- Conservation Reserve Enhancement (CREP – Federal/NRCS)

Estimated Emission Reductions for CY 2018

On track with previous years, reductions totaled 0.10 MMtCO₂e for 2018.

Table 2 Acres of Forest Planted in Maryland

Year	Afforestation⁽¹⁾⁽²⁾	Reforestation⁽¹⁾⁽³⁾	Riparian Buffers⁽⁴⁾	Private Natural Regeneration⁽⁵⁾	Total Acres
2006	845.7	3,318.0	388.2	1,400.0	5,951.9
2007	343.4	1,990.2	242.8	1,400.0	3,976.4
2008	404.9	1,598.2	191.2	1,400.0	3,594.3
2009	531.1	1,497.4	162.6	1,400.0	3,591.1
2010	596.0	417.4	545.6	1,400.0	2,959.0
2011	1,223.6	633.9	503.1	1,400.0	3,760.6
2012	433.7	615.3	320.1	1,400.0	2,769.1
2013	198.1	593.6	237.0	1,400.0	2,428.6
2014	409.8	559.2	287.3	1,400.0	2,656.2
2015	294.1	633.1	213.7	1,400.0	2,540.9
2016	180.0	638.9	263.0	1,400.0	2,481.9
2017	97.6	434.0	127.4	1,400.0	2,059.0
2018	134.2	423.4	212.9	1,400.0	2,170.5
2019	100.0	400.0	100.0	1,400.0	2,000.0
2020	100.0	400.0	100.0	1,400.0	2,000.0
Total	5,891.9	14,152.4	3,894.9	21,000.0	44,939.2
Average Annual	392.8	773.9	259.7	1,400.0	2,995.9
15 Year Target Goal	6,000.0	10,500.0	6,000.0	21,000.0	43,500.0
Percent of Goal Obtained	98%	135%	65%	100%	103%

Estimated 2030 Target Annual Goal	350.0	600.0	200.0	1,400.0	2,550.0
(1).	From the Maryland Forest Service PMAS report where a calendar year is defined as Quarters 3 & 4 of the preceding year, and Quarters 1 & 2 of the current Fiscal Year. For example, the number for 2006 represents the reported values from PMAS for Q3 & Q4 of FY2006 and Q1 & Q2 of FY2007.				
(2).	PMAS field CREP/HEL Afforestation plus the Other Afforestation Acres.				
(3).	PMAS field Reforestation Acres.				
(4).	Acres reported by the MD Forest Service Riparian Forest Buffer Restoration Program. http://dnr.maryland.gov/forests/Pages/programapps/rfbrestoration.aspx				
(5).	Estimated area of privately owned forest regenerated annually following timber harvest. Assumes 20% of Sediment and Erosion Control permitted acres reported by counties are actually harvested and regenerated. Historically, the average is 1,400 acre/year				

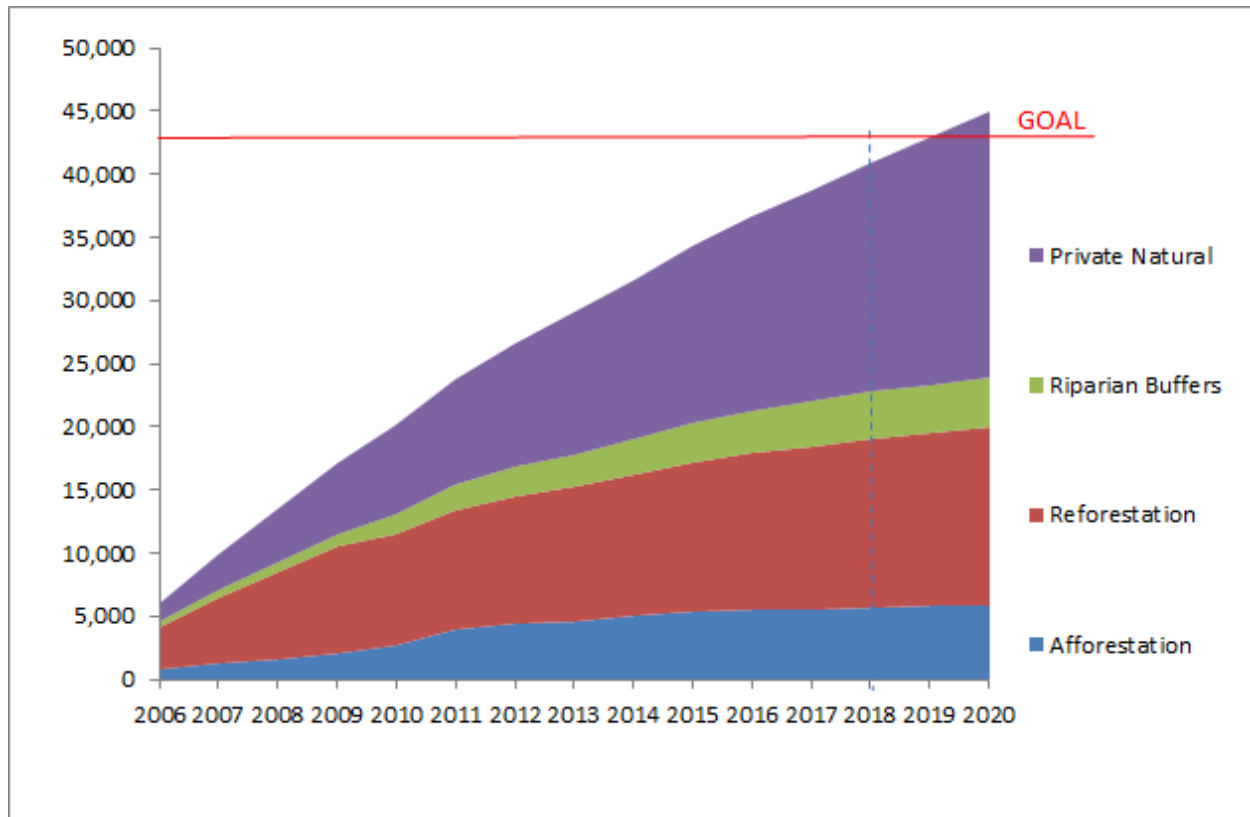


Figure 2 Planting Forests in Maryland.

Enhancement Opportunities

Provide dedicated staff to identify landowners interested in participating in programs like “Lawn to Woodland” and “Marylanders Plant Trees”.

Funding

See Challenges section below.

Challenges

Important challenges faced by this program include locating and obtaining funding to continue and build upon the “Lawn to Woodland” and “Marylanders Plant Trees” programs.

Relevant Information

RESI’s 2015 study estimated that the Planting Forests in Maryland program, once fully operational, would support a total of 92 jobs by 2020, \$11,077,882 in net economic output and \$14,862,060 in wages over the lifetime of the program. Chapter 6 and Appendix K of the 2015 GGRA Update report provides more detail on the RESI studies and the job creation and economic benefits associated with this program.

3. *Creating and Protecting Wetlands and Waterway Borders to Capture Carbon*

Program Description

In addition to forests, wetlands are known to be very efficient at sequestering carbon. The department is planting forested stream buffers and pursuing the creation, protection and restoration of wetlands to promote carbon sequestration through several means including the Natural Filters Program, which restores wetlands and buffers on state and public lands to meet water quality goals and is provided through the Chesapeake and Atlantic Coastal Bays Trust Fund. The objectives of the Coastal Wetlands Initiative include restoring natural tidal marsh hydrology to coastal wetlands through ditch plugging practices, the development of a terrestrial carbon sequestration protocol and the Sea Level Affecting Marshes Model (SLAMM). The following are accomplishments towards wetland and waterways goals made in 2018:

The Natural Filters Program restored 159.12 acres of wetlands on state and public land and planted 16 acres of streamside forest buffers on state and public lands in calendar year 2018, working towards the State's Watershed Implementation Plan (WIP) goals for state and public lands. Funded through The Chesapeake and Atlantic Coastal Bays Trust Fund, these projects are designed to accelerate Bay restoration by focusing limited financial resources on the most efficient, cost-effective non-point source pollution control projects, which include wetland and buffer restoration projects.

Through a partnership between the department, The Nature Conservancy (TNC), U.S. Fish and Wildlife Service, Natural Resources Conservation Service and National Oceanic and Atmospheric Administration, we were able to restore 2,174 acres via a 5 year grant agreement between TNC and the department (Chesapeake and Coastal Bays Trust Fund). The Pocomoke project's primary focus was to reconnect the mainstem, channelized Pocomoke River with its historic floodplain. The wetlands restored were mostly forested riparian wetlands, with some emergent wetlands restored in agricultural fields in the watershed.

Maryland's Innovative Technology Fund has invested in solutions that have the co-benefit of mitigating Greenhouse Gas (GHG) emissions. Manta Biofuel has a system to grow, harvest and convert algae into biofuel. This algal biofuel can be a substitute for fossil fuels, or mixed with fossil fuels and will emit less pollutants compared to fossil fuels. Dr. Russell Hill at the University of Maryland Center for Environmental Science Institute of Marine and Environmental Technology (UMCES IMET) has worked with the company to develop their system. HyTek Bio uses an algae scrubber system to reduce GHG and NOx emissions from the Back River Wastewater treatment plant. Dr. Feng Chen at UMCES IMET is partnering with HyTek Bio in the development of this technology.

In addition, the department is including another best practice for terrestrial carbon sequestration through its Shoreline Conservation Service projects to install Living Shorelines. These are additional coastal wetland restoration practices that function to sequester carbon.

Program Objectives

The potential cumulative emission reductions from the Creating and Protecting Wetlands and Waterway Borders to Capture Carbon program by 2020 are estimated to be 0.43 MMtCO₂e.

Implementation Milestones

On the ground wetland and waterway restoration projects:

Natural Filters Program: As of 2018, 1,794 acres of wetlands have been restored and 940 acres of streamside buffers have been planted. The Natural Filters Program has exceeded the established Watershed Implementation Plan goals for public land restoration.

The Chesapeake and Atlantic Coastal Bays Trust Fund has, as of the end of state fiscal year 2018, funded the restoration of 4,982 acres of wetlands and 1,201 acres of riparian buffers. These totals include restoration gains from the Natural Filters Program, as documented above, and projects that have occurred on private lands. From this point onward, implementation tracking will be expanded to include both public and private land restoration projects that are funded through the Trust Fund to more accurately reflect potential carbon sequestration gains.

Coastal Wetlands Initiative Program: As of 2018, 505.6 acres of coastal wetlands have been restored by plugging existing drainage ditches to restore these drained wetlands.

The Pocomoke River Restoration Project restored 2,174 acres of wetlands through 2018. It is now completed.

Living Shorelines through the Shoreline Conservation Service: Between 2006 and 2018, 13.24 acres of Living Shoreline have been created or restored.

Table 3. Shoreline and Marsh Creation in Maryland

Year	Linear Feet of Shoreline	Square Feet of Marsh Created/Restored	Acres Created/Restored
2006	2,901	55,779	1.28
2007	2,920	119,210	2.74
2008	2,485	87,670	2.01
2009	8,935	46,660	1.07
2010	1,944	37,871	0.87
2011	2,100	31,497	0.72
2012	None		

2013	2,000	24,000	0.55
2014	3,000	63,115	1.45
2015	None		
2016	3,100	66,000	1.52
2017	None		
2018	300	45,000	1.03
Total	29,685	576,802	13.24

Studies and Protocols

A tidal wetland and seagrass protocol has been developed in partnership with Restore America's Estuaries and the Verified Carbon Standard Program. The protocol provides a default value of 1.46 MG carbon sequestered/hectare/year for tidal wetland restoration projects if more detailed and precise accounting methodologies are not applied.

The Sea Level Affecting Marsh Model (SLAMM) has been completed for Maryland coastlines and is being actively used for a variety of wetland management practices including:

- Factor into the Department of Natural Resources' land acquisition efforts to areas that may provide a future wetland benefit through inland marsh migration resulting from sea level rise
- Developing new easement opportunities for landowners who own land within these wetland adaptation area transition zones
- Identifying the value of current and future wetlands for protecting communities and infrastructure from coastal flooding and shoreline erosion through the department's Coastal Resiliency Initiative

Future work will address using the SLAMM model to determine the potential loss of tidal wetlands and the potential gain to provide input to the Greenhouse Gas Reduction Act (GGRA) plan in understanding the effect of sea level rise on carbon storage pools in current and future wetlands.

Estimated Emission Reductions for CY 2018

The Verified Carbon Standard has accepted default values for carbon sequestration for tidal wetland restoration. Restoration gains from both the Coastal Wetland Initiative and the Shoreline Conservation Service total 517.81 acres since 2006. However, more information is needed before applying this default value. A significant factor in determining the net greenhouse gas benefit of tidal wetland restoration is the quantification of methane emissions. Methane emissions vary according to salinity levels. Current research at the University of Maryland is ongoing and may

soon be ready in a form that the state can use to more accurately reflect the greenhouse gas benefits once methane emissions are considered.

Enhancement Opportunities

The new protocol for Tidal and Seagrass restoration opens up opportunities to account for the greenhouse gas benefits of carbon sequestration through submerged aquatic vegetation (SAV) restoration and re-establishment.

Restore America's Estuaries and the Verified Carbon Standards program will be pursuing additional carbon sequestration accounting protocols for tidal wetland conservation. This protocol will provide justification for projects that prevent the degradation of tidal wetlands. Living Shorelines projects will prove to yield greater benefit through this new protocol as a result of the protection these buffers provide to tidal wetlands landward from the shoreline restoration project.

Funding

The Chesapeake and Atlantic Coastal Bays Trust Fund: In 2007, the Maryland General Assembly created the Chesapeake and Atlantic Coastal Bays Trust Fund (Trust Fund) to provide financial assistance to projects that advance Chesapeake Bay restoration. A large portion of this funding is targeted to local grants for counties and municipalities to reduce nutrient pollution to waterways which includes forested buffers, reforestation, wetland restoration, stream and floodplain restoration, stormwater retrofits and other bioremediation projects. In FY18, \$29.72 million was allocated for these projects.

Resiliency through Restoration Initiative: Over the past 10 years, Maryland has experienced seven weather-related events warranting Presidential Disaster declarations, including five coastal flood events totaling approximately \$103 million in economic damage. Recognizing that coastal habitats help buffer communities from these climate-related impacts, the Maryland Department of Natural Resources' Chesapeake and Coastal Service (CCS) launched a new Resiliency through Restoration Initiative. This Initiative, funded by Governor Hogan through the State Capital Budget, provides technical and financial assistance to restore, enhance and create coastal habitat with the goal of protecting Maryland communities and public resources from extreme weather and climate-related events. The Initiative has led to the design of 16 living shoreline, coastal, and inland restoration projects around Maryland.

Coastal Wetlands Initiative (CWI): There are no dedicated funds currently allotted to CWI. Funding is typically acquired through a competitive grant process which in the past have used State transportation and federal funding sources.

Shoreline Conservation Services: This program is funded through the Shore Erosion Control Construction Loan Fund through the department.

Department of Natural Resources/Department of Transportation Memorandum of Understanding: The Maryland Department of Natural Resources has partnered with the State Highway Administration (SHA) in an effort to lead by example in restoring the Chesapeake Bay

and local waters. State parks will provide opportunities for the State Highway Administration to implement restoration projects required by their Federal Stormwater Permit (MS4) and their nutrient and sediment reduction goals required under the Bay Total Maximum Daily Load (TMDL). A Memorandum of Understanding was signed in 2013 to initiate this program and is currently being updated to provide additional guidance. This MOU will increase the rate of restoration projects on state and public lands.

Challenges

While wetland restoration, in both inland, freshwater and tidal environments, are practices that significantly contribute to terrestrial carbon sequestration rates throughout the state, the highly variable rate of methane emissions has a marked effect on net greenhouse gas benefits. Research at state, regional, national and global scales continues to evolve and narrow in on more precise methods to evaluate the greenhouse gas benefits of wetland restoration.

Measures of success for the various Coastal Wetland Initiative projects are currently being monitored. In some cases, ditch plugging has been very effective in establishing sheet flow across the marsh and allowing sediment to naturally fill the plugged ditches. In other areas, the ditch plugging has resulted in excessive water pooling, creating a drowned marsh effect. Ongoing monitoring of these projects will improve the design, best practices and success of future efforts.

Removing barriers to accessing federal funds could also incentivize landowners to participate in restoration projects. The department is actively working with the Maryland Department of Agriculture and the United States Department of Agriculture on removing those barriers

Relevant Information

RESI's 2015 Study estimated that the Creating and Protecting Wetlands and Waterway Borders to Capture Carbon program, once fully operational, would support a total of 62 jobs by 2020, \$28,717,043 in net economic output and \$15,045,166 in wages over the lifetime of the program. Chapter 6 and Appendix K of the 2015 GGRA Update report provides more detail on the RESI studies and the job creation and economic benefits associated with this program.

4. Biomass for Energy Production

Program Description

Maryland is working to promote the use of locally produced woody biomass for generation of thermal energy and electricity. Energy from forest by-products can be used to offset fossil fuel-based energy production and associated GHG emissions. There are many end users that could employ wood heating and cooling and would benefit from such a program. For example, schools, hospitals, and municipalities could utilize local fuel markets as a key component of their tree management programs and all surrounding residents would also benefit by having access to a wood fuel market.

The goal of this program is to develop policies that recognize wood as a renewable energy source, recognize wood as the largest source of bioenergy production in Maryland, and offer incentives to utilize locally produced wood to meet thermal energy needs.

Program Objectives

The potential emission reductions from the Biomass for Energy Production program by 2020 were estimated to be 0.33 MMtCO₂e in the Greenhouse Gas Reduction Act plan, but we now estimate no greenhouse gas benefit from this program as there have not been any biomass to energy facilities built in the state, but Maryland is currently exploring opportunities for new facilities. .

Implementation Milestones

- Department of Natural Resources is actively working with partners including the Maryland Energy Administration, and the Maryland Department of Commerce (COMMERCE) to facilitate installation of wood energy systems
- Maryland Energy Administration has an existing grant program that could be reinstated if adequate demand is demonstrated.

Estimated Emission Reductions for CY 2018

None.

Enhancement Opportunities

An analysis of “woodsheds” where the available wood resource is quantified would help to raise confidence in the ability of an area to support industrial scale biomass to energy and in the feasibility of industrial scale biomass to energy. Additional educational outreach on the feasibility of biomass-to-energy to state agencies, academic institutions and the business community would likely help to establish this program. On the economic development side, a Strategic Economic Adjustment plan will help prepare Maryland’s industry for the future. The U.S. Department of Commerce Economic Development Administration just awarded a grant to the Western Maryland Resource Conservation and Development Council, who is partnering with the department and Commerce to develop the plan. Once finalized, the plan will serve as a roadmap for capitalizing on new opportunities in the forest industry including biomass for energy production,

Funding

See ‘Challenges’ section.

Challenges

Awareness of wood energy technology is the primary barrier to this program, in particular adequately informing the managers of commercial and institutional spaces of the opportunities to save money while improving environmental outcomes that are offered by the simple switching to wood fuels. Establishing some demonstration projects in Maryland would greatly assist with the department's ability to showcase available technology.

Maryland Energy Administration has discontinued its Commercial Wood Boiler grant incentive program due to a lack of success in identifying suitable grant recipients. This removes \$1 million of leverage in accelerating the adoption of carbon displacing wood energy, decreasing the likelihood of significant investment in future utilization of woody biomass to energy. The program could be reinstated if sufficient industry demand is demonstrated.

Actions that still need to be implemented include:

1. Developing policy supporting thermal energy.
2. Recognizing wood as a preferred renewable energy source, on par with solar, geothermal and wind.

Relevant Information

RESI's 2015 Study estimated that the Biomass for Energy Production program, once fully operational, would support a total of 51 jobs by 2020, \$24,871,827 in net economic output and \$12,756,348 in wages over the lifetime of the program. Chapter 6 and Appendix K the 2015 GGRA Update report provides more detail on the RESI studies and the job creation and economic benefits associated with this program.

5. Increasing Urban Trees to Capture Carbon

Program Description

Trees in urban areas are extremely important to Maryland's carbon budget because they help offset some of the greenhouse gas emissions from urban pollution sources such as power production and vehicle emissions, reduce heating and cooling costs and energy demand by moderating temperatures around buildings and slow the formation of ground level ozone as well as the evaporation of fuel from motor vehicles. Implementation is supported by several Maryland laws and programs that include outreach and technical assistance for municipalities to assess and evaluate their urban tree canopy goals and plant trees to meet those goals.

The goal of this program is to plant 12.5 million trees in urban areas through the Forest Conservation Act, Marylanders Plant Trees, Tree-Mendous Maryland and 5-103 State Highway Reforestation Act planting programs.

- Financial Assistance – Urban Lands: Public/Private Partnerships
 - Tree-Mendous/Arbor Day
 - 2,056 trees planted in 2018
- Marylanders Plant Trees/Private Nurseries
 - Reimbursed coupons for 4,212 trees in 2018
- Lawn to Woodland (e.g. National Arbor Day Foundation, etc.)
 - Kicked off in spring 2014 with 4.3 acres planted
 - 100.73 acres on 84 sites planted in spring 2015
 - 60.33 acres on 55 sites planted in spring 2016
- Maryland Urban and Community Forestry Committee Grants

- Small Community Urban Tree Canopy (UTC) Grants

This program is performing as designed.

Program Objectives

The potential emission reductions from the Increasing Urban Trees to Capture Carbon program by 2020 are estimated to be 0.02 MMtCO₂e. This number represents a conservative estimate of the cumulative carbon sequestered through this program. Appendix C of the 2015 GGRA Update provides a more detailed description of the process used to quantify greenhouse gas reductions.

Implementation Milestones

To date, 5,734,006 trees have been planted from 2006 to 2018 (total for this program and Planting Forests in Maryland).

Estimated Emission Reductions for CY 2018

Urban tree plantings are estimated to sequester 0.002 MMtCO₂e in 2018.

Table 4. Urban Tree Planting (number of trees).

Year	Forest Conservation Act (FCA)⁽¹⁾	Reforestation 5-103⁽¹⁾	Tree-Mendous & Marylanders Plant Trees Programs	Total Trees
2006	623,700	33,750	8,178	665,628
2007	473,400	27,000	6,057	506,457
2008	499,500	9,900	2,160	511,560
2009	450,900	13,950	39,020	503,870
2010	337,950	308,250	23,000	669,200
2011	481,050	15,750	17,200	514,000
2012	42,300	68,850	21,700	132,850
2013	119,250	23,850	23,800	166,900
2014	140,580	24,615	21,500	186,695
2015	142,875	6,251	8,435	157,561
2016	341,640	37,557	8,798	387,995
2017	412,300	8,388	12,545	433,233

2018	256,050	5,913	7,718	269,681
2019	0	0	0	0
2020	0	0	0	0
Total	4,321,495.0	584,024.0	200,111	5,105,630
Average Annual	288,099.7	38,934.9	13,340.7	340,375.3
Average of Last 3 Years (Rounded)	336,700.0	17,300.0	9,700.0	363,600.0
(1). Assumes 450 trees planted/acre.				

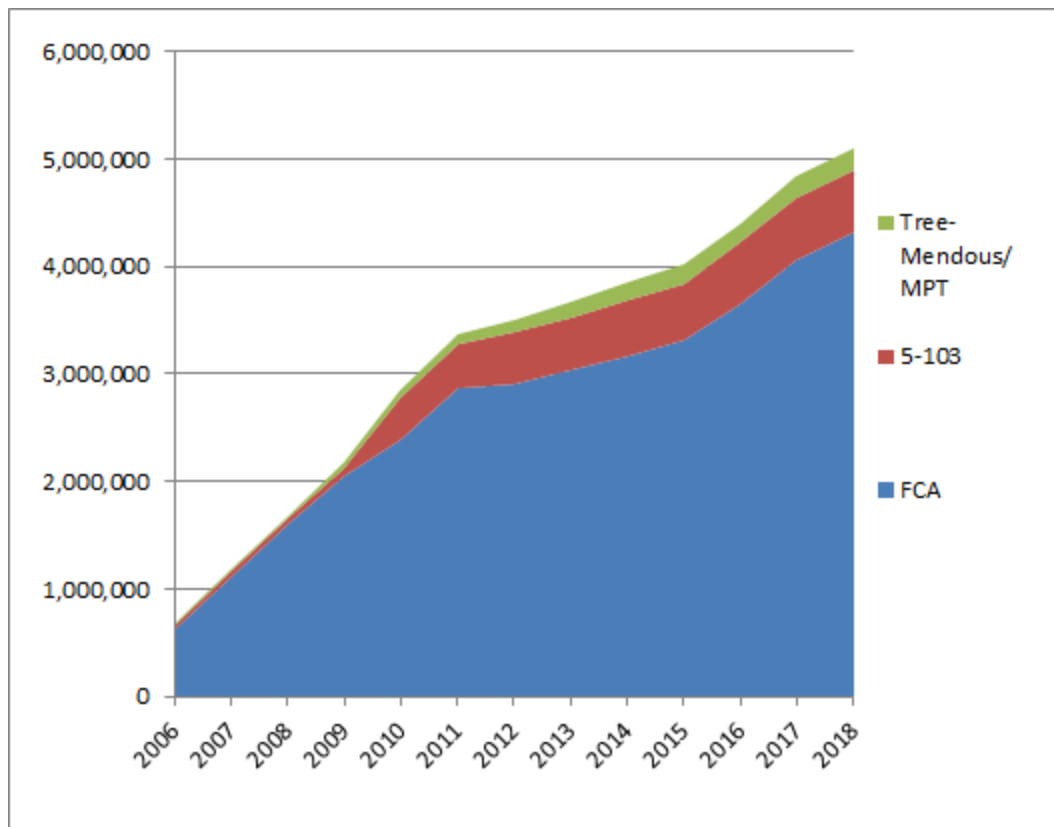


Figure 3. Increasing Urban Trees to Capture Carbon.

Enhancement Opportunities

The Department of Natural Resources Forest Service (Maryland Forest Service) developed two tree planting assistance programs that reach landowners within the urban/suburban areas of Maryland. The new programs target the 1.1 million acres of turf statewide. Each targets different

lot sizes and available planting space.

- The “Lawn to Woodland” program, a partnership with the Arbor Day Foundation, targets the small lot with 1-5 acres of plantable space or turf. The Foundation does outreach while Maryland Forest Service handles the tree planting at no cost to the lot owner. In the Spring of 2014, a pilot was done with 14 acres planted on 12 lots. In the Spring of 2015, 100 acres were planted on 84 sites and in the Spring of 2016, 60 acres were planted on 55 sites. All total, 174 acres were planted on 151 sites. This program is on hold until funding is identified.
- The “Marylanders Plant Trees” program, is a \$25 coupon reimbursement program targeting individuals wishing to plant a tree. It enables very small lot owners to purchase a tree valued at \$50 or more and reduce the cost by \$25. There are 85 participating nurseries across the state. From the program’s inception in FY09 to FY18, 45,545 coupons have been reimbursed.

Funding

The “Lawn to Woodland” and the “Marylanders Plant Trees” programs are both funded through forest mitigation funds received as a result of highway construction projects complying with Reforestation Law (NRA 5-103). This makes the funding variable from year to year, and for the past several years the “Lawn to Woodland” program was on hold due to limited available funds. Identifying an alternative funding source when mitigation funds are limited or not available would allow for the programs to be consistently offered to the public.

Challenges

See Funding section above.

Relevant Information

RESI’s 2015 Study estimated that the Increasing Urban Trees to Capture Carbon program, once fully operational, would support a total of 375 jobs by 2020, \$288,146,970 in net economic output and \$93,017,577 in wages over the lifetime of the program. Chapter 6 and Appendix K of the 2015 GGRA Update report provides more detail on the RESI studies and the job creation and economic benefits associated with this program.

6. Geological Opportunities to Store Carbon

Program Description

Geological carbon sequestration differs from other discussed sequestration methods because it captures carbon at the source, transports it to a sequestration site and then sequesters it. Maryland is one of eight partner states in the Midwest Region Carbon Sequestration Partnership whose role is to identify, locate, and characterize potential geologic storage opportunities. More than 10 gigatonnes of storage capacity has been identified within the terrestrial portion of Maryland (103 years of storage capacity at current CO₂ estimated production rate of 97 million metric tons per year). An unquantified amount of storage is located offshore of Maryland and is estimated to be much larger in magnitude.

The goal of this program is to identify and assess geologic storage opportunities. However, no quantification target has been assigned.

This program is performing as designed.

Program Objectives

The potential emission reductions from the Geological Opportunities to Store Carbon program have been aggregated with the estimated emission reductions from the Terrestrial Sequestration bundle (Forestry and Wetlands).

Implementation Milestones

The Department of Natural Resources' Resource Assessment Service (RAS) has completed or is currently working on the following implementation milestones.

- Total organic carbon content in Maryland black shales (e.g., Marcellus) is being evaluated as a precursor for determining the viability of these as storage units for carbon dioxide. This data is incorporated into regional and national databases for various integration projects. This project is completed.
- The potential for offshore carbon sequestration is being evaluated in partnership with Harvard University, Battelle, US Department of Energy, Rutgers University, University of Texas and the surrounding Mid-Atlantic States. Focus areas of this study included geologic characterization, capacity evaluations, injectability and risk analyses. This project has provided foundation knowledge and an assessment of potential for carbon sequestration offshore in the Baltimore Canyon Trough. This project is in final draft and is expected to be published by December 2019.
- The potential of saline aquifers located under the Coastal Plain in Maryland as a target for carbon sequestration is being evaluated in cooperation with multiple State Geological Surveys. There is currently no funding for this research and saline aquifers remain a potential option, but unvalidated sink for the greenhouse gas carbon dioxide (CO₂).
- Baseline data has been collected to provide the foundation for conducting risk analyses for potential development of stray gas migration into potable aquifers. The final report is in review.
- Research is ongoing to assess the CO₂ chemical adsorption capacity of power plant combustion by-products and the organic shales and clays in the closest geologic formations.
- Research has been completed to assess the possibility of CO₂ sequestration as both structural and chemical storage within triassic rift basins. The exposed Gettysburg-Culpepper basin has been characterized and documented as a proxy of the buried rift basins located throughout Maryland. Further research is planned to study the collected cores through the Taylorsville Basin; however, those cores are currently difficult to access. Phase I of this project is complete. Phase II is pending the availability of collected cores.

Other Resources Assessment Service program notes include:

- Site testing (carbon capture, transport and storage) continues in Michigan and Ohio (regional partners to Maryland in CO2 sequestration projects) and has been completed in Kentucky. These programs are being evaluated at a national level and the results continue to be favorable at this time.
- Depleted gas fields present the most immediate option for permanent storage of carbon dioxide in Western Maryland.
- A methane emissions study of the Deer Park Anticline by the Western Maryland Regional GIS Center has ruled out using this Anticline for structural storage of CO2 due to observed methane leaks primarily from the old Mountain Lake Park Gas Field. It could still have potential for chemical adsorption of CO2.
- Resource Assessment Service is working with Maryland Energy Administration to develop a CCUS conference in the fall of 2019.

Estimated Emission Reductions for CY 2018

None.

Enhancement Opportunities

The Taylorsville Formation is closest to the majority of Maryland's coal and gas fired power plants. An initial investigation characterizing the geology of these rift basins shows promising potential for CO2 sequestration. Coordination with the State of Virginia and Columbia University for further analysis of archived cores is occurring, but currently it is unfunded. Further investigations focused on the CO2 chemical adsorption capacity and risk analysis of this formation could best serve the Maryland electric power industry.

Funding

Previous Geological Carbon Sequestration funding has come from the US Department of Energy through Battelle. Research funds for geologic carbon sequestration will cease in 2019 with a refocusing of DOE funds into implementation of geologic carbon sequestration. Twenty thousand dollars per year is provided through the state's Environmental Trust Fund.

Challenges

The cost of capturing CO2 using current technologies involves a parasitic loss of approximately 20 percent at the generation site. This cost has decreased over the last 10 years by 30 percent. It is anticipated this will only decline to an 18 percent parasitic loss unless a vastly improved technology is identified. This cost, under the current carbon economic climate is cost-prohibitive for implementation at a grand scale. Thus, regardless of location and method of CO2 sequestration, there must be an order of magnitude reduction in the cost of capture, development of new, more affordable, sequestration methods, or a change in carbon policy for geologic carbon capture to become an economic option.

Relevant Information

RESI's 2015 Study estimated that the Geological Opportunities to Store Carbon program, once fully operational, would support a total of 217 jobs by 2020, \$312,011,719 in net economic

output and \$62,194,826 in wages over the lifetime of the program. Chapter 6 and Appendix K of the 2015 GGRA Update provides more detail on the RESI studies and the job creation and economic benefits associated with this program.

7. *Creating Ecosystems Markets to Encourage Greenhouse Gas Emission Reductions*

Program Description

Increased attention to the benefits and cost efficiencies that ecosystem markets could provide has spurred evaluation of the potential its programs and policies may have for fostering carbon market development. Maryland's Forest Conservation Act and Critical Area Act require mitigation for natural resource impacts generated through land development, and mitigation banking is an option to address these mitigation requirements

The goal of this program is to explore the establishment of ecosystem markets, create a tracking mechanism and develop protocols to assess/quantify GHG benefits of individual markets. However, no quantification target has been assigned.

Program Objectives

The potential emission reductions from the Creating Ecosystems Markets to Encourage greenhouse gas (GHG) Emission Reductions program in 2020 are estimated to be 0.11 MMtCO₂e. Appendix C of the 2015 GGRA Update provides a more detailed description of the process used to quantify GHG reductions.

Implementation Milestones

- The department has completed a study to economically value a suite of ecosystem services for select habitats along an urban to rural gradient.
- Ecosystem services from forests, wetlands, cropland, and pasture land have been spatially quantified across Maryland. Spatial models for coastal ecosystem services have been completed and are available on Maryland GreenPrint (www.geodata.md.gov/greenprint/).
- The Nontidal Wetlands Mitigation Banking bill passed in 2016 removes barriers to mitigation banking in Maryland with the goal of reducing the cost for meeting mitigation requirements in an ecologically beneficial way.
- Under Forest Conservation Act (FCA) banking, several counties in Maryland allow off-site mitigation for forest loss through purchasing credits in a forest bank. Over 2,000 acres of forest loss have been mitigated in this way over the past 15 years.

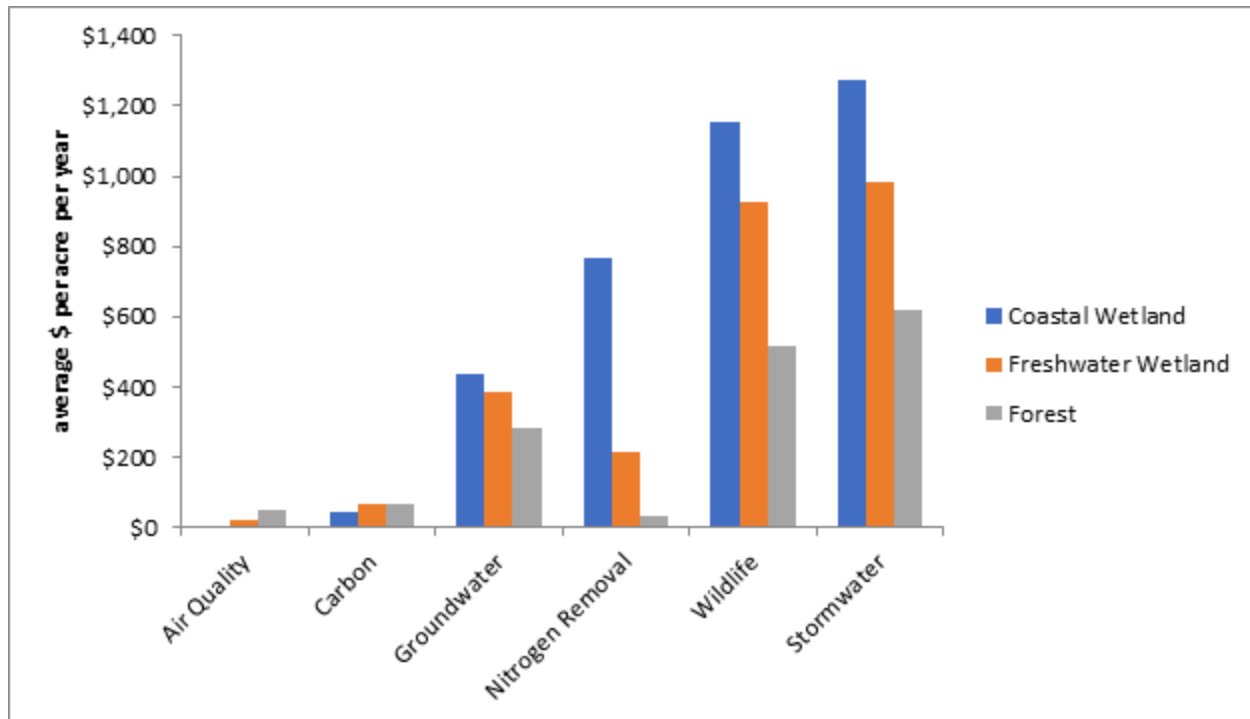


Figure 4. Ecosystem Service Non-Market Value in Maryland.

Enhancement Opportunities

Banking for forests and wetlands could prioritize habitat types that have high potential for carbon sequestration, like forested wetlands or deciduous forests.

Funding

See “Challenges.”

Challenges

Without a cap and trade program on the national level, the voluntary carbon market in the United States has largely failed. Working within the boundaries of currently functioning ecosystem marketplaces for wetlands, forests and habitat presents limited opportunities for generating net carbon reductions. RGGI does allow for carbon emissions offsets to be generated through forest planting or management activities, but at this time there have not been any offsets generated in this way because they are not currently cost competitive with emission allowances on the RGGI market. Greater investment in conservation and restoration of natural lands, and projects that promote co-benefits, will create a positive trend in ecosystem services provided, including the sequestration of carbon.

Relevant Information

RESI’s 2015 Study estimated that the Ecosystem Markets program, once fully operational, would support a total of 1,758 jobs by 2020, \$423,431,394 in net economic output and \$358,169,556 in wages over the lifetime of the program. Chapter 6 and Appendix K the 2015 GGRA Update provides more detail on the RESI studies and the job creation and economic benefits associated with this program.

Adaptation, Education, and Outreach

Even as the state moves forward with actions that will reduce greenhouse gasses, results may take a long time to be realized and there will still be climate impacts in the near future. Therefore, adaptation, together with mitigation, is necessary to address climate change.

Climate change will affect Maryland in a variety of ways. More obvious impacts could include an increased risk for extreme events such as drought, storms, flooding and forest fires; more heat-related stress; the spread of existing or new vector-borne diseases; and increased erosion, saltwater intrusion and inundation of low-lying areas along the state's shoreline and coast. In many cases, Maryland is experiencing these problems today. Climate change raises the stakes in managing these problems by increasing the frequency, intensity, extent and magnitude of these problems. To address these impacts, the department is working on a wide range of solutions for reducing Maryland's Climate Change vulnerability.

1. Practice and Place

Water Quality and Climate Change Resiliency Portfolio: Maryland works to restore the Chesapeake Bay and improve its environmental and economic resilience to a changing climate. Many of the actions needed to achieve these objectives are similar. Yet, many practitioners do not coordinate these actions as much as they could, or should, to maximize benefits to both. This effort identifies a long term portfolio of natural infrastructure projects that optimize water quality, living resources, GHG reduction, and other environmental benefits. Moreover, this effort reduces the risks posed by a changing climate to the commercial economies and recreational opportunities essential to Maryland's working coast. Having a pipeline of identified projects better prepares Maryland and its communities to build climate resilience by taking advantage of existing and emerging funding opportunities that promote the use of natural infrastructure. The State has identified potential funding opportunities

- **Innovative Technology Fund:** Expand the scope of eligible techniques and technologies to include consideration of climate aspects of Innovative Technology Fund project proposals. The State will invest in the research, development, and commercialization of solutions addressing climate mitigation to help accelerate the adoption of climate resiliency and GHG mitigation
- **Chesapeake and Atlantic Coastal Bays Trust Fund:** In addition to forests, wetlands are known to be very efficient at sequestering carbon. The state is planting forested stream buffers and pursuing the creation, protection and restoration of wetlands to promote carbon sequestration through several means including the Natural Filters Program, which restores wetlands and buffers on state and public lands to meet water quality goals and is

provided through the Chesapeake and Atlantic Coastal Bays Trust Fund. Projects such as the Pocomoke River restoration encourages broader riparian buffers along stream corridors to allow for channel migration resulting from increased precipitation.

Coast Smart Council Assessment and Certificate: The Maryland Coast Smart Council created a Coast Smart Assessment and Certificate to help Maryland state agencies and others understand and apply the Coast Smart Construction Program guidelines for various phases of their projects to prevent or minimize the future impacts of coastal and riverine flooding, storm surge and sea level rise.

Community Resilience Grants/Resiliency through Restoration: The department continued management of the Resiliency through Restoration Initiative, which leverages federal dollars with funds from the State capital budget. The short term goal of the Initiative is to demonstrate how natural and nature-based features can be integrated into local resilience planning and help protect communities and economies from climate change impacts. This goal will be reached through the implementation and tracking of at least 15 nature-based projects that address coastal, stormwater and floodplain impacts. Projects funded in 2018 also included risk reduction planning in Annapolis, Laurel, Talbot, Berlin, Charlestown, Hebron, and Cecil County and implementation projects in Anne Arundel, Talbot, and Worcester counties. Six projects were selected via the department's competitive Community Resilience Grant solicitation and were approved by the BPW. The department worked with local governments and nonprofits in four jurisdictions to begin design of the selected shoreline, stormwater and wetland enhancement projects. Additionally, CBNERR developed a monitoring protocol to assist in project monitoring and performance tracking. These efforts complement six ongoing design projects from 2017. In 2019, four additional projects were selected via the department's competitive Grants Gateway solicitation and were approved by the Board of Public Works. Projects were selected to expand the suite of resiliency practices by integrating dredged material and addressing precipitation-induced flooding. The department worked with local governments and nonprofits in four jurisdictions to begin design of the selected shoreline, stream connectivity, urban flooding and beneficial use projects. Through these projects, the department is helping Maryland communities become more resilient to flood risks, and enhance the protection and management of the state's resources including the bay and the ocean. This work continues a decade-long effort to provide support to local communities to assess risk, plan risk-reduction efforts and implement projects.

Implementation of projects to address resilience needs: Through the Chesapeake and Atlantic Coastal Bays Trust Fund, the department supported a series of bioretention projects in Oxford aimed at reducing local flooding and improving bay water quality. The project integrates two new substantial bioretention areas, and expands and improves existing bioretention areas in order to increase stormwater retention capacity, improve water quality, and increase coastal resiliency for a critical area of the community. Bioretention projects have been identified in federal and state vulnerability studies as a recommended best management practice both for water quality improvement and for tidal flooding resiliency. This project has been designed to allow for the incorporation of additional retention areas as needed in the future and eventually improvements

to the critical state road connection through town, allowing the town to continue to address and accommodate long-term sea level rise predictions.

Resiliency through Restoration Monitoring: In 2018, the Chesapeake Bay National Estuarine Research Reserve developed monitoring protocols to track the effectiveness and adaptive capacity of restoration projects designed to enhance community resilience to the impacts of climate change. The department tested protocols in 2018 and 2019 at a site in Somerset County. Findings will support adaptive management activities at a local scale and inform the design and implementation of future restoration projects.

Resiliency and Land Conservation: The department updated its Stateside Program Open Space scorecard to evaluate potential acquisition of properties for their coastal community resilience to climate change benefits. These benefits are provided by areas along the shoreline where natural habitats, such as marshes and coastal forests, have the potential to reduce the impact of coastal hazards to the adjacent coastal communities by dampening waves, stabilizing sediment and absorbing water. This recent enhancement complements existing land conservation criteria that avoids conserving lands that will be inundated by sea-level rise and targets adaptation areas important for wetland migration. The Stateside Program Open Space scorecard provides the ecological, resiliency and management justification that Maryland's Board of Public Works relies upon to approve funding for land conservation.

Maryland's Parcel Evaluation Tool: As a compliment to the Stateside Program Open Space scorecard, the department also developed a public-facing, web-mapping tool which allows for rapid valuation and comparison of parcel level ecological benefits and ecosystem services provided by Maryland's natural resources. The Parcel Evaluation Tool - accessible through the Maryland Greenprint Map - can be used to support stateside land conservation as well as to support the activities of external conservation partners. The tool generates an instant report, which includes an Ecological Benefits Assessment and an Ecosystem Service Assessment. Among the Ecological Benefits assessed are the Coastal Community Resiliency and Future Wetland Habitat scores. The Coast Community Resiliency score describes the potential of a parcel's existing natural habitats, such as marshes and coastal forests, to reduce the impact of coastal hazards to adjacent coastal communities. The Future Wetland Habitat score identifies areas important for inland wetland migration resulting from sea level rise that will support high value coastal habitats of the future. Among the Ecosystem Services assessed are the parcel-level biophysical and economic values of annual Net Carbon Sequestration in forests and wetlands. Carbon sequestration directly offsets carbon emission within the state of Maryland and represents a critical component to the GGRA workplan. This component of the tool allows for identification and conservation of natural habitats providing high carbon sequestration benefits.

Patapsco Valley State Park Resiliency Project: The department, working with the University of Maryland Center for Disaster Resilience alongside the Maryland Park Service and Patapsco Valley State Park staff in Baltimore County, conducted an assessment of watershed issues driving inland flooding events following flashy and intense precipitation events at the Glen Artney area of the park. The project team is working on completing watershed or engineering studies,

developing management strategies and/or engaging the surrounding community to address the problem to reduce future impacts.

Beneficial Use of Dredged Material: The beneficial use of dredged material increases coastal shoreline and community resilience while dramatically reducing the financial costs of dredged material disposal and coastal restoration projects. To support these efforts, the department launched a webpage in 2019 detailing the department's work related to the beneficial use of dredged material. Chesapeake and Coastal Service in partnership with Mahan Rykiel Associates Inc. developed a mapping tool, "Beneficial Use: Identifying Locations for Dredge (BUILD)," to enable proactive identification of beneficial use opportunities. BUILD accompanied by a user manual and story map was made available to the public via the Maryland Coastal Atlas in 2019.

Clean and Resilient Marinas: The Maryland Clean Marina Initiative continues to provide extensive climate change and severe weather resiliency information to marinas via workshops, on line, and via newsletters. Updated resources related to adaptation and resiliency have also been added to the Maryland Clean Marina website:

<http://dnr.maryland.gov/boating/Pages/Hurricane-Storm-Preparations.aspx>

2. Community Engagement and Communication

Nature Cities Forum: On March 26th 2019 the department co-hosted the NatureCity Forum, a full day exploration of green infrastructure and community health for designers, practitioners, planners and advocates. The day included local, regional and national case studies, as well as tools and research on the planning and implementation of green infrastructure for climate resiliency, community building, human health and ecological benefit. This event was attended by more than 100 participants from across the region and was co-hosted by the Greater Baltimore Wilderness Coalition, Project Green Classrooms, Maryland Recreation and Parks Association, Montgomery County Parks and Recreation, Brookside Gardens, Maryland Department of Natural Resources, Chesapeake Bay Trust, U.S. Fish and Wildlife Service, National Wildlife Federation and Blue Water Baltimore.

Shoring Up Resiliency Through Education (SURE): This project aims to support Somerset County Public Schools in addressing regional vulnerability to climate impacts and community resilience through understanding how environment, science and cultural heritage work together to strengthen a community. Students in fifth, seventh and ninth grades experience, study and understand trends in local conditions such as weather and water quality that affect the natural resources upon which much of their local economy depends. Participating teachers received professional development and have begun to write lessons to support this project. Partners include the Maryland Department of Health and Somerset County Public Schools.

Cultivating Community Flood Resilience: Practitioner Roundtable Discussion: In January 2018 the department facilitated a round-table discussion for a group of practitioners focused on reducing flood impacts in Maryland communities. Practitioners included representatives from University of Maryland, Maryland Sea Grant Extension; The Nature Conservancy; the Maryland Department of Natural Resources; Maryland Historical Trust; and the National Wildlife

Federation. The purpose was to give an overview of the methodologies used for the Integrated Coastal Resilience Assessment on the Deal Island Peninsula to the group. Additionally, there were peer-to-peer discussions about different ways each of the organizations is working with communities on reducing flood risk and discussions on opportunities to work more collaboratively on this issue. This roundtable was an extension of the Deal Island Peninsula Project.

Maryland's Climate Leadership Academy: Maryland's Climate Leadership Academy is the nation's first state-sponsored institution providing continuing education and executive training programs specifically designed for state and local government officials, infrastructure executives and business leaders. Since the inception, the Maryland Climate Leadership Academy has trained over 400 professionals in the Certified Climate Change Professional (CC-P) course with close to 40 individuals so far receiving their CC-P Certification. The Academy supports the work of the Maryland Commission on Climate Change, serving as a tool that establishes a community of climate smart local government and infrastructure leaders. The Academy's programs and planning efforts are informed by an advisory council that includes senior leadership from numerous Maryland state agencies in order to ensure continuity and coordination with the Commission. The Academy's programming is coordinated with universities, community colleges, and other convening organizations to offer training programs statewide. The Academy has expanded beyond CC-P training to offer sector specific training on climate competencies. The academy continues to advance professional competencies in integrating climate change into decision-making across sectors and occupations helping to ensure Maryland is able to effectively integrate climate change considerations into their operations and activities.

Installation of Tide Gauges in Somerset and Talbot County: Department staff facilitated with Maryland Emergency Management Agency, US Geological Survey, Somerset and Talbot Counties on the installation of tide gauges in Crisfield and Claiborne. The gauges will become part of the network of gauges throughout the bay measuring water levels. The two new gauges fill a data gap and will allow for more local and accurate reporting of water levels ongoing and during flood events. The gauges will be maintained by the US Geological Survey and by the end of 2018 will be accessible on the National Weather Service Advanced Hydrologic Prediction Service website.

Maryland Flood Tabletop Exercise: The Maryland Department of the Environment and Federal Emergency Management Agency Region III in collaboration with department staff hosted a one day training on April 11, 2018. The purpose of the workshop was to see how state and local partners can work together before, during and after a significant flood event. As part of the workshop a situational manual was developed to accompany the training. There were over 75 participants from state and local jurisdictions participated.

Maryland Marine Debris Emergency Response Plan: The National Oceanic and Atmospheric Administration's Marine Debris Program staff led the planning and preparation of an emergency marine debris response plan for Maryland. The plan's goal is to improve preparedness for response and recovery operations following an acute waterway debris incident in coastal

Maryland. As severe weather events become more frequent, the plan will allow better communication and clarify responsibilities and capabilities among agencies.

Building Risk Communication Training: In partnership with National Oceanic and Atmospheric Administration and the Eastern Shore Land Conservancy, the department hosted a 2-day training on June 27 and 28, 2018, with the goal for participants to have a better understanding of how people respond to risk and how to develop new communication skills for discussing hazards in their community. State, local and non-governmental organization partners participated.

Aquatic Resources Education: The department incorporated climate change into a variety of education efforts including Project WET (Water Education for Teachers) Educator workshops, WOW! The Wonder of Wetland Workshops and Invasive Species Workshops that were delivered in 2018 and 2019. Climate issues are currently being worked into all professional development for educators given by Aquatic Resources Education staff.

Maryland Forest Service: The Maryland Forest Service with other partners - including the US Forest Service and the University of Maryland Center for Environmental Science and Extension - released topic-related fact sheets and technical guidance on woodland and climate change stewardship principles. The Forest Action Plan for 2016-2020 now includes the strategy 'Make Landscapes More Resilient to Climate Change' to help guide forest management on state and public lands. http://dnr.maryland.gov/forests/Documents/2015_DRAFT_percent20_ForestStrategyUpdate.pdf
http://extension.umd.edu/sites/extension.umd.edu/files/docs/programs/woodland-steward/MD_Climate_Adaptation_Guide_for_Forest_Landowners_2013.pdf

Maryland Park Service Education Programming: The Maryland Park Service incorporated climate change education into its programs, including training and awareness for staff. For example, park rangers attended a day long Climate Change Academy in 2015 hosted by MADE CLEAR (Maryland and Delaware Climate Change Education, Assessment and Research). In addition, the Chesapeake and Coastal Service provided all park managers with a Climate Change awareness training. Climate change themes are incorporated in Meaningful Watershed Education Experiences programming, Scales and Tales outreach and nature centers in state parks, which reach tens of thousands of students and visitors.

Communicating Risk to the Public: Department staff engaged audiences throughout the year regarding climate communication, including during the Eastern Shore Land Conservancy's Culture and Climate Change Conference where staff presented Communicating About Climate Change With Confidence to approximately 125 individuals. Staff also participated in conferences for teachers, including the Maryland Association for Environmental and Outdoor Education (MAEOE) where staff presented lessons for understanding climate and Next Generation Science Standards. Partners included the National Oceanic and Atmospheric Administration, Audubon Maryland-DC and Partners Advancing Climate Change Education.

3. Advancing the Science

Climate Sensitivity Study: The department, in partnership with National Centers for Coastal Ocean Science (NCCOS), University of Maryland Center for Environmental Science, Chesapeake Environmental Communications and the Chesapeake Bay National Estuarine Research Reserves (NERR), analyzed climate data from the NERR locations and the National Weather Service. By examining 114 years of meteorological data, the team found clear evidence that physical climate changes are well underway and that species and habitats are responding to those changes. This study, provides localized impact data which can inform how we manage our natural areas on a watershed scale. For more information, visit:

<http://www.chesapeakeedata.com/changingchesapeake/>

Thin-layer Sediment Placement: Evaluating an Adaptation Strategy to Enhance Coastal Marsh Resilience: The department is a participating investigator in a National Estuarine Research Reserve Science Collaborative Grant aimed at gathering data to inform thin-layer placement as a restoration technique to promote marsh resilience in the face of sea level rise. Through this project, replicated restoration experiments are being conducted at several reserve sites across the nation, with the purpose of examining the effectiveness of thin-layer sediment placement as a marsh adaptation strategy. Novel aspects of the project include the broad distribution of sites, the examination of the effectiveness of thin-layer sediment placement at different marsh elevations, a standardized monitoring protocol and the incorporation of biochar (carbon material produced through the conversion of biomass in an oxygen limited environment) to improve soils and plant health.

CO2 Sequestration Documentation: The Maryland Geological Survey invested in research and documentation regarding geologic CO2 sequestration in multiple geologic avenues including: offshore injection, saline aquifer injection and rift basin injection. All of these vary in the manner of sequestration as some are structural sequestration and some of these are mineral re-crystallization sequestration. There is limited outreach occurring on these projects; however, these projects are coordinated with 11 different states, several private companies and two different federal agencies (United States Geological Survey and Department Of Energy). This group has partnered with several different energy companies and academic institutions (Core Energy and University of Kentucky) to demonstrate CO2 injection and sequestration.

Wave Attenuation Monitoring: The department partnered with George Mason University and The Nature Conservancy on a small-scale site-level monitoring effort to measure the hydrodynamics of storm surge and waves within a tidal marsh in Somerset County, and quantify the marsh's existing protective services. Wave, water level, and current sensors were deployed May through December 2018, with analysis ongoing in 2019. This study expands on previous monitoring conducted in Virginia and represents a first step in improving the understanding of the resiliency benefits of natural and nature-based features in Maryland.

Resource Assessment Service Monitoring: Based on climate change projections, Maryland's streams are likely to become warmer and the flows are likely to become more extreme. Some coastal streams could also become inundated as a result of sea level rise. These changes may

alter the ecology, water quality and physical habitat of streams. The Maryland Biological Stream Survey (MBSS) tracks trends in factors such as aquatic species distributions, water temperature and erosion that are indicators of potential climate change influences on Maryland's streams. Based on temperature and species distribution information, the MBSS has also specifically identified stream animals that prefer cold water and, as a result, may be particularly sensitive to stream temperature increases. Detailed stream temperature information from the MBSS may also help identify streams with particularly cold water and thus are likely to be resilient to temperature increases.

In addition to representative sampling of Maryland's streams, the MBSS has been monitoring 29 "Sentinel" streams since 2000 to specifically examine for potential influences of factors such as climate and weather on Maryland's stream ecology, temperature, water quality and physical habitat. For more information -

<http://dnr.maryland.gov/streams/Publications/2014SentinelSiteReportWEB.pdf>

Since 2000, along with biological, water quality and habitat data, the MBSS has deployed data loggers in thousands of streams that measure the water temperature throughout the summer. These data are useful for determining habitat for stream biota and for tracking stream temperature conditions. From 2014 – 2018 the MBSS returned to about 200 streams where initial sampling occurred 14 years ago to help represent the condition of Maryland's streams at that time. The data from this repeated survey will be used to evaluate change over time in the factors measured. For more information - <http://dnr.maryland.gov/streams/Pages/round4.aspx>

The Maryland Biological Stream Survey also participated in EPA's Regional Monitoring Network (RMN) and assisted the Environmental Protection Agency with determining temperature sampling protocols for this network. The goal of the RMN project is to partner with state agencies and select stream sites that can be sampled to establish a long-term record of biological and physical parameters that can be used to assess the vulnerability and response of these streams to climate change. For more information -

<https://cfpub.epa.gov/ncea/global/recordisplay.cfm?deid=30797>

Since 1986, Maryland's ambient water quality monitoring program has measured water quality from more than 120 locations in Chesapeake Bay, Coastal Bays and non-tidal large rivers on a monthly basis. This sampling is used to determine trends in conditions for nutrients, temperature and other water quality-related factors that could be influenced by climate change. Benthic macroinvertebrate samples have also been collected from select large rivers and used to track biological changes over the more than 30-year period.

The department also partners with US Geological Survey for tracking stream and river flows throughout the state and the department measures stream flow in two streams where the Chesapeake and Atlantic Coastal Bays Trust Fund supports practices to improve pollution runoff.



Larry Hogan, Governor



Jeannie Haddaway-Riccio, Secretary

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