Accounting for Maryland's Ecosystem Services

Appendix

Table of Contents

This appendix to the 2017 Maryland DNR report Accounting for Maryland's Ecosystem Services details the procedures used to generate the spatial datasets presented in that report. The procedures listed here are also contained in the metadata for the spatial data associated with this work available on Maryland iMap (http://imap.maryland.gov).

1. CARBON SEQUESTRATION

A. Forests

<u>A.1 Forest Carbon Flux</u>

<u>A.2 Study Area: Maryland Forests</u>

<u>A.3 Data and Methods</u>

1) Run i-Tree Landscape at the Block Group level; export i-Tree high resolution location and tree benefit data to .csv format.

i-Tree Landscape is an online web application which provides estimates of carbon sequestration removal (kg/yr) and associated economic value ($/ yr) over a user defined study area at a user defined level of geographic detail

The resulting i-Tree output contains estimates of carbon sequestration and associated economic value for each block group in Maryland. Though outputs are extracted from the high resolution model run, high resolution tree canopy data was available for only a subset of counties (Anne Arundel, Baltimore, Baltimore City, Harford, Howards, Montgomery, Prince George's, and Wicomico, as well as small portions of Frederick and Allegany). In all other areas, outputs are based on NLCD 2011 percent tree canopy data. (Hirabayashi, 2014; Hirabayashi, 2016; Nowak and Greenfield, 2010; Nowak and Greenfield, 2012; Nowak et al., 2014; i-Tree Landscape Methods)

2) Derive block group level carbon sequestration (t/m2) and economic value ($/m2, *or $/kg*) multipliers using iTree Landscape output.

The iTree output was imported into Excel, and formatted for optimal processing. Block group level removal and economic value multipliers for carbon sequestration were calculated using the following formulas:

Removal Multiplier (tons/m2) = iTree Removal (kg/yr)/ iTree Tree Canopy (m2)
C_Sq_t_m2 = C_Sq_t_yr / Canopy_m2

Economic Value ($/ton) = iTree Removal ($/yr)/ iTree Removal (ton/yr)
C_Sq_d_t = C_Sq_d_yr / C_Sq_t_yr

3) Create 30 m raster layers of carbon sequestration and economic value multipliers

In ArcMap, join Excel sheet containing block group level removal and economic value multipliers to the Census block group shapefile. For each multiplier, use the "Polygon to Raster" tool to convert the block group shapefile to a raster coverage with the value field populated by the multiplier of interest. Set Environmental Inputs to ensure that output multiplier rasters have the same extent and cell size (30m) as the Tree Canopy Area layer, and snap to the Area Tree Canopy layer.

"c_sq_t_m2_tc" This is the estimated carbon sequestration rate in tons/m2 tree canopy for a given pixel, based on iTree BG level coefficients

"c_sq_d_ton" This is the estimated dollar value per ton carbon sequestered for a given pixel, based on iTree BG level coefficients

4) Convert 30 m lidar-derived Percent Tree Canopy data into 30 m tree area, using the following Map Algebra equation in Arc:

Lidar-derived Percent Tree Canopy (30 m), was used to represent forest cover across the state of Maryland. Percent tree canopy was converted to meters squared tree canopy to **"tc_m2_sp"**, **tc_m2_sp** = Percent Tree Canopy (per 30m pixel) * 900 m (per pixel)

5) Calculate carbon sequestration in tons/ m2 / yr
c_sq_yr_est = "tc_m2_sp" * "c_sq_t_m2_tc"

6) Calculate the value of carbon sequestration in $/ ton / yr
c_sq_d_ton = "c_sq_yr_est" * "c_sq_d_ton"

B. Wetlands

1 Wetland Carbon Flux

2 Study Area: Maryland Wetlands

a. Wetland carbon sequestration rate

b. Data and Methods

c. Wetland carbon sequestration rates

Carbon sequestration rates were determined based on review of published literature values from field studies conducted in or near Chesapeake Bay wetland areas. Studies were grouped based on wetland system type, Palustrine vs. Estuarine. Based on observed differences in sequestration rates, Palustrine studies were further stratified by dominant vegetation type (forested or emergent), while Estuarine studies were stratified by salinity (freshwater, oligohaline, mesohaline).

For each strata, the mean yearly carbon sequestration rate (g m^{-2} yr^{-1}) was calculated. It should be noted that there were no studies identified for polyhaline estuarine wetlands. Based on the negative relationship between salinity and carbon sequestration rate observed in both this and previous studies, the sequestration rate for mesohaline wetlands was applied to polyhaline wetland areas, with the caveat that this may overestimate sequestration in these areas.

Carbon sequestration rates are summarized in Table 1.

Table 1.

Carbon Sequestration Rates			
Wetland System Type	**N Sites**	**Mean** *(Mg $ha^{-1}yr^{-1}$)*	**Mean** *(g $m^{-2}yr^{-1}$)*
Palustrine: Forested	18	1.0615	106.15
Palustrine: Emergent	11	3.3341	333.41
Estuarine: Freshwater (<0.5 ppt)	30	*3.9172*	*391.72*
Estuarine: Oligohaline (0.5 - 5.0 ppt)	15	*2.9301*	*293.01*
Estuarine: Mesohaline; Polyhaline (5.0 - 18.0 ppt); (> 18 ppt)	47	2.0670	206.70

1. Wetland methane emission rates

Methane (CH_4) emission rates were determined based on review of published literature values from studies conducted in or near Chesapeake Bay wetland areas. Studies were grouped based on salinity zone: Freshwater, Oligohaline, Mesohaline, Polyhaline. This stratification was selected based on the relationship between sulfate concentrations and methane emissions, with salinity level serving as a proxy for sulfate concentration.

For each salinity zone, the geometric mean methane emission rate (g m^{-2} yr^{-1}) was calculated. No published studies were identified for wetlands in Oligohaline zones in the Chesapeake Bay region, therefore the mean emission rate was calculated based on studies conducted outside of the region.

Methane emission rates were then converted to the equivalent Carbon emissions rates, to allow for calculation of net carbon sequestration in (g m^{-2} yr^{-1})

Methane emission rates are summarized in **Table 2**.

Methane Emission Rates					
Salinity Class	**N Sites**	**Mean** *(Mg $ha^{-1}yr^{-1}$)*	**CO2 equiv** *(Mg $ha^{-1}yr^{-1}$)*	**C equiv** *(Mg $ha^{-1}yr^{-1}$)*	**C equiv** *(g $m^{-2}yr^{-1}$)*
Tidal Freshwater (<0.5 ppt)	9	0.8203	20.5083	5.5881	558.81
Oligohaline (0.5 - 5.0 ppt)	6	0.4568	11.4208	3.1119	311.19
Mesohaline (5.0 - 18.0 ppt)	13	0.1920	4.80	1.3079	130.79
Polyhaline (> 18 ppt)	6	0.0085	0.2125	0.0579	5.79

2. Prepare spatial data

a. Wetland Extent

There are 3 major sources of wetlands data available for the state of Maryland.

- National Wetlands Inventory (NWI), US Fish and Wildlife Service
- DNR Wetlands
- Wetlands of Special State Concern (WSSC), MD DNR

The **NWI** was created based on visual interpretation of digital ortho quads from 1981 – 1982 infrared photographs. This layer provides the approximate location (areal extent) and type of wetlands across Maryland. NWI wetlands are delineated based on definitions by Cowardin et al. (1979). Due to the limitations of aerial photography, seagrasses and submerged aquatic vegetation often found in intertidal and subtidal estuarine and coastal zones are excluded from the NWI mapping program.

The original **DNR** wetlands layer is based on visual interpretation of digital ortho quads from 1988-1989 infrared photographs. The **DNR** began updating the **NWI** mapping of wetlands in Maryland in the early 1990s, and this process is ongoing.

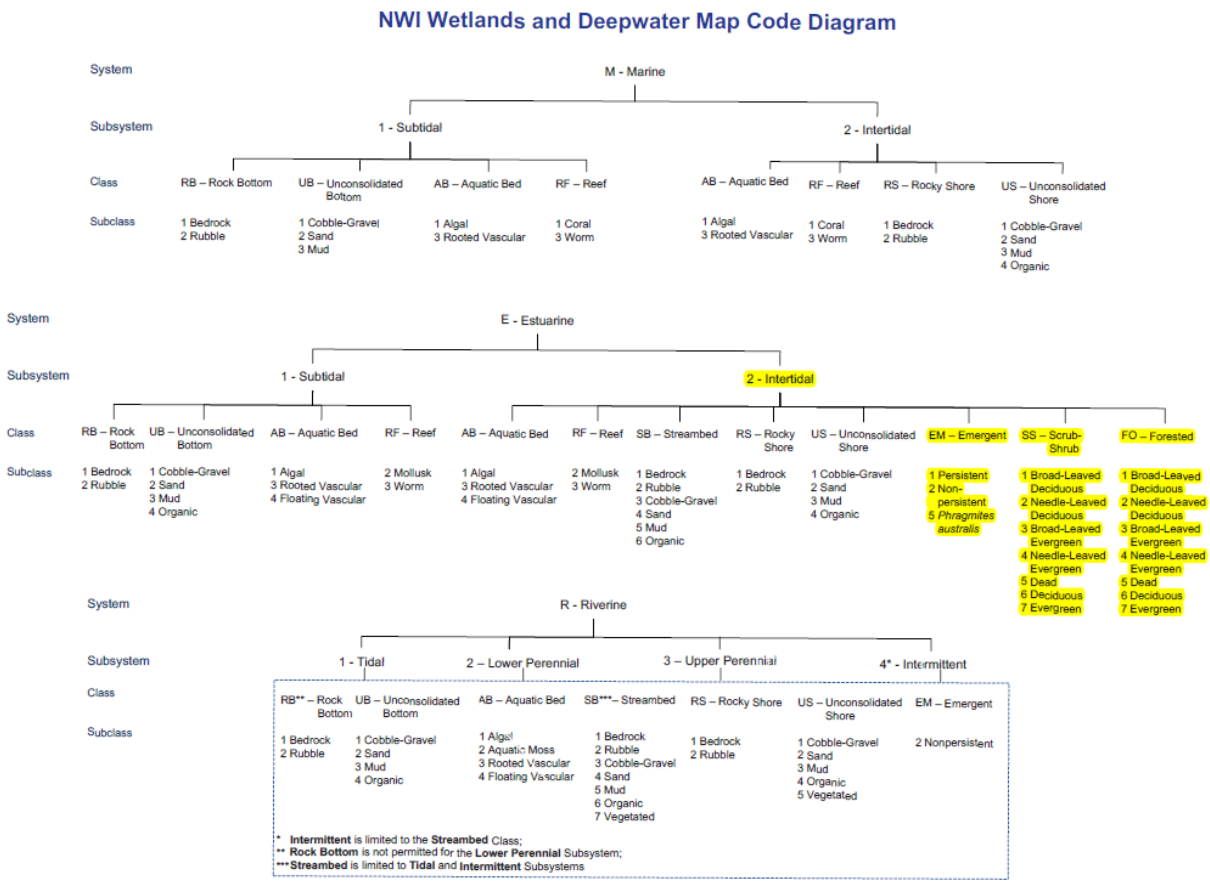
In an effort to maintain consistency across AMES ES models, as well as with other DNR data products, an internally available data layer **"DNR_NWI_wetland"** was selected. This data layer represents the DNR-updated NWI wetland polygons, as of 2008. This layer was chosen as it was also used as the underlying wetland extent data in both the **DNR Green Infrastructure** and **Coastal Resiliency** analyses.

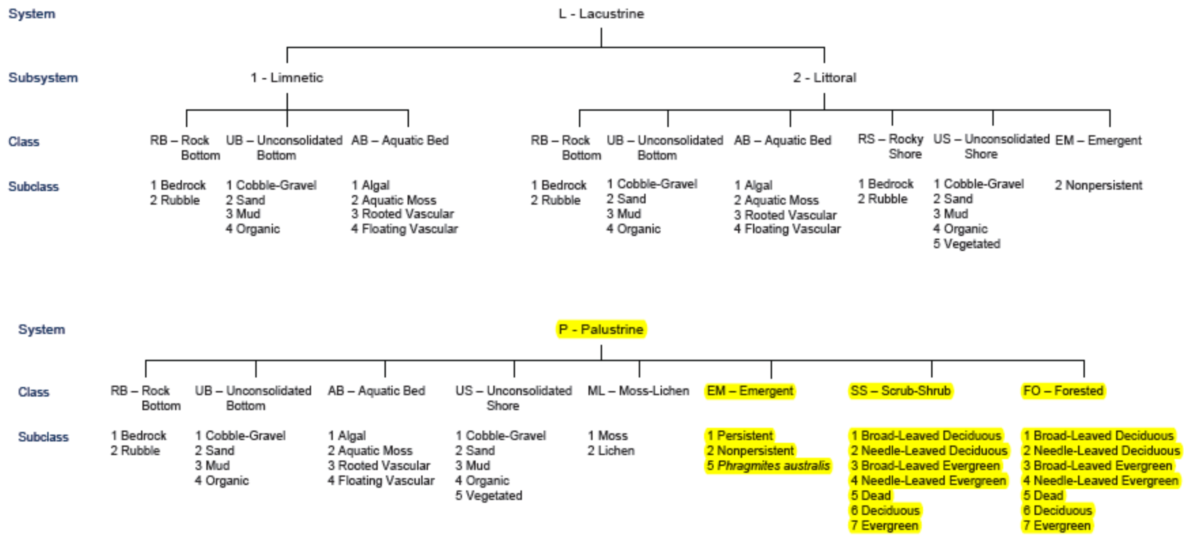
1) Subset wetland data

The original **"DNR_NWI_wetland"** layer was reprojected to NAD 1983 State Plane (m), and subset to include only those wetland classes for which carbon sequestration dynamics could be reasonably quantified. In the current model, these wetland types include Intertidal Estuarine wetlands (emergent, scrub-shrub, and forested only) and Palustrine (emergent, scrub-shrub, and forested only). **“DNR_NWI_wetland_subset”**

A new attribute, Wet_Type, was created, and the field was populated to designate the wetland class, either Palustrine (P) or Estuarine (E). All Palustrine wetlands were selected and data was exported to create a new layer containing only Palustrine wetlands, **“DNR_NWI_08_Pal”**.

The process was repeated for Estuarine wetlands, to create **“DNR_NWI_08_Est”**.





2) Create fishnet for Maryland

A fishnet was created having the same extent and cell size as the raster data used across the AMES model. Set Environmental Inputs to ensure that output multiplier rasters have the same extent and cell size (30m) as the Tree Canopy Area layer, and snap to the Area Tree Canopy layer. **"MD_Fishnet"**

3) Combine Wetland data with Maryland fishnet

Union **"MD_Fishnet"** and **"DNR_NWI_08_Pal"**, to create **"Wet_08_Fish_Pal"**. This new layer will include a polygon for the portion of Palustrine wetland falling within each 30m2 fishnet polygon. As there could be multiple wetland polygons falling within in a given fishnet polygon, **"Wet_08_Fish_Pal"** was dissolved based on the Fishnet_ID attribute, to create **"Wet_08_Fish_Pal_Diss"**, containing only one wetland polygon per fishnet polygon.

This process was repeated for Estuarine wetlands, to create **"Wet_08_Fish_Est"** and **"Wet_08_Fish_Est_Diss"**.

4) Create fishnet of Maryland wetlands

Three new fields were created in the attribute table of **"Wet_08_Fish_Pal_Diss"**, X_coor, Y_coor, and Area_m2. Calculate Geometry was used to calculate the X and Y centroids, as well as the area (m2) of each wetland polygon.

The attribute table of **"Wet_08_Fish_Pal_Diss"**, was then exported to create a new DBF table, **"Wet_08_Fish_Pal_Diss"**. The XY data was then displayed, and the resulting Event layer was exported to create **"Wet_08_Fish_Pal_pts"**. This new layer contains one point per wetland polygon, along with calculated area (m2) of the associated wetland polygon.

A spatial join was performed between **"MD_Fishnet"** and **"Wet_08_Fish_Pal_pts"**, to create a new fishnet layer, **"Wet_08_Fish_Pal_Pts_Join"**. This layer now provides the area (m2) of Palustrine wetland per 30m fishnet polygon.

This process was repeated for Estuarine wetlands, to create **"Wet_08_Fish_Est_pts"** and **"Wet_08_Fish_Est_Pts_Join"**.

5) Create Palustrine and Estuarine wetland rasters

The Polygon to Raster tool was used to convert the 30m2 wetland polygons in **"Wet_08_Fish_Pal_Pts_Join"** to a 30m2 raster layer, using "Area_m2_1" as the value field. Set Environmental Inputs to ensure that output multiplier rasters have the same extent and cell size (30m) as the Tree Canopy Area layer, and snap to the Area Tree Canopy layer. The resulting raster layer, **"Wtlnd_Pal_m2"**, the area of Palustrine wetland per 30m pixel.

This process was repeated for Estuarine wetlands, to create **"Wtlnd_Est_m2"**.

b. Identification of "forested" wetland

Lidar-derived Percent Tree Canopy (30 m), **"tc_m2_sp"**, was used as the underlying dataset to identify areas of "forested" wetland. The National Landcover Database defines forests as "areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover." While canopy height is available for the majority of Maryland in the **"tc_m2_sp"** layer, lidar data was not available for several small areas across the state, and thus these areas lack height data. For the purposes of this study, forests were defined using only the 20% minimum canopy cover criteria, with NLCD percent canopy data used to fill lidar gaps.

Data were reclassified using the Reclassify tool, with areas less 20% = 0, and areas greater than or equal to 20% = 1, to create the layer **"tc_20p_mask"**. Set Environmental Inputs to ensure that output multiplier rasters have the same extent and cell size (30m) as the Tree Canopy Area layer, and snap to the Area Tree Canopy layer.

Raster calculator was then used to convert areas of "NoData" to zeros, using the equation below

TC_20p_Z = Con(IsNull("tc_20p_mask"),0,"tc_20p_mask")

c. Salinity

Salinity zone was derived from the Chesapeake Bay Segment attribute of the 2007 VIMS SAV data layer, **"SWsav2007".** This attribute, "CBPSEG" included a 2-letter code for the salinity zone (TF = tidal fresh, OH = oligohaline, MH = mesohaline, PH = polyhaline). This 2-letter code was parsed from the attribute text, to a new text attribute field, "Salinity_Z". A new integer attribute field was then reated, Salinity_n, where each zone was assigned an integer value (TF = 1, OH = 2, MH=3, PH=4).

“SWsav2007” was dissolved by Salinity_Z, to create **“SAV_Salinity_Zones” .**

The Polygon to Raster tool was used to convert **“SAV_Salinity_Zones”**, using “Salinity_Z” as the value field. . Set Environmental Inputs to ensure that output multiplier rasters have the same extent and cell size (30m) as the Tree Canopy Area layer, and snap to the Area Tree Canopy layer.

d. Estimation of net wetland carbon sequestration

1) Calculate carbon sequestration for Palustrine wetlands, convert “NoData” to zeros

Pal_Carb_1 = Con("TC_20p_Z" == 1, "Wet_Pal_Z" * 106.15, "Wet_Pal_Z" * 333.41)

Pal_Carb_Z = Con(IsNull("Pal_Carb_1"),0,"Pal_Carb_1")

2) Calculate carbon sequestration for Estuarine wetlands, convert “NoData” to zeros

Est_Carb_1= Con("Sal_Zone_Z" >= 3, "Wet_Est_Z" * 206.704, Con("Sal_Zone_Z" == 2, "Wet_Est_Z" * 293.007, Con("Sal_Zone_Z" == 1, "Wet_Est_Z" * 391.715)))

Est_Carb_Z = Con(IsNull("Est_Carb_1"),0,"Est_Carb_1")

3) Combine Palustrine and Estuarine wetalands

Wet_Carb_Z = "Pal_Carb_Z" + "Est_Carb_Z"

4) Calculate methane emissions

Palustrine

Pal_Meth_1 = "Wet_Pal_Z" * 558.81

Pal_Meth_Z = Con(IsNull("Pal_Meth_1"),0,"Pal_Meth_1")

Estuarine

Est_Meth_1 = Con("Sal_Zone_Z" == 1, "Wet_Est_Z" * 558.81, Con("Sal_Zone_Z" == 2, "Wet_Est_Z" * 311.19, Con("Sal_Zone_Z" == 3, "Wet_Est_Z" * 130.79, Con("Sal_Zone_Z" == 4, "Wet_Est_Z" * 5.79))))

Est_Meth_Z = Con(IsNull("Est_Meth_1"),0,"Est_Meth_1")

Total

Wet_Meth_Z = "Est_Meth_Z" + "Pal_Meth_1"

5) Calculate net carbon sequestration

Net_Carb_Z = ("Wet_Carb_Z" + "For_c_g_yr_Z") - "Wet_Meth_Z"

6) Calculate economic value of carbon sequestration

Set minimum net sequestration value to 0 (zero).

net_carb_min_z =

2. WILDLIFE HABITAT & BIODIVERSITY MODEL SUMMARY

2.1 Input Data

1) Lidar-derived Percent Tree Canopy (30 m) with Aberdeen from NLCD

   http://carbonmonitoring.umd.edu/index.html

   http://carbonmonitoring.umd.edu/map.html

2) MD Green Infrastructure ecovalue raster coverage
   http://dnrweb.dnr.state.md.us/gis/data/

3) MD BioNET- Biodiversity Conservation Network
   http://dnrweb.dnr.state.md.us/gis/data/

4) Maryland Wetlands, merge of NWI and DNR, Wtlnd_m2

2.2 Methods: Forests and Wetlands

1. Resample Green Infrastructure ecological score coverage (swgicelleco) from 35 m pixels to 30 m pixels.
2. Extract by Mask: Extract swgicelleco using Tree Canopy as a mask
3. Raster Calculator: Multiply swgicelleco by $283 (estimated high value of wildlife per 900 m^2), raster coverage titled WildifeValue30m_GI
4. Select by attribute: Select Tier 1 and Tier 2 from the MD BioNET shapefile.
5. Create New Coverage based on selection from BioNET
6. Add field titled 30mvalue and give the field the value 283
7. Convert Polygon to raster: convert the Tier 1 and 2 selection to a 30 m raster coverage titled 30mraster_Tier1Tier2, use 30mvalue to determine Value field in the created raster
8. Mosaic WildlifeValue30m_GI and 30mraster_Tier1Tier2 to create raster entitled WildlifeValue30mFinal
9. Wetlands- Raster calculator- Wtlnd_m2 / 900 * swgicelleco, yields rastercalc28
10. Raster calculator- rastercalc28 / 100 * 283, yields WildlifeValueWetlands30m
11. Mosaic to New Raster using WildlifeValueWetlands30m with WildlifeValues30mFinal, using maximum values, yields FinalWildlifeForWet30m

3. AIR QUALITY MODEL SUMMARY

3.1 Background

3.2 Input Data

1) Lidar-derived Percent Tree Canopy (30 m)

   http://carbonmonitoring.umd.edu/index.html

   http://carbonmonitoring.umd.edu/map.html

2) iTree Census Block level tree benefit data

   https://landscape.itreetools.org/

3) 2010 Census Block Group Polygons (Tiger/LINE)

   https://www.census.gov/cgi-bin/geo/shapefiles/index.php

3.3 Methods: Forests

1) **Run iTree Landscape at the Block Group level; export iTree high resolution location and tree benefit data to .csv format.**

   iTree Landscape is an online web application which provides estimates of annual pollutant removal (kg/yr) and associated economic value ($/ yr) for 6 air pollutants (CO, NO_2, O_3, PM 2.5, SO_2, and PM 10) over a user defined study area at a user defined level of geographic detail

   The resulting iTree output contains estimates of pollutant removal and associated economic value for each block group in Maryland. Though outputs are extracted from the high resolution model run, high resolution tree canopy data was available for only a subset of counties (Anne Arundel, Baltimore, Baltimore City, Harford, Howards, Montgomery, Prince George's, and Wicomico, as well as small portions of Frederick and Allegany). In all other areas, outputs are based on NLCD 2011 percent tree canopy data. (Hirabayashi, 2014; Hirabayashi, 2016; Nowak and Greenfield, 2010; Nowak and Greenfield, 2012; Nowak et al., 2014; iTree Landscape Methods)

2) **Derive block group level pollutant removal (kg/m2) and economic value ($/m2, *or $/kg*) multipliers for each pollutant using iTree Landscape output.**

   The iTree output was imported into Excel, and formatted for optimal processing. Block group level removal and economic value multipliers for each pollutant were calculated using the following formulas:

   Removal Multiplier (kg/m2) = iTree Removal (kg/yr)/ iTree Tree Canopy (m2)

   Economic Multiplier ($/m2) = iTree Removal ($/yr)/ iTree Tree Canopy (m2)

   -or- Economic Value ($/kg) = iTree Removal ($/yr)/ iTree Removal (kg/yr)

3) **Convert 30 m lidar-derived Percent Tree Canopy data into 30 m tree area, using the following Map Algebra equation in Arc:**

Tree Canopy Area = Percent Tree Canopy (per 30m pixel) * 900 m (per pixel)

4) **Create 30 m raster layers of pollutant removal and economic value multipliers for each pollutant**

In ArcMap, join Excel sheet containing block group level removal and economic value multipliers to the Census block group shapefile. For each multiplier, use the "Polygon to Raster" tool to convert the block group shapefile to a raster coverage with the value field populated by the multiplier of interest. Set Environmental Inputs to ensure that output multiplier rasters have the same extent and cell size (30m) as the Tree Canopy Area layer, and snap to the Area Tree Canopy layer.

5) **Calculate annual pollutant removal and associated annual economic value for each pollutant at the pixel level across MD forests using 30m lidar-derived percent canopy data**

For each pollutant, use the following Map Algebra equations to calculate annual pollution removal (kg/yr) and associated annual economic value for the area of tree canopy found within each 30 m pixel. Set Environmental Inputs to ensure that output multiplier rasters have the same extent and cell size (30m) as the Tree Canopy Area layer, and snap to the Area Tree Canopy layer.

Annual Pollutant Removal (kg/yr) = Tree Canopy Area (m2) * Pollutant Multiplier (kg/m2)

Annual Economic Value ($/yr) = Tree Canopy Area (m2) * Economic Multiplier ($/m2)

-or- Annual Economic Value ($/yr) = Annual Pollutant Removal Economic Multiplier ($/kg)*

6) **Calculate total annual pollutant removal and associated annual economic value at the pixel level across MD forests**

Use the following Map Algebra equations to calculated the total combined annual pollutant removal and associated annual economic value of all pollutants. Set Environmental Inputs to ensure that output multiplier rasters have the same extent and cell size (30m) as the Tree Canopy Area layer, and snap to the Area Tree Canopy layer.

Total Annual Pollutant Removal = $\sum$ Annual Pollutant Removal of each pollutant

Total Annual Economic Value = $\sum$ Annual Economic Value of each pollutant

7) **Aggregate outputs to the block group, tract, county, and state level.**

For each individual Annual Removal or Economic value raster, use the "Zonal Statistics as Table tool," to calculate the sum of Annual Pollutant Removal and Annual Economic Value for each pollutant for all forested pixels falling within each polygon at the block group level

Once the zonal statistics table(s) have been run at the block level, removal and economic value attributes can be Summarized, to further aggregate to the county and state level.

3.4 Results:

	Pollutant Removal (kg / yr)	Value ($ / yr , m2)	Value ($ / yr , kg)
CO	1,479,582.57	$593,939.18	$592,618.39
NO2	11,037,156.64	$1,235,843.50	$1,234,655.77
O3	72,442,391.97	$42,872,606.88	$42,872,305.33
PM25	2,867,290.05	$83,937,759.78	$83,929,963.64
SO2	4,663,672.71	$122,014.09	$122,362.00
PM10	16,142,334.66	$20,466,421.98	$20,468,234.11
Total	**108,632,429.56**	**$149,228,585.17**	**$149,220,139.26**
Area (m2)	25,630,890,300.00	-	-
Canopy (m2)	12,520,784,221.45	-	-

4. NITROGEN REMOVAL MODEL SUMMARY

4.1 Input Data

4) Lidar-derived Percent Tree Canopy (30 m) with Aberdeen from NLCD

   http://carbonmonitoring.umd.edu/index.html

   http://carbonmonitoring.umd.edu/map.html

5) NHD Hydrography dataset for Maryland

   https://nhd.usgs.gov/

6) SPARROW Model Results

7) Chesapeake Bay Salinity

8) Maryland Floodplains

9) Maryland Wetlands, merge of NWI and DNR, palustrine category, estuarine category

4.2 Nutrient Methods: Forests and Wetlands

1. Calculate nitrogen incremental load per ha in excel output of the SPARROW model (total incremental load * (1-delivered fraction) / area). Join excel sheet to NHD catchment shapefile.
2. Perform polygon to raster with incremental nitrogen load as the value, resulting in NperHa raster coverage.
3. Performed Reclassify on NperHa, values 0-2.5 to 1, 2.5-10 to 2, 10+ to 3 corresponding to low, medium and high loading rates, new coverage NutrientRanking
4. Clip Palustrine wetlands by floodplain coverage

Table 1. Nitrogen Uptake by Loading	kg/ha/yr	$/ha	$/m2	$/30 m pixel
Forest				
low loading N	5	91.70	0.00917	8.253
med loading N (8-15)	10	183.40	0.01834	16.506
high loading N	12	220.08	0.022008	19.8072
Floodplains wetlands				
low loading N	30	550.2	0.05502	49.518
med loading N (8-15)	80	1467.2	0.14672	132.048
high loading N	150	2751	0.2751	247.59
Depressional wetlands				

low loading N	10	183.4	0.01834	16.506
med loading N (8-15)	25	458.5	0.04585	41.265
high loading N	50	917	0.0917	82.53

Rates reported in Chesapeake Bay Program Report- "Quantifying the Role of Wetlands in Achieving Nutrient and Sediment Reductions in Chesapeake Bay" for wetlands, Goodale et al. 2002 for forests

5. For each category above (forest, floodplain wetland, depressional wetland) reclassify Nutrient ranking to corresponding $ per 30m pixel and multiply value by corresponding coverage (forest, floodplain wetlands and depressional wetlands), results in fldplnnutriVal, PalusWetNutriVal, ForNutriValu

6. Estuarine Wetlands: Nitrogen burial and denitrification varies by salinity regime (see table 2). Reclassify Salinity raster coverage to $ per 30 m pixel and multiply resulting coverage by estuarine wetland raster coverage, results in EstuarineNutrients

Table 2. Total N Removal (denitrification and burial)	N kg per ha	$/ha	$/m^2	$/30 m pixel	Reference
Tidal Fresh	381	4438.56	0.443856	399.4704	Merrill & Cornwell 2000
Brackish	210	2568.24	0.256824	231.1416	Merrill & Cornwell 2000, Kemp 2006
Salt	49	794.62	0.079462	71.5158	Thomas & Christian 2001

7. Mosaic to New Raster: Combine the four resulting raster datasets with $ values using the maximum value function, results in AllNutriValue

5. GROUNDWATER RECHARGE & SURFACE WATER PROTECTION MODEL SUMMARY

5.1 Input Data

1) Lidar-derived Percent Tree Canopy (30 m) with Aberdeen from NLCD

   http://carbonmonitoring.umd.edu/index.html

   http://carbonmonitoring.umd.edu/map.html

2) NHD Hydrography dataset for Maryland

   https://nhd.usgs.gov/

3) Maryland 8 Digit Watersheds
   http://data.imap.maryland.gov/datasets/maryland-watersheds-8-digit-watersheds

4) Lakes and Reservoir coverage

   http://data.imap.maryland.gov/datasets/maryland-waterbodies-lakes-detailed

5) Maryland Wetlands, merge of NWI and DNR, Wtlnd_m2

5.2 Groundwater Recharge Methods: Forests and Wetlands

1. Added fields to National Hydrography Dataset entitled m3Recharge and Recharge_30m to GWRecharge shapefile from the NHD dataset.
2. Use field calculator in m3Recharge field to multiply the MEAN_RCHRG data field by 900 meters / 1000 mm/m in order to convert field to meters of gw recharge per year per 30 m pixel (i.e. 900 m^2)
3. Use field calculator in Recharge_30m field to multiply m3Recharge by 0.5 (the average eco-price for water, $/m3).
4. Polygon to Raster tool using the Recharge_30m field as raster value
5. Performed the following calculation in raster calculator: 30m LiDAR tree canopy/900 * GWRechES, yielding GWTCcorrect2
6. Performed the following calculation in raster calculator: Wtlnd_m2 / 900 * Recharge_30m, yielding WetlandESRech
7. Used Mosaic to New Raster to combine GWTCcorrect2 and WetlandESRech using the maximum value function, saved as GWRechargeFinal

5.3 Surface Water Protection: Forests

1. Select by attribute was performed on the Maryland 8 Digit Watersheds shapefile (swsub). Selected attributes were Loch Raven Reservoir, Pretty Boy Reservoir, Liberty Reservoir, Brighton Dam, and Rocky Gorge Dam, the watersheds of reservoirs used for water supply in Maryland.
2. Create New Coverage Based on Selection used, created new coverage swsub selection.
3. Extract by Mask tool was run on the 30 m LiDAR raster using swsub selection as the mask to create new raster coverage, ReservoirCanopy.
4. Raster Calculator used to multiply Reservoir Canopy to perform the following calculation: Value/900 * 304.2 $/900 m, resulting raster entitled SWTC2Final.

6. STORMWATER MITIGATION MODEL SUMMARY

6.1 Input Data

1) Lidar-derived Percent Tree Canopy (30 m) with Aberdeen from NLCD

   http://carbonmonitoring.umd.edu/index.html

   http://carbonmonitoring.umd.edu/map.html

2) NHD Hydrography dataset for Maryland

   https://nhd.usgs.gov/

3) Maryland Watershed Resource Registry Modified Model

   Inputs: National Elevation Dataset (NED) 30 m elevation
   http://imap.maryland.gov/Pages/lidar-dem-download-files.aspx
   Slope Rank 1-4
   DNR Wetlands
   NWI Wetlands
   NLCD Landcover/Impervious Cover
   Soil Drainage Class
   Working_Floodplain sw

4) Maryland Wetlands, merge of NWI and DNR, Wtlnd_m2

6.2 Procedure for Modified Model
Input the following factors into weighted sum- Is SteepSlope, IsWellDrained, IsWetland, IsFloodplain, Forested Near Stream or Waterbody, Is forested Near or In High Impervious Area, Scores evenly weighted then assigned into 5 categories using Jenks natural breaks.

a. Stormwater Methods: Forests and Wetlands

8. Run the modified WRR model resulting in 1-5 score for relative ability of natural lands ability to mitigate stormwater runoff (low to high), polygon coverage entitled h20pres2.
9. Polygon to Raster: Convert the sw score to a 30 raster, SWRankSlope.
10. Extract by Mask: Use 30mTree Canopy coverage as the mask, output= SWRSlopeCanopy
11. Reclassify: Reclassify SWRSlopeCanopy from -1, 1, 2, 3, 4, 5 to 0, 115, 172, 230, 287, 345, output is Reclass_SWRS1
12. Raster Calculator: Multiply Reclass_SWRS1 by Lidar Tree Canopy 30 m / 900, yields CanopySWaberdeen
13. Raster Calculator: Multiply Reclass_SWRS1 by Wtlnd_m2 / 900, yields, WetlandSWvalue
14. Use Mosaic to New Raster on CanopySWaberdeen and WetlandSWvalue, using maximum value, yields CanopyWetAllFinal

7. FOREST COVER MODIFICATION TO INCLUDE ABERDEEN PROVING GROUND

LiDAR data is not available for the Aberdeen military base region in Maryland due to no-fly restrictions. In order to include this region we added the portion of the NLCD tree canopy spatial dataset to the LiDAR derived tree canopy dataset.

7.1 Input Data

1) Lidar-derived Percent Tree Canopy (30 m)

   http://carbonmonitoring.umd.edu/index.html

   http://carbonmonitoring.umd.edu/map.html

2) National Land Cover Database Percent Tree Canopy (30 m)
   https://www.mrlc.gov/nlcd11_data.php

3) Shapefile of military installations, DNR internal geodata

7.2 Procedure

1. Extract by Mask was used to reduce the NLCD tree canopy raster to the area of Maryland.

2. Raster calculator was used to convert the percentage value in the NLCD coverage to m^2 of tree canopy (Value*9). The shapefile of Military installations (SWplfe_Military) was reduced to only Aberdeen Proving ground by selecting by attributes and creating a new shapefile from selected features.

3. Resulting shapefile did not cover the entire missing region of the Lidar derived tree canopy so the edit polygon feature was used to reshape the polygon so the entire missing region was covered.

4. Extract by Mask was used on the NLCD tree canopy coverage for Maryland using the shapefile for the Aberdeen region, resulting in a 30 m tree canopy coverage for the Aberdeen area.

5. Mosaic to New Raster was then run on the LiDAR derived percent tree canopy coverage and the extracted NLCD tree canopy coverage for the Aberdeen Region, using the Snap to Raster feature under the environments tab on the Mosaic to New Raster tool.

References

Chesapeake Bay Program. 2008. Quantifying the Role of Wetlands in Achieving Nutrient and Sediment Reductions in Chesapeake Bay. Chesapeake Bay Program STAC Responsive Workshop. Sponsored by the Chesapeake Bay Program's Land Growth and Stewardship, and Living Resources Subcommittees

Cowardin, L. M., V. Carter, F. C. Golet, and E.T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. FWS/OBS-79/31, U.S. Department of Interior, Fish and Wildlife Service, Washington, D.C.

Goodale, C.L.,Lajtha,K.,Nadelhoffer,K.J.,Boyer,E.W.,Jaworski,N.A.,2002.Forest nitrogen sinks in large eastern U.S. watersheds: estimates from forest inventory and an ecosystem model. Biogeochemistry 57/58, 239–266.

Hirabayashi, S. 2014. i-Tree Canopy Air Pollutant Removal and Monetary Value Model Descriptions. The Davey Institute, 5 Moon Library, State University of New York, Syracuse, New York 13210, United States

Hirabayashi, S and David Nowak. 2016. Comprehensive national database of tree effects on air quality and human health in the United States. Environmental Pollution 215 (2016) 48-57

i-Tree Landscape Methods, Limitations and Uncertainties. https://www.itreetools.org/landscape/resources/Landscape_Methods.pdf

Kemp, Michael. 2006. Monie Bay NERR Site Literature Review and Synthesis. Report Submitted to Maryland Department of Natural Resources.

Nowak, D.J., E.J. Greenfield. 2010. Evaluating the National Land Cover Database tree canopy and impervious cover estimates across the conterminous United States: A comparison with photointerpreted estimates. Environmental Management. 46: 378-390.

Merrill, Jennifer and Jeffery Cornwell. 2000. The Role of Oligohaline Marshes in Estaurine Nutrient Cycling. Weinstein MP, Kreeger DA, eds. Concepts and Controversies in Tidal Marsh Ecology. Dordecht, The Netherlands: Kluwer Academic Publishers, Springer, 2000, pp. 425-442.

Nowak, D.J., E.J. Greenfield, R. Hoehn, and E. LaPoint. 2013. Carbon storage and sequestration by trees in urban and community areas of the United States. Environmental Pollution. 178: 229-236.

Nowak, D.J. S. Hirabayashi, E. Ellis and E.J. Greenfield. 2014. Tree and forest effects on air quality and human health in the United States. Environmental Pollution 193:119-129

Thomas, Cassondra R., Christian, Robert R. 2001. Comparison of nitrogen cycling in salt marsh zones related to sea-level rise. MARINE ECOLOGY PROGRESS SERIES. Vol. 221: 1–16, 2001