

Maryland Department of Natural Resources Climate Adaptation, Mitigation and Education 2018 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. 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 Response Working Group (ARWG), which recommends actions on preparedness from sea level rise and more intense storms.

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. 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

- 50,000 Forest Acres Managed in 2017 - 166 percent of yearly goal
- 2,000 Forest Acres Planted in 2017 - 100 percent of yearly goal
- Both Planting and Managing Forests on Track for 2020 Goal
- The Chesapeake and Atlantic Coastal Bays Trust Fund restored 149 acres of wetlands in 2017 and 1,879 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

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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 goals of this program are to improve sustainable forest management on 30,000 acres of private land annually and on 100 percent of state-owned resource lands 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 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.
- DNR's 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 include a planned 2,611 acres of timber harvests for FY18, that will be naturally regenerated.

Private Lands:

- Since 2006 we have implemented-
 - 247,769 acres of stewardship plans
 - 151,739 acres of sediment control

- 98,378 acres of forest stand improvements (eg., tree planting, timber stand improvements, wildlife habitat)
- Total of 497,886 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. Expected project completion: 2030.

Estimated Emission Reductions for CY17

- 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

<u>Calendar Year</u>	<u>Stewardship Plan⁽¹⁾</u>	<u>Sediment Control⁽¹⁾</u>	<u>State Forest Regeneration⁽²⁾</u>	<u>Timber Stand Improvement⁽¹⁾</u>	<u>Wildlife Habitat⁽¹⁾</u>	<u>Total Acres</u>
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	18,000.0	11,000.0	1,500.0	4,500.0	2,800.0	37,800.0
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	301,769.0	184,738.7	27,428.3	64,312.8	33,036.8	611,285.5
Average Annual	20,117.9	12,315.9	1,828.6	4,287.5	2,202.5	40,752.4
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	112 percent	112 percent	122 percent	95 percent	79 percent	108 percent
Estimated 2030 Target Annual Goal	20,000.0	12,000.0	1,600.0	4,000.0	2,000.0	39,600.0

(Red indicates projections)

From the Maryland Forest Service PMAS report where a calendar year is defined as Quarters 3 and 4 of the preceding year and Quarters 1 and 2 of the current Fiscal Year. For example, the number for 2006 represents the reported values from PMAS for Q3 and Q4 of 2006 and Q1 and Q2 of 2007.

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.

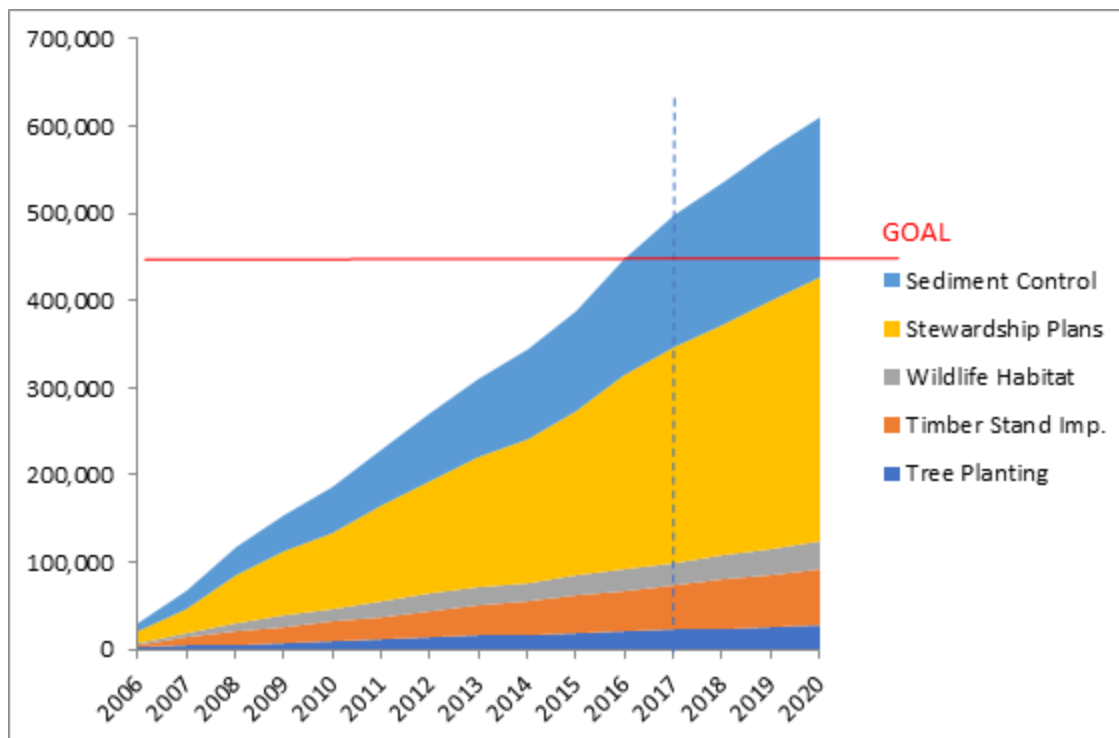


Figure 1: Managing Forests to Capture Carbon. The Maryland Department of Natural Resources is promoting sustainable forestry management practices in existing forests on public and private land through a suite of efforts, policies and programs.

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 is very variable from year to year (\$9,500 in FY17, \$94,500 in FY18 and \$205,700 in FY19) and identifying a way to make the funding allocation more reliable would aid in consistently providing cost-share to landowners for forest management activities. Removing barriers to accessing federal funds could also help forest landowners, particularly smaller landowners.

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 2017

On track with previous years, reductions totaled 0.10 MMtCO₂e for 2016.

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	100.0	400.0	100.0	1,400.0	2,000.0
	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	5,857.8	14,129.0	3,782.0	21,000.0	44,768.8
	Average Annual	390.5	772.2	252.1	1,400.0	2,984.6
	15 Year Target Goal	6,000.0	10,500.0	6,000.0	21,000.0	43,500.0
	Percent of Goal Obtained	98 percent	135 percent	63 percent	100 percent	103 percent
	Estimated 2030 Target Annual Goal	350.0	600.0	200.0	1,400.0	2,550.0

	(Red Indicates Projections)
(1).	From the Maryland Forest Service PMAS report where a calendar year is defined as Quarters 3 and 4 of the preceding year and Quarters 1 and 2 of the current Fiscal Year. For example, the number for 2006 represents the reported values from PMAS for Q3 and Q4 o
(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 percent of Sediment and Erosion Control permitted acres reported by counties are actually harvested and regenerated. Historically, the average is 1,400 acre/year

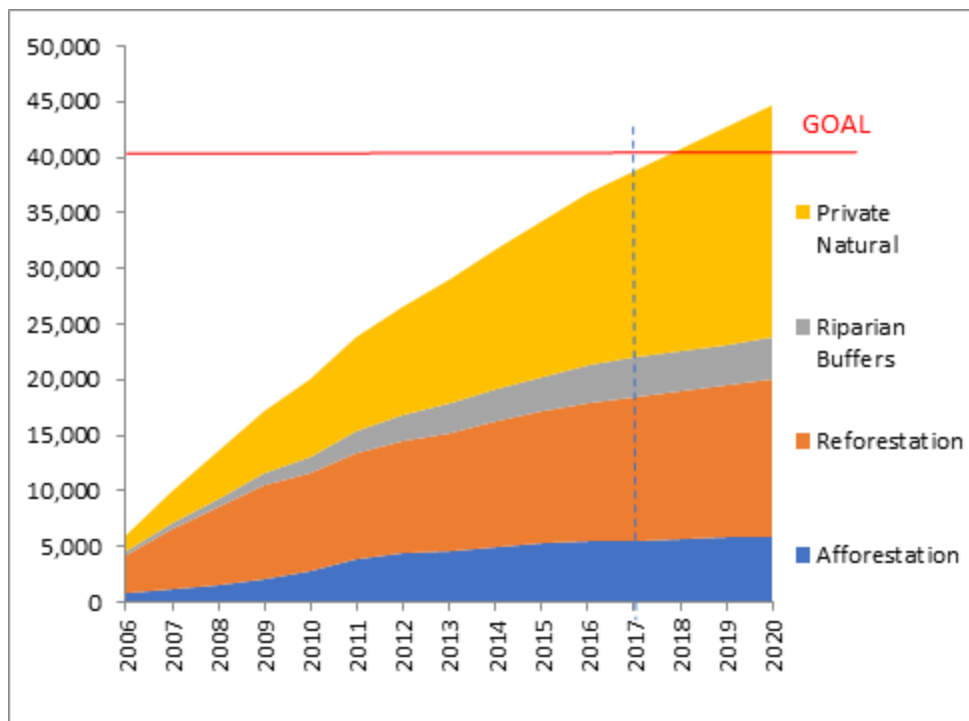


Figure 2 Planting Forests in Maryland.

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

Challenges

Identifying willing landowners to participate in tree planting programs, particularly given the difficult economic conditions for Maryland forestry activities.

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 2017:

The Natural Filters Program restored 149.4 acres of wetlands on state and public land and planted 56.17 acres of streamside forest buffers on state and public lands in 2017, 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 over 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 2017, 1,635 acres of wetlands have been restored and 924 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 2017, funded the restoration of 1,879 acres of wetlands and 1,184 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 2017, 505.6 acres of coastal wetlands have been restored by plugging existing drainage ditches to restore these drained wetlands.

Living Shorelines through the Shoreline Conservation Service: Between 2006 and 2017, 12.21 acres of Living Shoreline have been implemented.

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		
Total	29,385	531,802	12.21

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:

- Targeting 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 2017

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 ten 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. Governor Hogan provided funding for this initiative through the State Capital Budget. The department 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. Year one of the Initiative will lead to the design of six living shoreline and coastal restoration projects in five jurisdictions.

Coastal Wetlands Initiative (CWI): Funding for this initiative is typically acquired through a federally funded competitive grant process.

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.

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 greenhouse gas emissions. There are many end users that could potentially benefit from such a program, including Maryland's public schools which could employ wood heating and cooling; hospitals which could utilize wood as a primary heating/cooling source; municipalities which could utilize local fuel markets as a key component of their urban tree management programs; and all rural landowners who would have access to a wood fuel market.

The goal of this program is to develop policies that recognize wood as a preferred 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.

This program is no longer performing as designed.

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

- Maryland DNR is working with partners Maryland Environmental Service, Maryland Energy Administration, Maryland Department of Commerce and US Forest Service to facilitate installation of wood energy systems
- Maryland Energy Administration has temporarily discontinued offering grant opportunities supporting wood energy at commercial and institutional settings but could reinstate the program if adequate demand is demonstrated.

Estimated Emission Reductions for CY 2017

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.

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

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. Develop policy supporting thermal energy.
2. Recognize 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 provide 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 goals of this program are 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
 - 4,800 trees (48 acres) planted in 2016
- Marylanders Plant Trees/Private Nurseries

- Reimbursed coupons for 3,998 trees (39.9 acres) in 2016
- 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 2017 (total for this program and Planting Forests in Maryland).

Estimated Emission Reductions for CY 2017

Urban tree plantings are estimated to sequester 0.002 MMtCO₂e in 2017.

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

Year	Forest Conservation Act (FCA)⁽¹⁾	Reforestation 5-103⁽¹⁾	Tree-Mendous and 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	2,705	8,798	353,143
2017	265,050	8,388	12,545	285,983
2018	0	0	0	0
2019	0	0	0	0
2020	0	0	0	0
Total	3,918,195.0	543,259.0	192,393	4,653,847
Average Annual	261,213.0	36,217.3	12,826.2	310,256.5
15 Year Target Goal	N/A	N/A	N/A	N/A
Percent of Goal Obtained	N/A	N/A	N/A	N/A
Average of Last 3 Years (Rounded)	249,900.0	5,800.0	9,900.0	265,600.0
(1).	Assumes 450 trees planted/acre.			

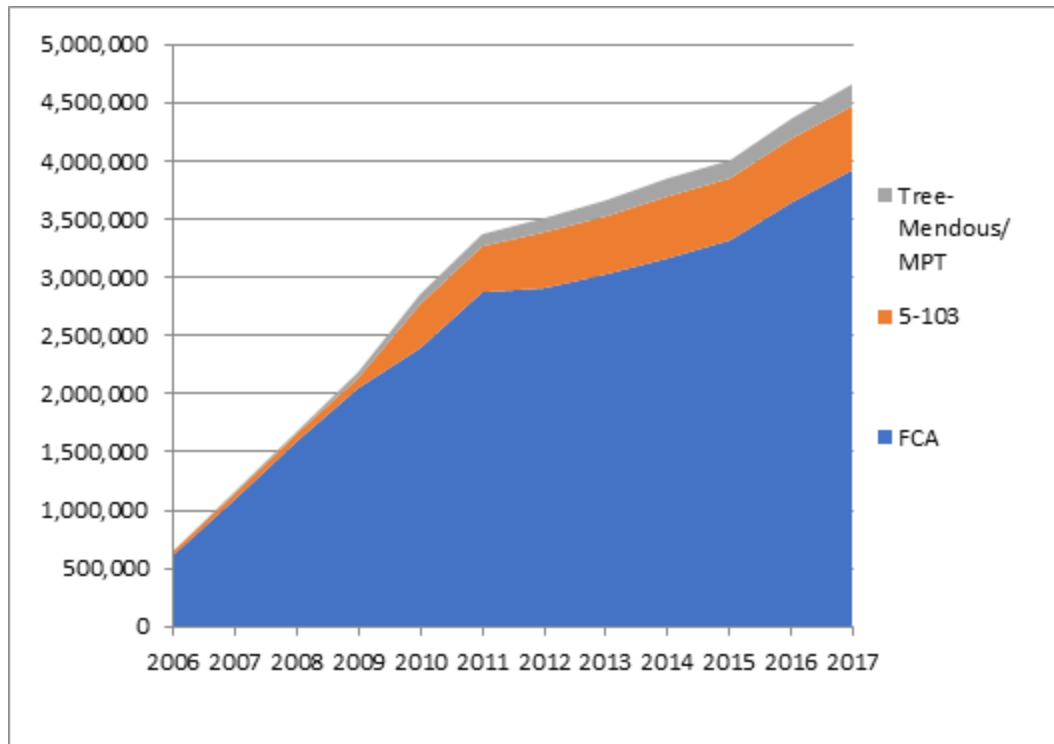


Figure 3. Increasing Urban Trees to Capture Carbon.

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 Spring of 2014, a pilot was done with 14 acres planted on 12 lots. In Spring of 2015, 100 acres were planted on 84 sites and in Spring of 2016, 60 acres were planted on 55 sites. All total, 174 acres were planted on 151 sites. 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 the use of the \$25 coupon. 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 fund 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 as it captures carbon at the source, transports it to the 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 to be available 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, but estimated larger in magnitude potential amount of storage is located offshore of Maryland.

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 include geologic characterization, capacity evaluations, injectability and risk analyses. This project will provide foundation knowledge and an assessment of potential for carbon sequestration offshore in the Baltimore Canyon Trough. Projected completion date is June 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.
- 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 is ongoing to assess the CO₂ structural and chemical storage within failed rift basins. The Gettysburg-Culpepper basin is being documented in depth due to its exposure and a comparison is being made with the Taylorsville basin. Projected completion date is December 2019.

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.
- The department is currently assessing the potential of utilizing black shales (e.g., Marcellus) as permanent sequestration locations as a logical reutilization of natural gas infrastructure.
- 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.

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 investigation focused on the CO₂ chemical adsorption capacity of this formation could best serve the Maryland electric power industry. The department is leveraging funds from

Battelle to analyze the exposed Gettysburg-Culpepper Basin as a proxy for the Taylorsville Basin. This study begun in 2016.

Funding

Most of the funding for Geological Carbon Sequestration is coming from the U.S. Department of Energy, organized and administered through Battelle. 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 25 percent at the generation site. This cost has decreased over the last 5 years by 5 percent. It is anticipated this will 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 programs and policies that could foster carbon market development. Maryland's Forest Conservation Act and Critical Area Act, for example, require mitigation for natural resource impacts resulting from land development. Mitigation banking is a market-based solution to address these mitigation requirements

The goal of this program is the establishment of ecosystem markets, creation of a tracking mechanism and the development of protocols to assess and quantify greenhouse gas 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 initiated 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 the State of Maryland. Spatial models for coastal ecosystem services have been completed and are available on Maryland GreenPrint (geodata.md.gov/greenprint/)
- The preliminary assessment for the State of Maryland estimates a total value of \$11 billion of benefits from natural lands provided every year (see figure).
- The Nontidal Wetlands Mitigation Banking legislation passed by the Maryland General Assembly in 2016 removes barriers to mitigation banking in Maryland, with the goal of reducing costs for meeting mitigation requirements in an ecologically beneficial way.
- Under the Forest Conservation Act (FCA), several counties in Maryland allow off-site mitigation for forest loss through purchasing credits in a forest bank. Over 2000 acres of forest loss have been mitigated in this way over the past 15 years.

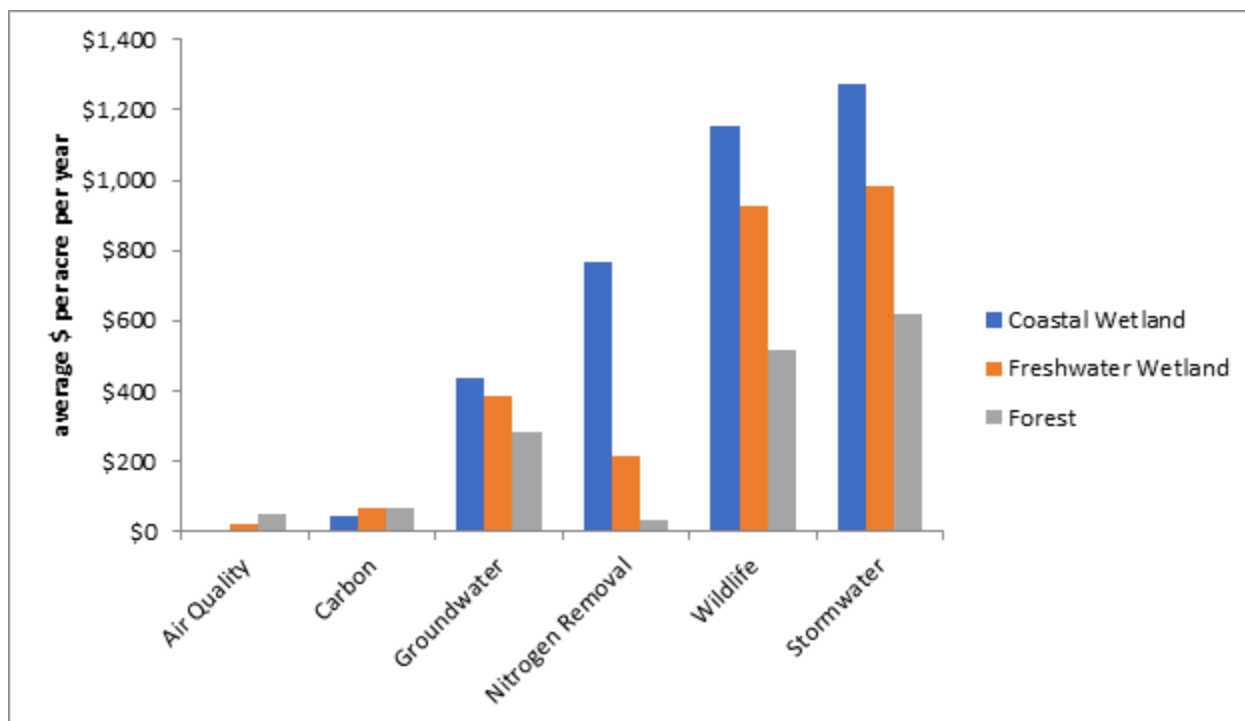


Figure 4. Ecosystem Service Non-Market Value in Maryland.

Enhancement Opportunities

As currently functioning, ecosystem markets in Maryland are not designed to meet the goals of climate change mitigation. Banking for forests and wetlands could prioritize habitat types that have high potential for carbon sequestration, like forested wetlands or deciduous forests. If

mitigation were to be required on more acreage than is impacted it is likely there will be net carbon sequestration.

Funding

Were the state to require, or exhibit preference for, forest and wetland mitigation activities or nutrient reduction best management practices with greater carbon sequestration potentials this may be more costly. If it proves to be cost effective when compared to other greenhouse gas reduction alternatives, the state could subsidize this additional cost. Results from the Accounting for Maryland's Ecosystem Services assessment indicate that investing in preservation or restoration of green infrastructure is often more cost effective than "grey" infrastructure alternatives, when factoring in the multiple benefits of green infrastructure, including sequestering carbon. This has potential implications for funding of various state programs.

Challenges

Without a cap and trade program on the national level, the voluntary carbon market in the United States has remained modest. Working within the boundaries of currently functioning ecosystem marketplaces for wetlands, forests and habitat presents limited opportunities for generating net carbon reductions. The Regional Greenhouse Gas Initiative (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

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 solicited and funded resilience projects in 2017 and 2018 through the Community Resilience Grant Program. The program leverages federal dollars with newly available state "Resiliency through Restoration" capital funding to promote and support comprehensive, holistic planning and implementation projects that address both water quality and quantity. Through these projects, the department is supporting Maryland community efforts to become more resilient to flood risks, work to ascertain that bay and ocean waters meet living resource and human needs and serve to enhance the protection and management of the state's resources. Projects funded in 2017 included risk reduction planning in Cambridge, Hyattsville and Calvert County and implementation projects in Baltimore City as well as Prince George's, St. Mary's, Somerset and Dorchester Counties. Projects funded in 2018 included risk reduction planning in Annapolis, Laurel, Oxford, Berlin, Charlestown, Hebron and Cecil County and implementation projects in Anne Arundel, Talbot and Worcester Counties.

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 aiming to reduce local flooding and improve 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 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 department is currently evaluating and developing policies and processes to proactively identify environmentally and economically sound beneficial use of dredged material practices to improve coastal resiliency. Through the development of a

mapping tool - Beneficial Use: Identifying Locations for Dredge (BUILD) - project managers will be able to quickly identify beneficial use opportunities. To enhance BUILD, the department partnered with Mahan Rykiel Associates Inc. to develop a beneficial use site suitability model that prioritizes placement of dredged material based on societal and environmental coastal resiliency needs.

Clean and Resilient Marinas: During 2018 Maryland Clean Marina workshops (held in Abingdon, Annapolis and Cambridge), the department provided to participants extensive climate change and severe weather resiliency information. Speakers specializing in marine insurance provided data about massive losses to marinas from the hurricanes in the south in 2017. The speakers also reviewed typical losses during storms in Maryland. 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. This project is in development. 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. The Academy will support 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. Through extensive partnerships and guidance from a body of Maryland leaders and nationally recognized experts, the Academy's programming will be coordinated with universities and community colleges throughout the state, as well as other convening organizations, to deliver training programs statewide. The Academy will advance professional competencies in integrating climate change into decision-making across sectors and occupations and will help ensure that decision-makers across sectors and Maryland communities are appropriately trained and educated to successfully integrate climate change 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.

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 2017 and 2018.

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 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.chesapeakeclimate.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 (USGS and DOE). This group has partnered with several different energy companies and academic institutions (Core Energy and University of Kentucky) to demonstrate CO2 injection and sequestration.

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 the 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, Acting Secretary

Elliott Campbell, PhD
Director, Center for Economic and Social Science
410-260-8702

Chesapeake and Coastal Service
580 Taylor Ave., D-2
Annapolis, MD 21401

Toll free in Maryland: 877-620-8367
Out of state call: 410-260-8702
TTY Users call via the MD Relay 711

dnr.maryland.gov

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