Forestry and Land Use Sector Modeling (draft)

Evaluating Maryland’s natural carbon sequestration potential

Tree and Forest Carbon

Potential Pathways for Growing the Forest Carbon Sink

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Coastal Wetlands and SAV

Blue Carbon: Wetland Area and Carbon Change in 2030 and 2045

Maryland Department of Natural Resources

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Summary

A set of new modeling scenarios for growing the state's forest carbon sink thru 2031 and 2045 was developed in consultation with DNR) and MDE using the state's new remote sensing based forest carbon monitoring system (MDE 2022a, 2022b and 2023). In total, three versions of four scenarios were evaluated. Each scenario considered the potential afforestation/reforestation of a specified area of land, ranging from 12,000-400,000 acres. The "Full" statewide potential for afforestation/reforestation was included as an upper bound only for context. For each scenario, the afforestation/reforestation area was evenly phased in annually throughout its respective planting period, and the associated statewide total forest carbon sequestration rate was quantified.

Method

The carbon sink potential of afforestation/reforestation hinges on several factors, including the area planted, its geographical location, timing, and associated environmental conditions. Here, we estimated the net forest carbon removal rate using the state's new remote sensing based forest carbon monitoring system. More specifically, we used the Ecosystem Demography (ED) model (Hurtt et al. 1998, Moorcroft et al. 2001). The latest version of ED (v3) has been globally calibrated, validated, and incorporated into NASA's Carbon Monitoring System (Hurtt et al. 2019, Ma et al. 2021, 2022 and 2023). Inputs to the model for Maryland included air temperature, precipitation, air humidity from NASA Daymet and MERRA2 reanalysis datasets (Thornton et al. 2016, Gelaro et al. 2017), CO_2 concentration from NOAA CarbonTracker, soil hydraulic properties (Chaney et al. 2016). Using this model and inputs, geospatial estimates of potential future carbon sequestration rate as a function of time were quantified for each scenario.

For each scenario, three methodological versions were explored, each differing in the complexity of underlying modeling assumptions.

- Version 1 used a constant carbon sequestration rate for each unit of planting area, both spatially and temporally.
- Version 2 used variable carbon sequestration rate over time accounting for the effects of forest aging.
- Version 3 used variable carbon sequestration rate over space and time accounting for both spatial differences in potential growth rates and temporal effects of forest aging. This version utilized spatial maps of feasible plantable areas to be considered and resulted in a range of values representing different options for the phasing of planting locations over time.

For Version 3, a map delineating feasible plantable areas was employed in the modeling analyses. This map was generated by combining the NASA CMS 30m high-resolution tree canopy cover map with the USGS NLCD land cover map. In this map, plantable areas are the non-tree fraction of 30 m grids that are categorized as developed-open spaced, pasture, and cropland in NLCD land cover data (Figure 1).

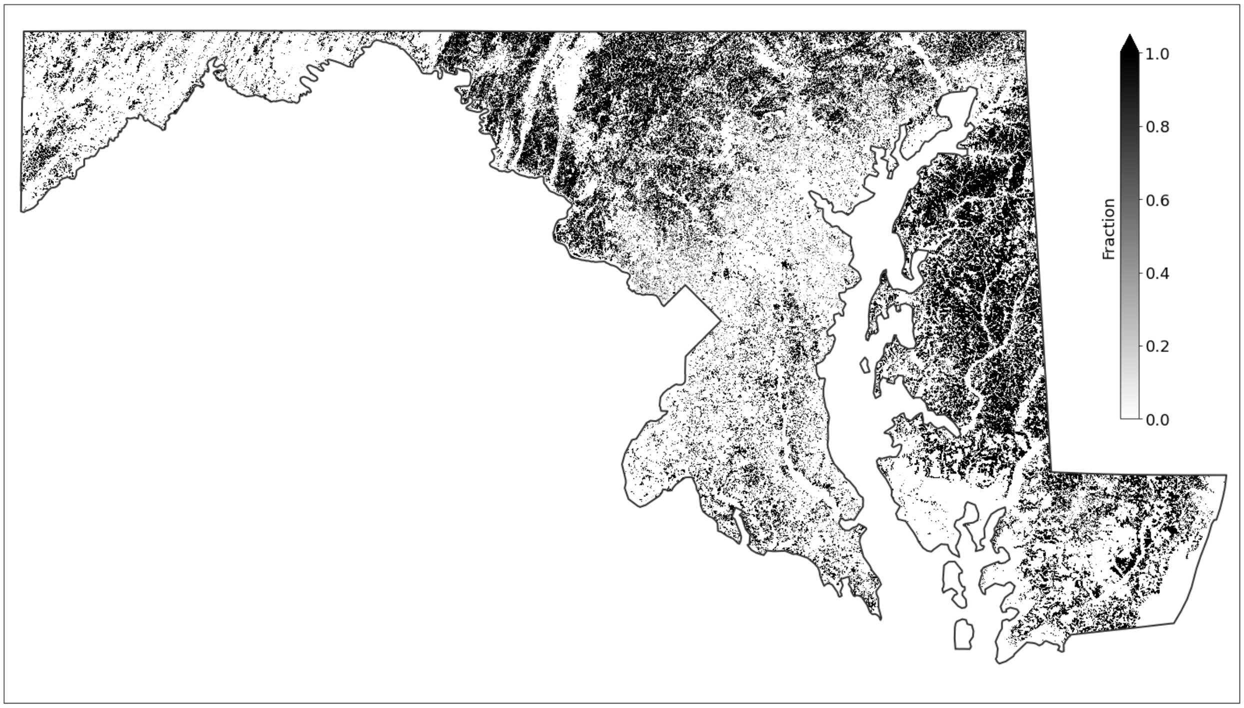

Figure 1. A map of feasible plantable area derived by combining NASA CMS 30m tree canopy cover and USGS NLCD land cover.

Results

The state of Maryland has potential to store additional carbon in forests through afforestation/reforestation activities thru 2031, 2045, and beyond. Table 1 provides a summary of the afforestation/reforestation scenarios considered and their and corresponding estimates of their projected statewide carbon removal in 2031 and 2045 specifically. Figures 2-4 provide quantitative estimates for each scenario annually 2021-2100.

Annual forest carbon sequestration on land ranged from 0.013 - 0.501 MMT CO_2e/yr in 2031, and 0.-1.995 MMT CO_2e/yr in 2045, across all scenarios and model versions (Table 1). The 5M Tree scenario resulted in an estimated 12,000 acres planted and corresponding 0.015-0.051 MMT CO_2e/yr in 2031, and 0.039-0.067 MMT CO_2e/yr in 2045, depending on model version. The 100K scenario resulted in an estimated 100,000 acres planted and corresponding 0.042-0.127 MMT CO_2e/yr in 2031 and 0.370-0.422 MMT CO_2e/yr in 2045. The 200K scenario resulted in an estimated 200,000 acres planted and corresponding 0.013-0.264 MMT CO_2e/yr in 2031, and 0.118-1.017 MMT CO_2e/yr in 2045. The 400K scenario resulted in an estimated 400,000 acres planted and corresponding 0.031-0.501 MMT CO$_2$e/yr in 2031, and 0.291-1.995 MMT CO$_2$e/yr in 2045. For context, the full statewide potential was estimated to be 0.048-0.725 in 2031 and 0.474-2.797 MMT CO$_2$e/yr in 2045.

Scenario Name	Area (x1000 acres)	Planting Period	2031			2045		
			v1	v2	v3	v1	v2	v3
5M Trees[1]	12	2021-2030	-0.048	-0.031	[-0.051, -0.015]	-0.048	-0.057	[-0.067, -0.039]
100K[2]	100	2024-2045	-0.127	-0.056	[-0.101, -0.042]	-0.382	-0.367	[-0.422, -0.370]
200k[2]	200	2024-2045	-0.255	-0.112	[-0.264, -0.013]	-0.764	-0.735	[-1.017, -0.118]
400k[2]	400	2024-2045	-0.509	-0.225	[-0.501, -0.031]	-1.527	-1.469	[-1.995, -0.291]
Full[2]	1992	2024-2100	-0.725	-0.320	[-0.688, -0.048]	-2.174	-2.091	[-2.797, -0.474]

Table 1. Summary of planting scenarios considered in modeling analysis, including planting areas (thousand acres), planting period, and annual carbon sequestration (MMT CO2e/yr) (vegetation + soil) in the years of 2031 and 2045. The 'Full' case includes all available land and is provided only as an upper bound for context. Units for annual carbon sequestration are negative for atmosphere reference. [1] 5 Million Tree initiative [2] Total acres of planting area.

Over the entire interval 2021-2100, model estimates of annual forest carbon sequestration potential increased with scenario of planted area and time up to 2045 when additional planting was assumed to be completed, and either held constant or was projected to decline thereafter due to consideration of tree aging (Figures 2-4).

Figure 2 presents the model results assuming constant carbon sequestration rate for each unit of planting area, both spatially and temporally (Version 1). Scenarios of annual forest carbon sequestration in this case peak in 2045, when new planting is assumed to be complete, and held constant thereafter due to assumption of constant sequestration rate. Estimates of statewide potential continue to increase linearly as planting is assumed to continue thru end of century.

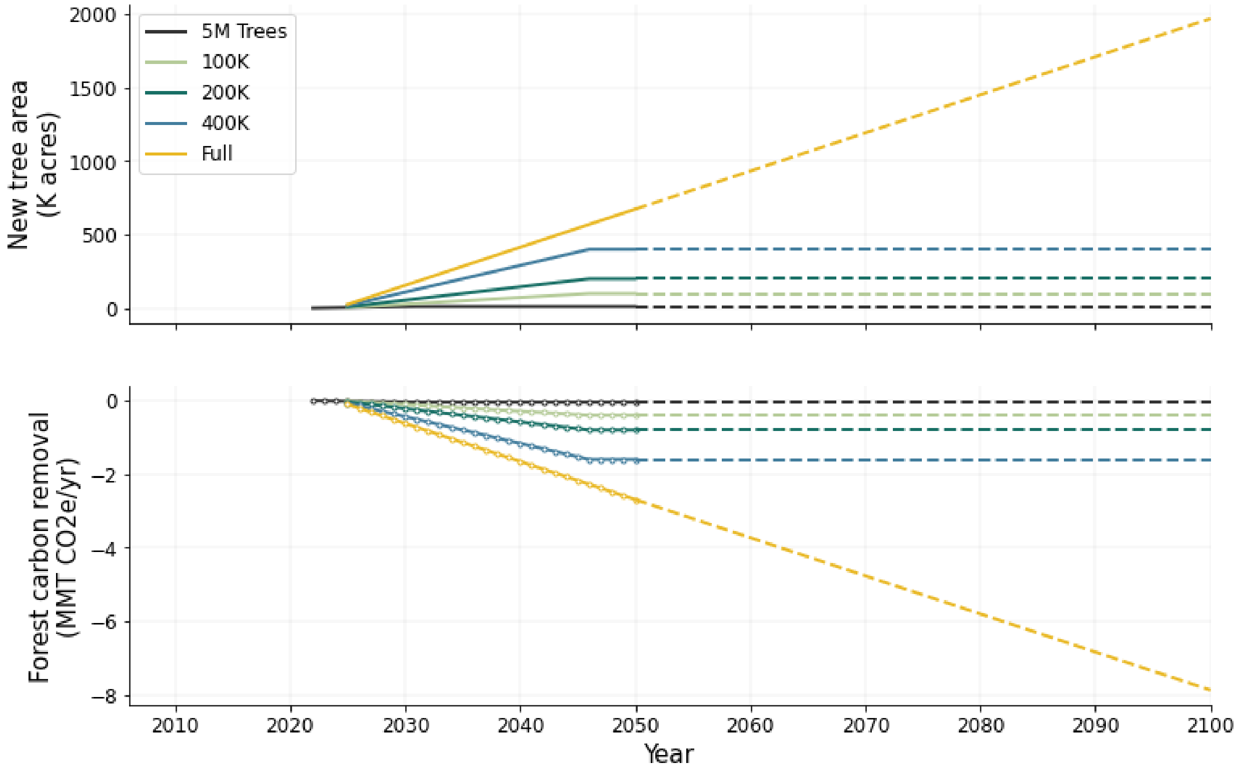

Figure 2. Planting scenarios and corresponding estimates of forest carbon removal- Version 1. (Top panel) Scenarios for new tree area. (Bottom panel) Forest carbon removal. Units for annual carbon sequestration are negative for atmosphere reference.

Figure 3 presents the model results assuming variable carbon sequestration rate over time accounting for the effects of forest aging (version 2). Scenarios of annual forest carbon sequestration potential peak somewhat after 2045, when new planting is assumed to be complete due to delayed maturity, and decline thereafter due to aging. Estimates of statewide potential carbon sequestration continue to increase non-linearly as planting is assumed to continue thru end of century and the effects of aging slow net carbon uptake.

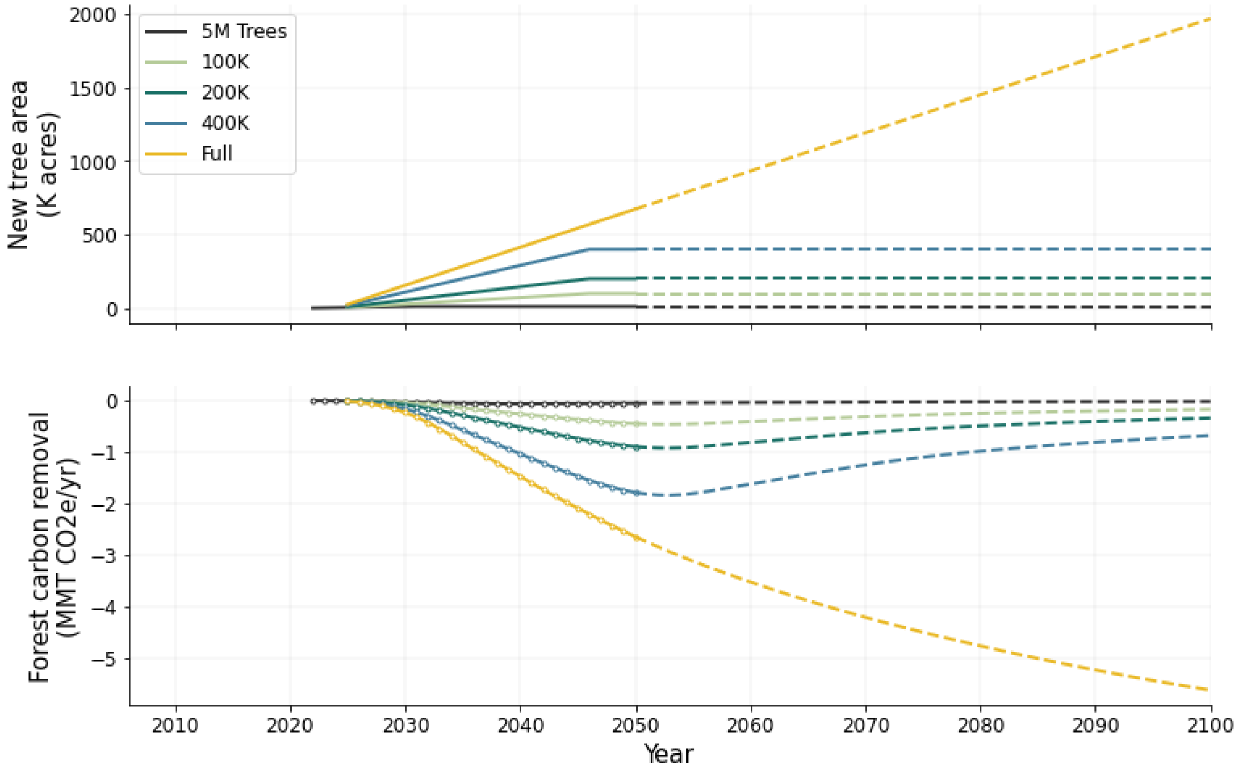

Figure 3. Planting scenarios and corresponding estimates of forest carbon removal- Version 3. (Top panel) Scenarios for new tree area. (Bottom panel) Forest carbon removal. Units for annual carbon sequestration are negative for atmosphere reference.

Figure 4 presents the model results assuming variable carbon sequestration rate over space and time accounting for both spatial differences in potential growth rates and temporal effects of forest aging (Version 3). Like Version 2, model estimates of annual forest carbon sequestration potential peak somewhat after 2045 when new planting is assumed to be complete due to delayed maturity, and decline thereafter due to aging. Estimates of statewide potential carbon sequestration continue to increase non-linearly as planting is assumed to continue thru end of century and the effects of aging slow net carbon uptake. Different options for the phasing of planting locations over space and time resulting in large uncertainties of projected annual carbon sequestration rates.

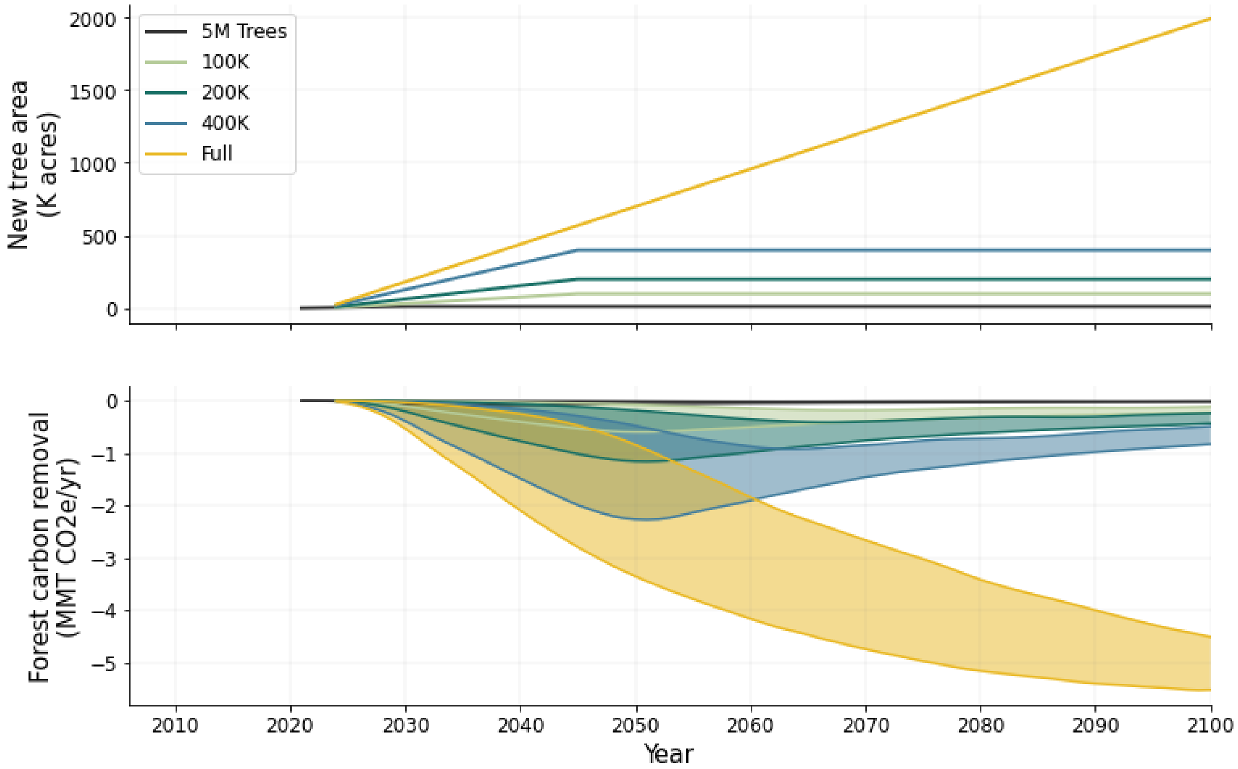

Figure 4. Planting scenarios and corresponding estimates of forest carbon removal- Version 3. (Top panel) Scenarios for new tree area. (Bottom panel) Forest carbon removal. Units for annual carbon sequestration are negative for atmosphere reference.

Acknowledgements

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Blue Carbon: Wetland Area and Carbon Change in 2030 and 2045

Maryland Department of Natural Resources

Blue carbon in Maryland refers to the carbon captured by the ocean and coastal ecosystems, including coastal salt marshes and seagrasses. For the Maryland GHG inventory, blue carbon stocks and fluxes comprise the state's estuarine wetlands and seagrasses, otherwise referred to as submerged aquatic vegetation (SAV). Methane emissions are an important consideration when assessing the climate impact of wetlands. Freshwater and brackish wetlands tend to support a bacterial community within their soils that produces methane, with higher salinity (18 ppt+) wetland soils typically not producing methane. For that reason, we only considered wetlands in the southern, saltier region of the Chesapeake Bay and the Coastal Bays for the MD GHG Inventory and for the projections here. This includes the mesohaline region, where salinities range between 5 and 18 ppt and significant methane emissions do exist, but carbon sequestration in soils has a larger climate benefit, on average. The relationship between salinity and methane emissions is not observed for SAV, so all SAV in the Bay is included in the inventory. It should also be noted that the choice of global warming potential (GWP) for methane greatly impacts the net GHG impact of wetlands. Under a 20-year GWP where methane is 84 times that of carbon dioxide the coastal wetlands sink is negligible. Results here are presented using the 100-year GWP of methane (28 times that of CO2), however the 20-year GWP is applied when incorporating the results in the economywide plan.. The 2020 GHG inventory includes net emissions from wetland land-use change. This factor was omitted here because of the high uncertainty around the timing and magnitude of carbon stock change associated with conversion to or from wetlands. This factor is a relatively small (~1.5%) component of the overall blue carbon inventory.

Wetland Area and Carbon Change in 2030 and 2045

In 2021 Maryland DNR partnered with The Nature Conservancy, George Mason University and Warren Pinnacle, Inc. to simulate change in coastal wetlands and other lands over a 100 year period in 10 year increments under six different sea level rise (SLR) scenarios using the Sea Level Affecting Marshes Model (SLAMM). The scenarios ranged from 1.2 to 1.5 feet of SLR by 2050, with results for the scenario simulating 1.4 feet by 2050 used here. Results for 2045 were obtained by averaging the 2040 and 2050 model results. In all of the scenarios wetland area increased over time, due to migration into areas that are now upland forests, agriculture, or open areas and existing marshes largely being able to keep up with SLR through building of new soils. Low elevation counties on the southern Eastern Shore in particular are expected to experience extensive wetland migration into uplands. This region is already experiencing the impacts of saltwater intrusion as sea level rises, with ghost forests and less productive or barren agricultural fields becoming more common. Carbon loss due to land-use conversion driven by SLR is likely to be significant, but is not quantified here. The changes projected are just due to expected SLR and do not account for any ecological restoration efforts the state may engage in, such as thin layer placement or tidal wetland creation. Rates of coastal wetland restoration implementation have been low; only 510 acres have been restored by the state and 2,096 acres restored by federal agencies since 2006.

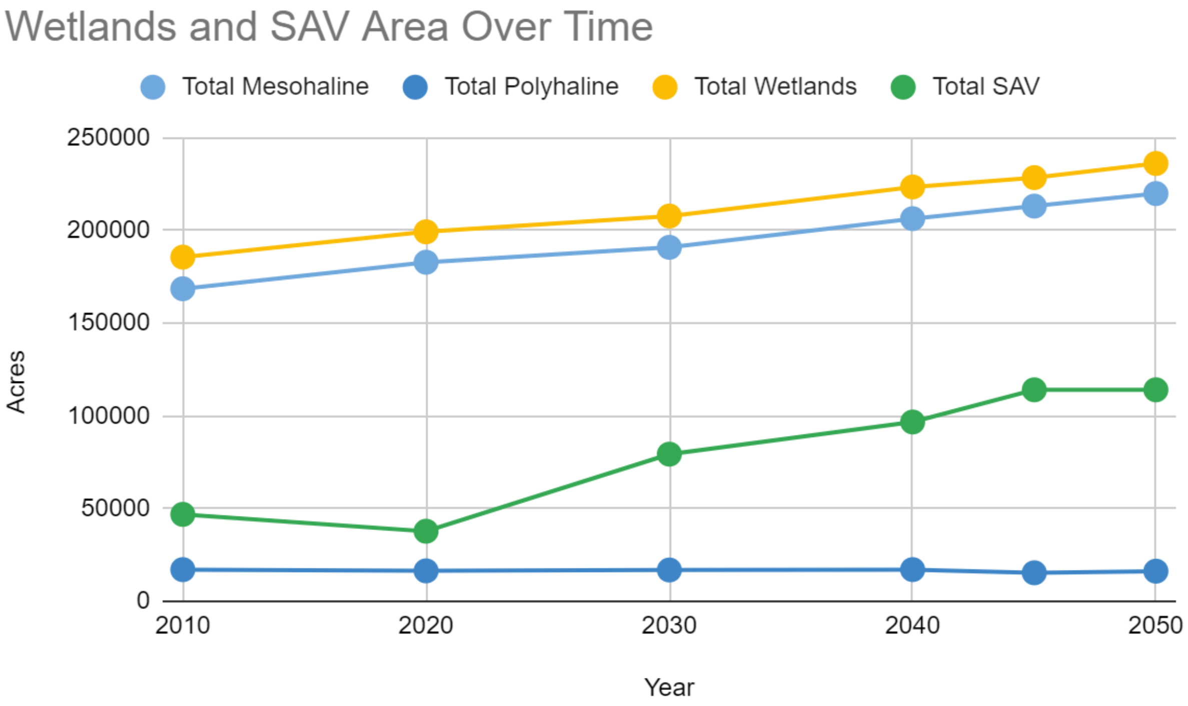

Figure X: Change in Maryland's mesohaline and polyhaline wetlands and SAV over time under a 1.4 feet of SLR by 2050 scenario and assuming SAV restoration goals are achieved

According to the SLAMM results for wetland area change under the chosen SLR scenario and our current best understanding of wetland carbon accumulation and methane emission rates Maryland's blue carbon sink is projected to increase by 14%, from -336,000 metric tons of CO2e per year in 2020 to -383,000 metric tons of CO2e per year in 2045. While this is one plausible scenario, different models of SLR and wetland change may result in different results, although the differences between models and scenarios becomes greater as they extend into the future. In the scenarios modeled under this SLAMM run 2070-2080 is an important inflection point, with higher rates of SLR outpacing many wetlands' ability to keep up through soil building and rapid, extensive wetland loss projected to occur. However, under lower SLR projections, such as those expected to be experienced under a stable emissions scenario, many wetlands are able to keep up with those lower rates and wetland area is projected to be relatively stable.[1]

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[1] Warren Pinnacle. 2021. Application of the Sea-Level Affecting Marshes Model to Coastal Maryland https://warrenpinnacle.com/prof/SLAMM/EESLR_MD/EESLR_MD_SLAMM_Report_12-28-2021.pdf

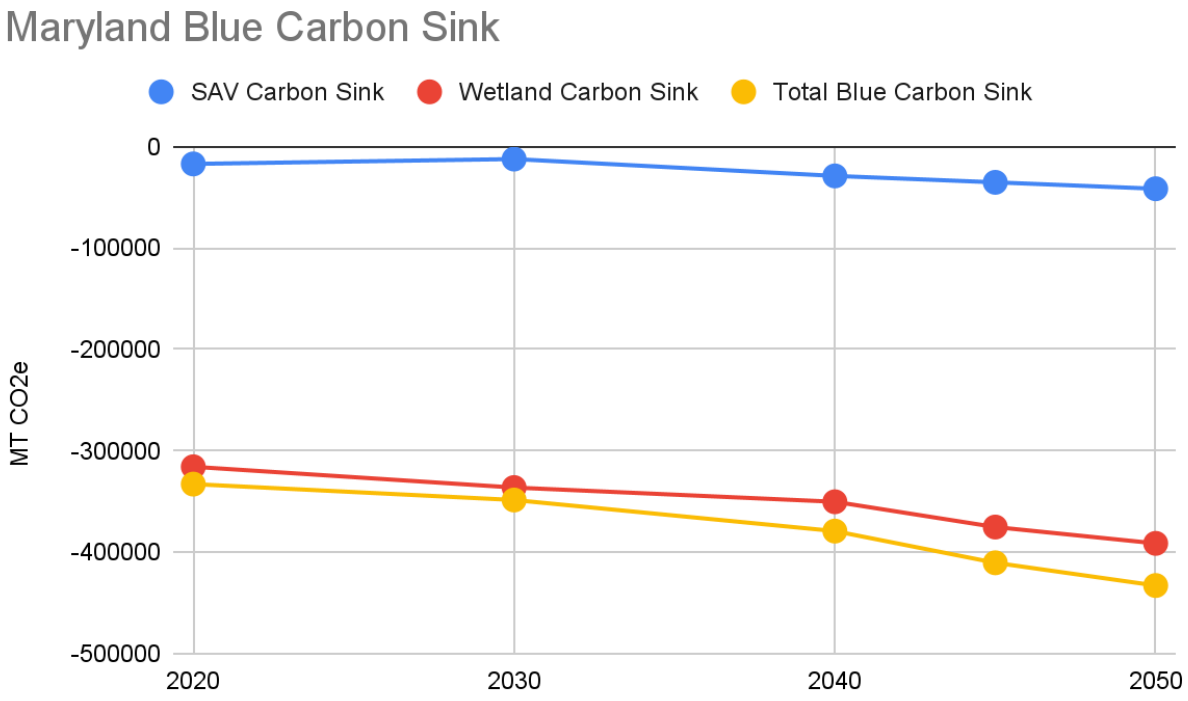

Figure X: Change in Maryland's Blue Carbon Sink over time (negative values indicate a net removal of carbon from the atmosphere; figure uses the 100 year GWP of methane)

Submerged Aquatic Vegetation (SAV)

Projections of carbon sequestration and methane emission in submerged aquatic vegetation (SAV) utilize acreage projections provided by the Maryland Department of Natural Resources. For SAV, the Current Policies scenario holds 2020 acreage constant and the technical potential reflects the SAV goals for Maryland's portion of the Chesapeake Bay. In this analysis the 2025 goal of 79,355 acres was used for 2031 and the long term goal of 114,065 acres was used for 2045.

Blue Carbon Funding

As mentioned previously, restoration of coastal wetlands has not been widely implemented in Maryland, apart from the large island creation projects where dredge material is used to build up islands that are partially composed of wetlands. While coastal wetlands are vital ecosystems that provide important ecosystem services like erosion prevention and wildlife habitat restoration of these systems is quite expensive, frequently exceeding $50,000 per acre restored. Maryland DNR has partnered with The Nature Conservancy and ESA, Inc. to conduct a blue carbon feasibility study of several existing or potential wetland restoration projects in Maryland. Results indicate that the sale of blue carbon credits would not be able to support the costs associated with project implementation, even if the price of carbon were to rise dramatically. Under certain price points it is possible for the sale of credits to fund a portion of the cost of maintaining the project. Given project costs, it is likely that going forward projects will be done for reasons other than blue carbon, like enhancing coastal resiliency or ensuring habitat for endangered species, but blue carbon will remain an important co-benefit of this work.