Mapping Ecosystem Services in Maryland to Inform Decision Making

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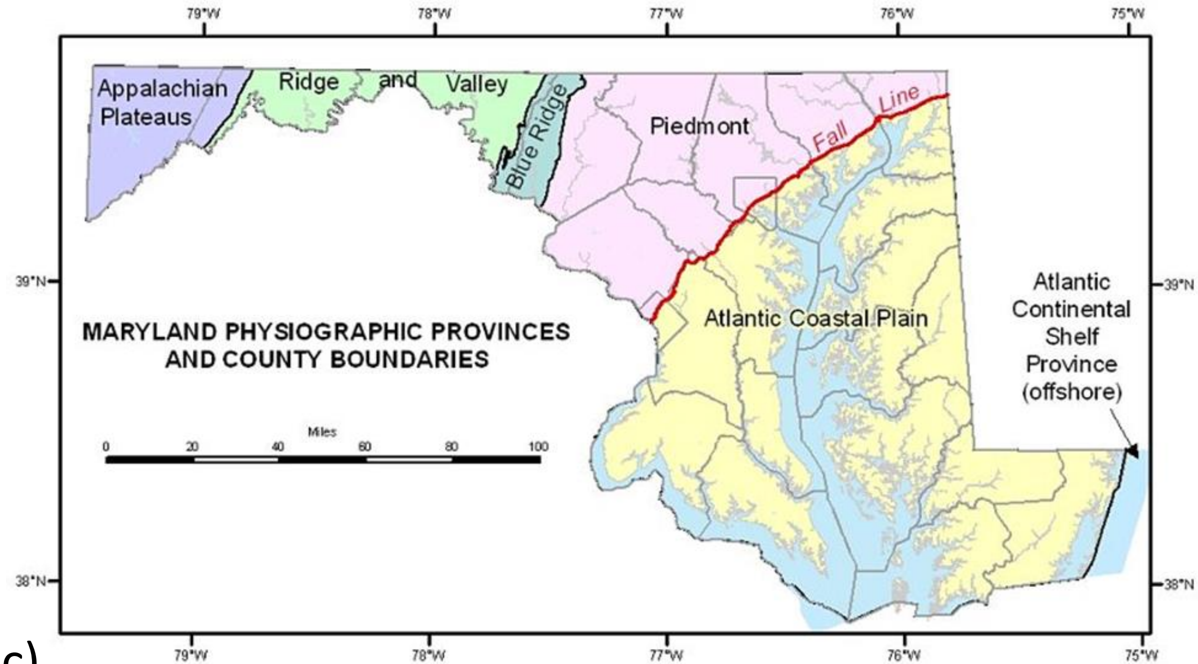
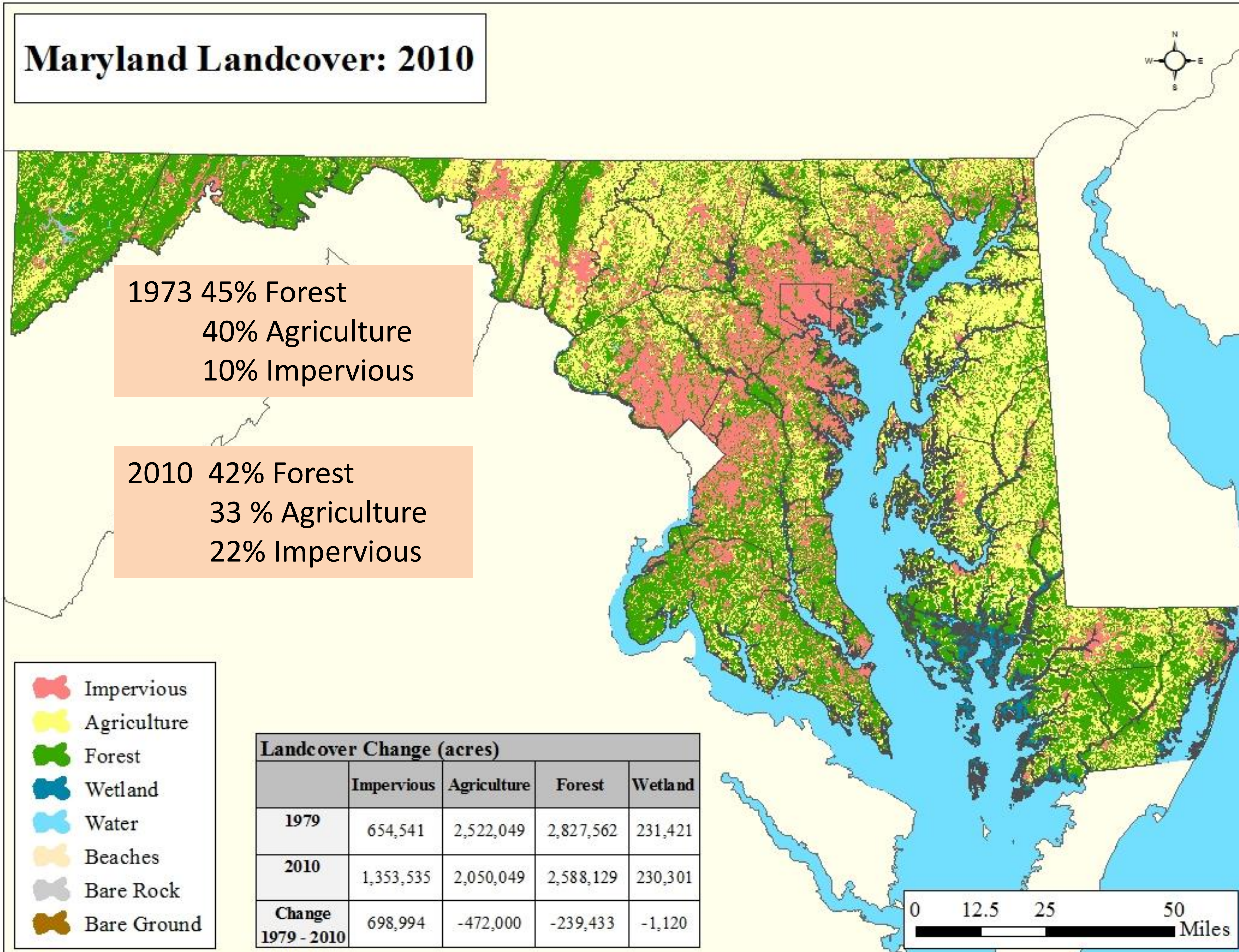
Outline

1. Introduction to Maryland
2. Ecosystem Services
3. Mapping and Valuation Methods Used
4. Results
5. Demonstration of the Parcel Evaluator Tool

State of Maryland

- 8^{th} Smallest State in US
- 6 million residents
- 6^{th} most densely populated state in the US
- Physiographically diverse
- 41% forested (~2.5 million ac)
- 9.5% wetlands
  - 5.4% palustrine
    - (343,000 ac)
  - 4.1% estuarine
    - (252,000 ac)





Landcover Change (acres)				
	Impervious	Agriculture	Forest	Wetland
1979	654,541	2,522,049	2,827,562	231,421
2010	1,353,535	2,050,049	2,588,129	230,301
Change 1979 - 2010	698,994	-472,000	-239,433	-1,120

State of Ecosystem Services in Government

- Many federal agencies have efforts to quantify ecosystem services (e.g. EPA's EnviroAtlas, USGS's SoLVES, USDA OEM, NOAA, NESP Guidebook)
- Few states have similar efforts within state government (Oregon's Willamette Partnership)
- Maryland has maintained interest in ES (2011 Ecosystem Service Working Group Report)
- **Charge: Create tool to allow ES to be integrated into State of Maryland decision making**

Ecosystem Services

Broadly- "*Benefits gained by people from the environment*"

Many typologies of ecosystem services exist BUT

Practical definition for decision making-
"*Benefits gained by people from the environment that are not already being paid for in a market and are contributing to a marginal increase in human well-being*"

i.e.
"*Final Ecosystem Services*"

Non-market monetary valuation can depend on the perspective From which you are doing the valuation, intended applications (the State of Maryland here)

How Do We Value Ecosystem Services?

- Assessing economic value (i.e. willingness to pay) for ES is difficult because in most cases a market does not exist (contingent valuation, hedonic pricing, travel cost, etc. are often used)

- Other methods try and assess social preference for ES in a non-economic way (deliberative monetary valuation)

- Studies that only assess biophysical aspect of ES sometimes assess services, usually assess function

- All of these options typically miss the vital connection between sustainability of a resource and the contribution it makes to human well-being

Ecosystem Services

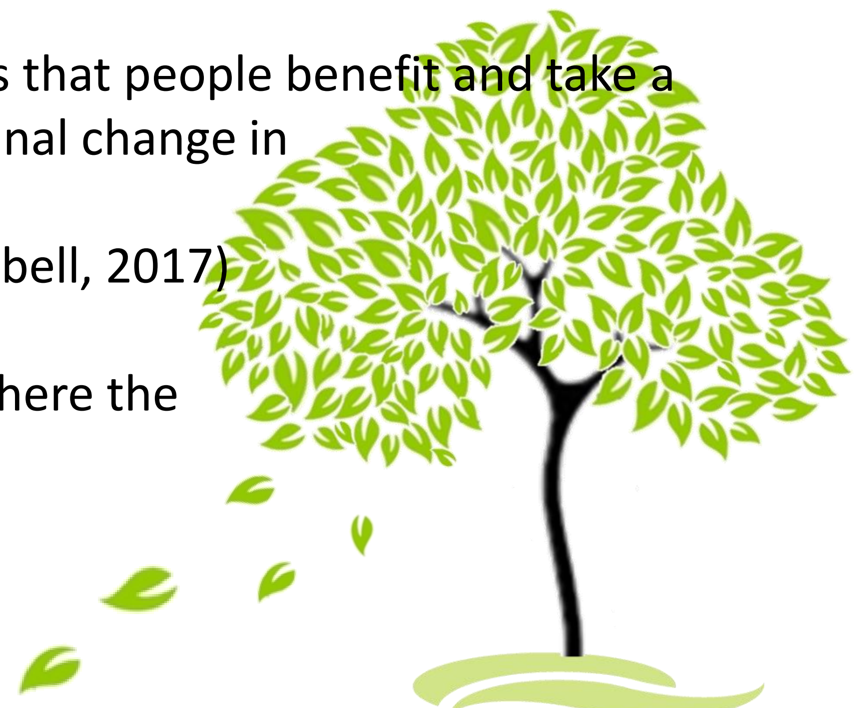
Benefit Relevant Indicators (BRI)- “measurable indicators that capture this connection by considering whether there is demand for the service, how much it is used (for use values) or enjoyed/valued (for nonuse values)” Olander et al. 2016

Quantifying how people benefit from a BRI can be difficult, particularly at the landscape scale

One potential solution is to look at many ways that people benefit and take a categorical average of how we pay for a marginal change in
The BRI
(we term this the “eco-price” method – Campbell, 2017)

We use this method for ecosystem services where the
Value is uncertain

Incorporates the range of possible values



Methodology: Eco-Price

- Ecosystem services are paid for in many different ways

- People view responsibility for providing ecosystem services to be a collective obligation- survey results, Public Trust Doctrine (Ruhl and Salzman 2006)

- We look at the many different ways society invests in protecting or replacing the environment

  - In a market
  - Cost of restoration
  - Through mitigation fees
  - Cost to regulate

Assesses the Social Value for decision making

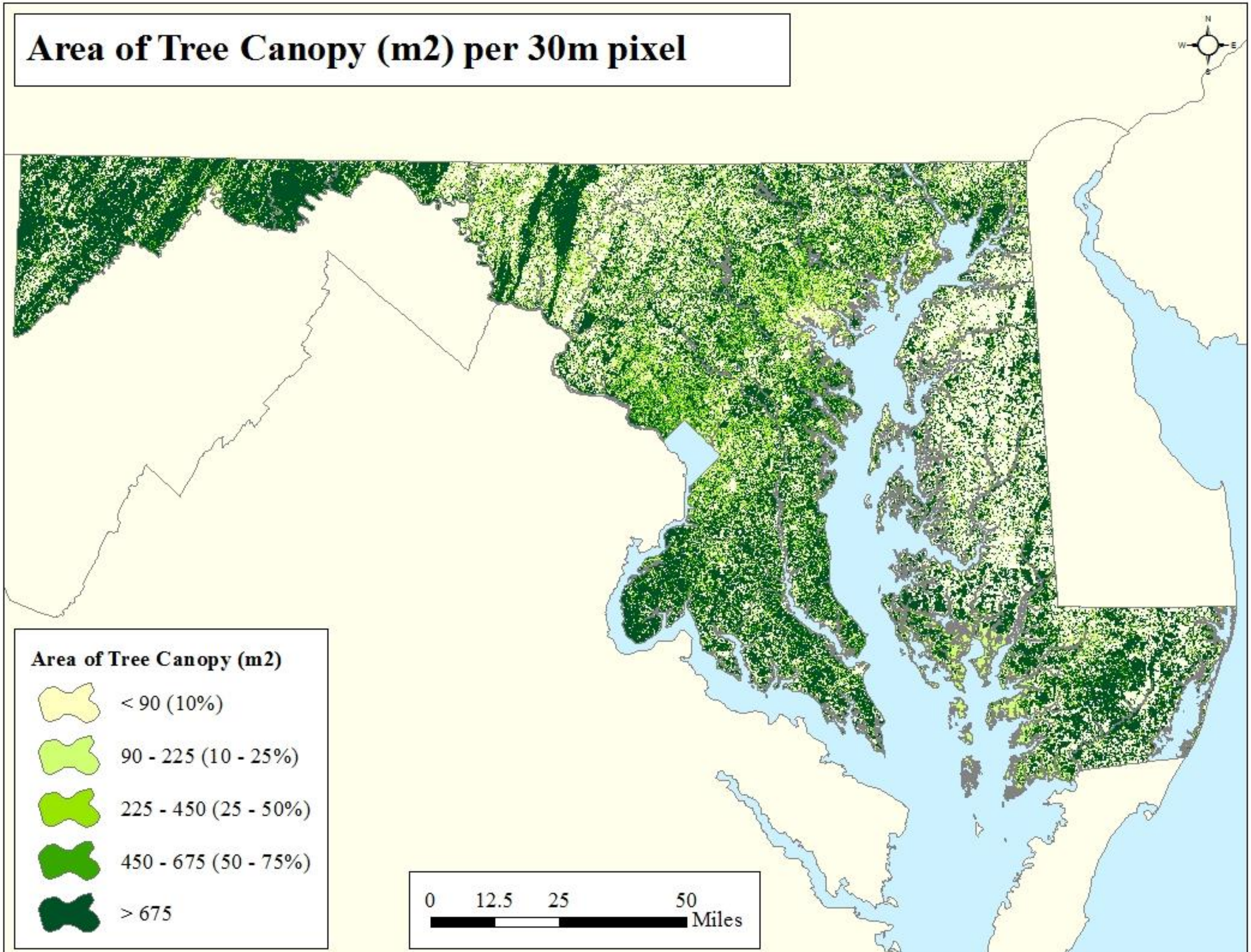
≠ Market Value

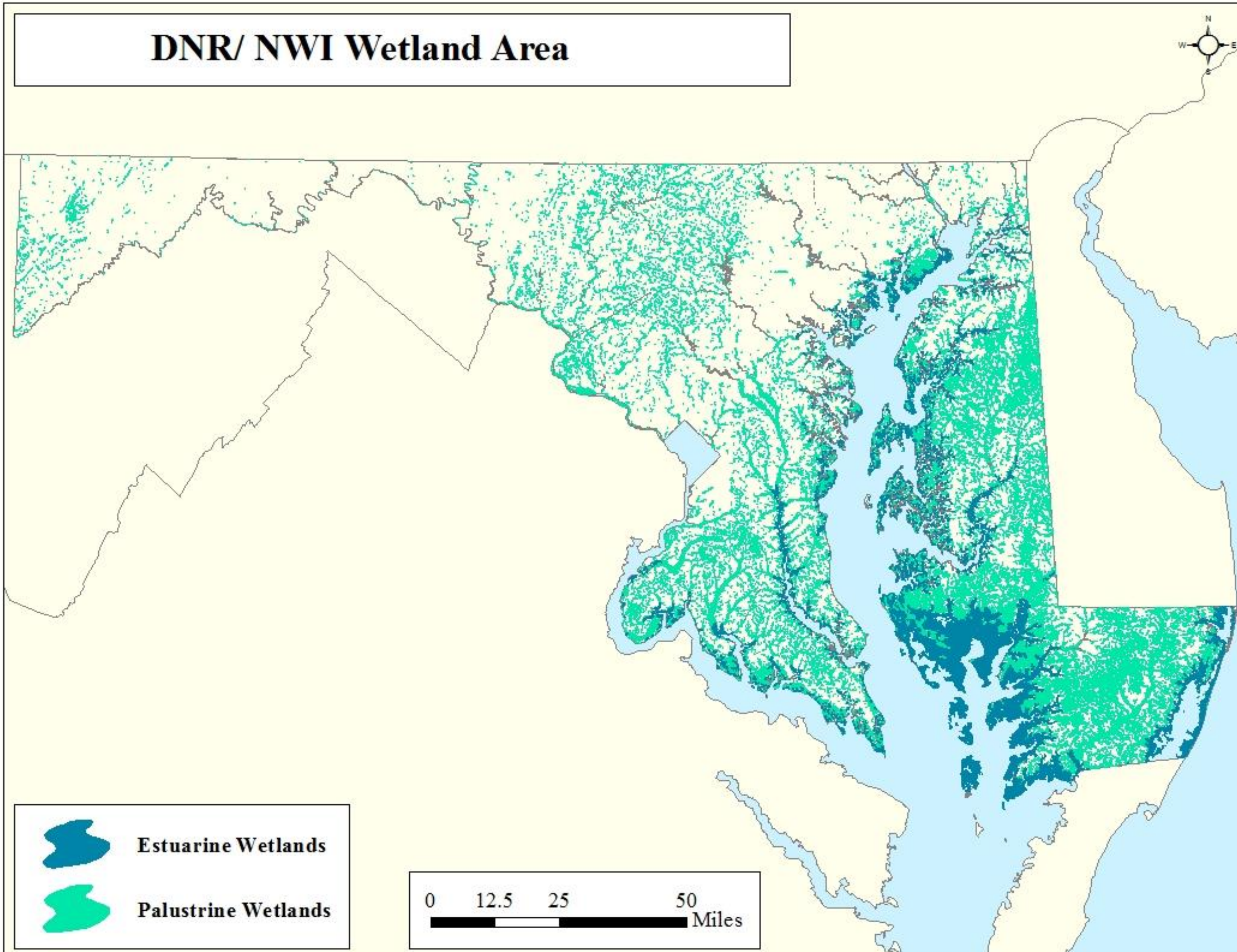
Mapping Ecosystem Services

- Ecosystem Services vary spatially across the landscape
- ES vary in the biophysical supply of the service, i.e. benefit relevant indicator (e.g. amount of carbon that is sequestered, water being recharged to aquifers)
- ES vary in the way and amount that people benefit (e.g. number of people and value of infrastructure vulnerable to flooding)
- We attempt to consider both sources of variation when mapping ES in Maryland

Mapping Ecosystem Services

- Air Pollution Removal
- Net Carbon Sequestration
- Groundwater Recharge
- Surface Water Protection
- Flood Prevention and Stormwater Mitigation
- Nitrogen Removal
- Wildlife Habitat and Biodiversity


Area of Tree Canopy (m2) per 30m pixel
N
W
E
S
Area of Tree Canopy (m2)
< 90 (10%)
90 - 225 (10 - 25%)
225 - 450 (25 - 50%)
450 - 675 (50 - 75%)
> 675
0 12.5 25 50
Miles


DNR/ NWI Wetland Area
Estuarine Wetlands
Palustrine Wetlands
0
12.5
25
50
Miles
N
W
E
S

Air Pollution

- Used i-Tree Landscape, which models the uptake of 6 atmospheric pollutants:
  - Carbon Monoxide (CO)
  - Nitrogen Dioxide (NO2)
  - Sulfur Dioxide (SO2)
  - Ozone (O3)
  - Particulate Matter 10 (PM 10)
  - Particulate Matter 2.5 (PM 2.5)

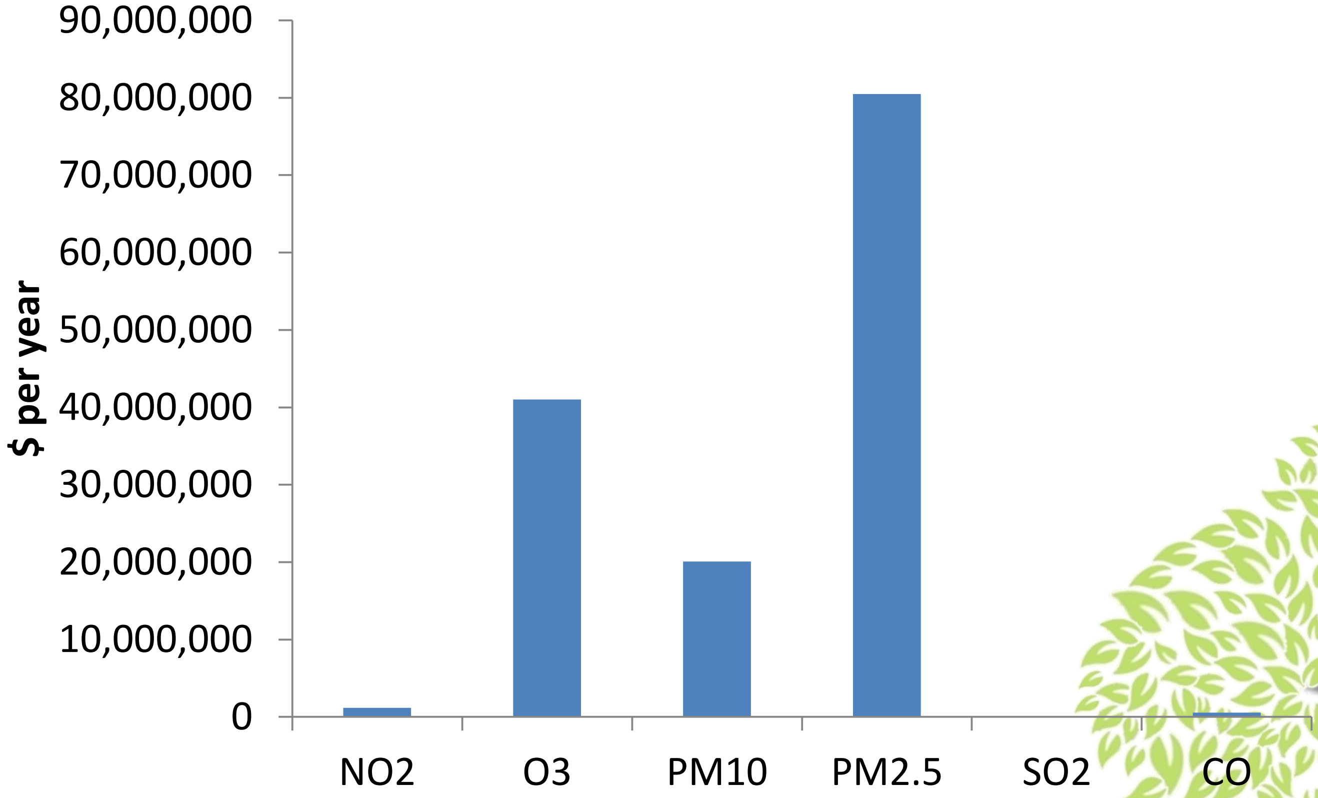
- Applied USFS i-Tree Landscape pollution removal coefficients at the Census block group level to updated % tree canopy extent data.

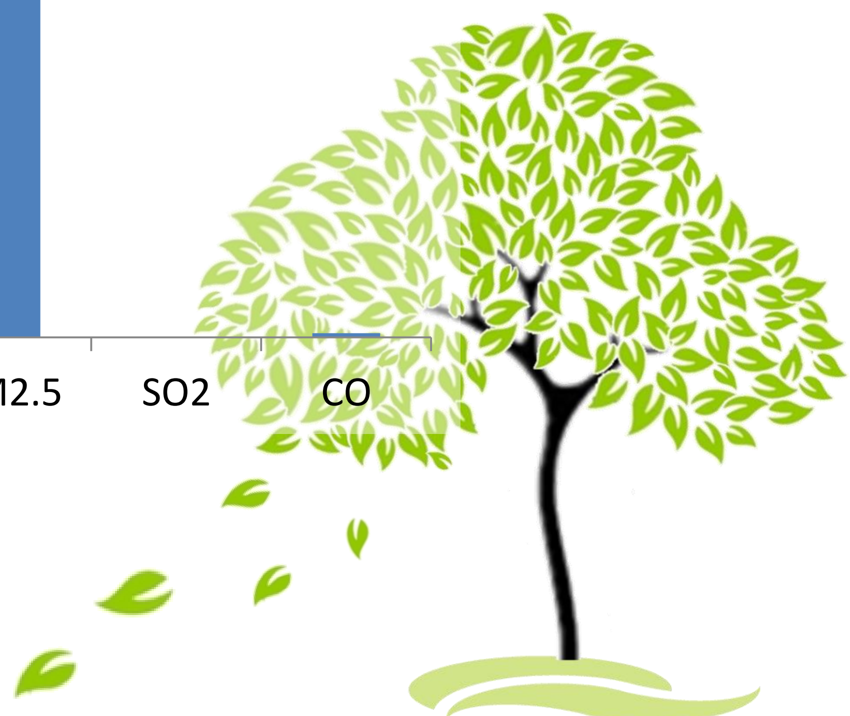
- The amount of pollution removed varies geographically based on the % tree canopy per area, as well as the relative level of the given pollutant in the atmosphere. This effect is typically greater in urban areas, due to higher concentrations of air pollution in urban areas.

i-Tree Landscape

https://landscape.itreetools.org/

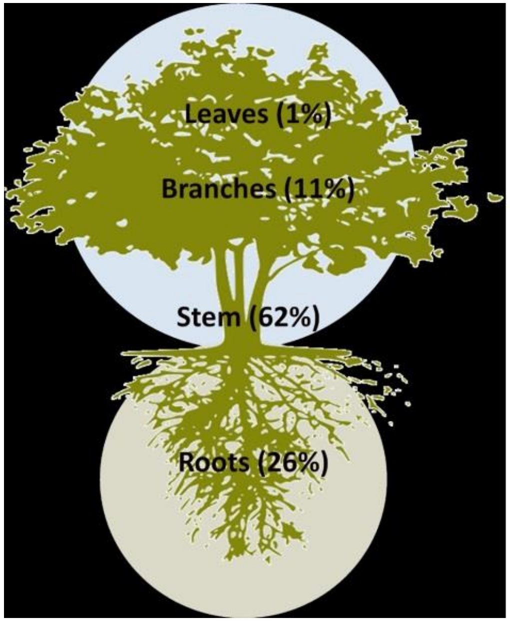
Benefit of Air Pollutant Removal





Carbon Sequestration – Forests

- Built a model of net carbon sequestration in forest and wetland areas across Maryland at the 30m scale.
- Applied USFS i-Tree Landscape carbon sequestration coefficients at the Census block group level to updated % tree canopy extent data.
- The rate and amount of carbon sequestration within forests varies spatially across Maryland. The primary sources of variation in forested areas are tree age and species composition
  - Sequestration increases exponential in the first 30 years, slowing and plateauing as trees reach maturity.
  - Deciduous trees such as oaks and hickories sequestering more carbon than do evergreen trees such as pines and hemlocks.
- Carbon sequestration rates were taken extracted from i-Tree Landscape ranged from 0.4 Mt per ha to 3 Mt per ha



https://landscape.itreetools.org/

Carbon Sequestration – Wetlands

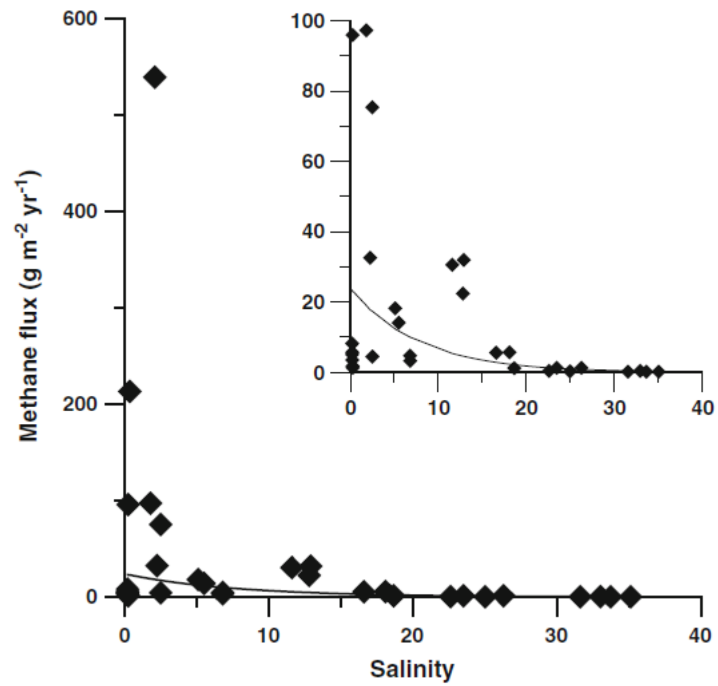
- Developed new model of NET carbon sequestration in wetland areas across the state of Maryland.

- The rate and amount of carbon sequestration and methane emissions within wetlands varies spatially across Maryland, by wetland type and along a gradient of water salinity.

- Derived average rates of carbon sequestration and methane emissions across different wetland types (estuarine and palustrine) and salinity types (fresh, oligohaline, mesohaline) based on field data for the Chesapeake Bay region published in scientific literature. (121 and 34 sites respectively)

- Carbon sequestration rates were taken extracted from iTree Landscape ranged from 0.4 Mt per ha to 3 Mt per ha

- Valued carbon using the US EPA's Social Cost of Carbon, $143 per mt



Tidal marsh methane emissions versus salinity from published sources and field sites in Maryland (Poffenbarger, 2011)

Net Carbon Sequestration – Wetlands

Carbon Sequestration

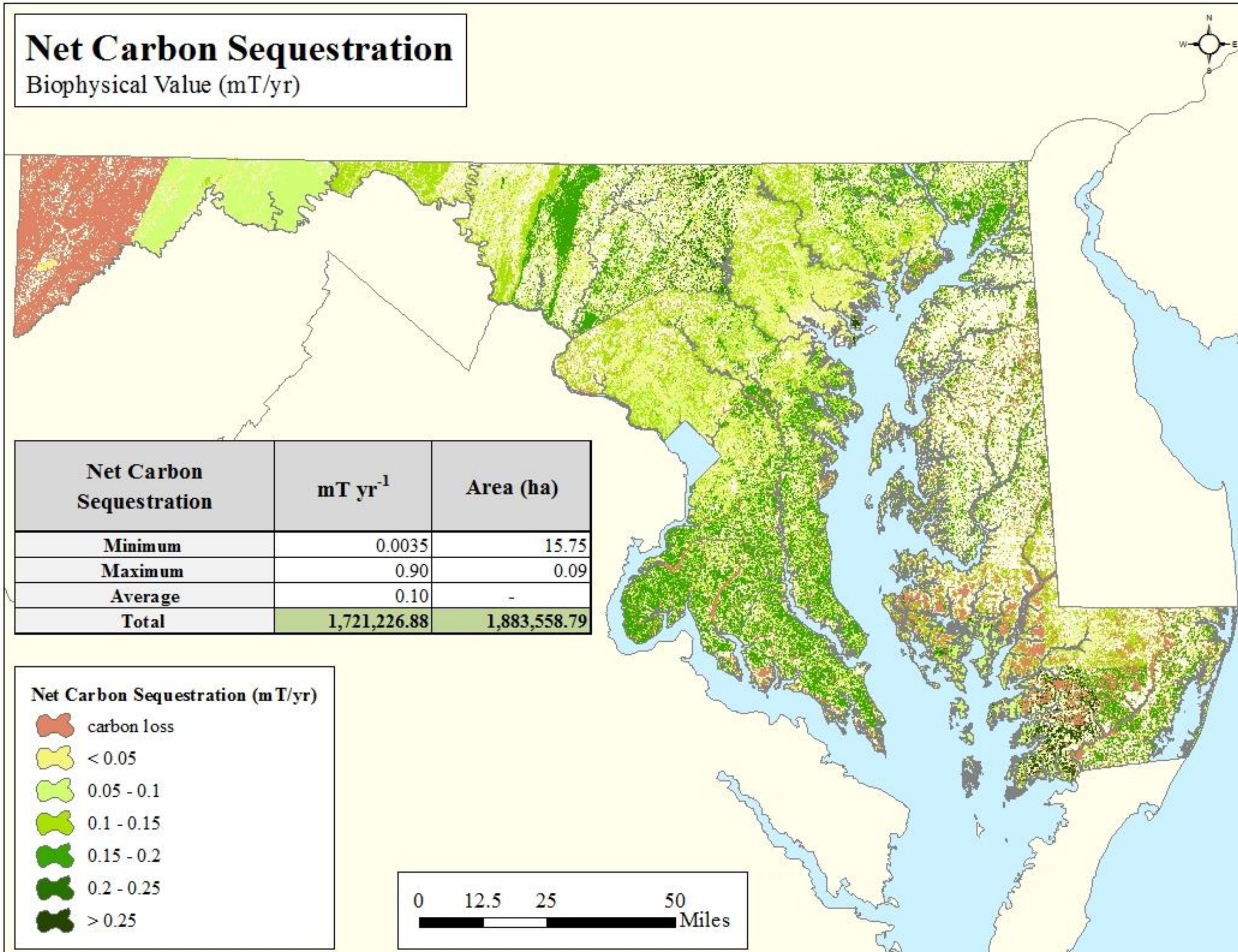
Wetland System	N Sites	Mean C Rate (g/m2/yr)	Mean C Rate (MT/ha/yr)	Deviation
Estuarine				
Fresh	30	391.72	3.92	2.46
Oligohaline	15	293.01	2.93	1.47
Mesohaline	47	206.70	2.07	0.61
Palustrine				
Emergent	11	333.41	3.33	1.87
Forested	18	106.15	1.06	-0.40
Verificed Carbon Standard (VCS) Average[28]			1.46	

Methane Emissions

Salinity Class	*N Sites*	*Mean (MT ha⁻¹yr⁻¹)*	*CO2 equiv (MT ha⁻¹yr⁻¹)*	*C equiv (MT ha⁻¹yr⁻¹)*	*C equiv (g m⁻²yr⁻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*	*0.192*	*4.8*	*1.3079*	*130.79*
Polyhaline *(> 18 ppt)*	*6*	*0.0085*	*0.2125*	*0.0579*	*5.79*

Net Carbon Sequestration

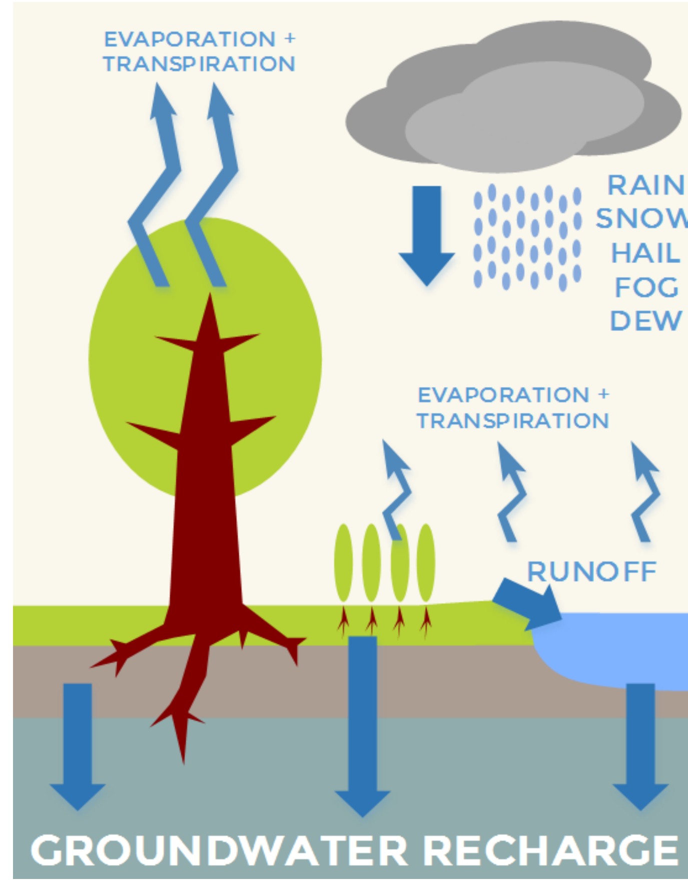
Biophysical Value (mT/yr)



Net Carbon Sequestration	mT yr^{-1}	Area (ha)
Minimum	0.0035	15.75
Maximum	0.90	0.09
Average	0.10	-
Total	**1,721,226.88**	**1,883,558.79**

Groundwater Recharge

- Used the “Estimated Mean Annual Natural Groundwater Recharge, 2002” for MRB1 Catchments (mid-Atlantic)
- This layer was specifically created to estimate the mean annual natural groundwater recharge, in millimeters, per watershed catchment segment in the application of the national SPAtially Referenced Regression On Watershed attributes (SPARROW) model.
- Converted groundwater estimates to m^3 per 30m pixel.
- The underlying geology across the landscape is the primary driver of the rate that water enters unconfined and confined aquifers. The amount of impervious surface and soil condition also affect the amount of water reaching aquifers.

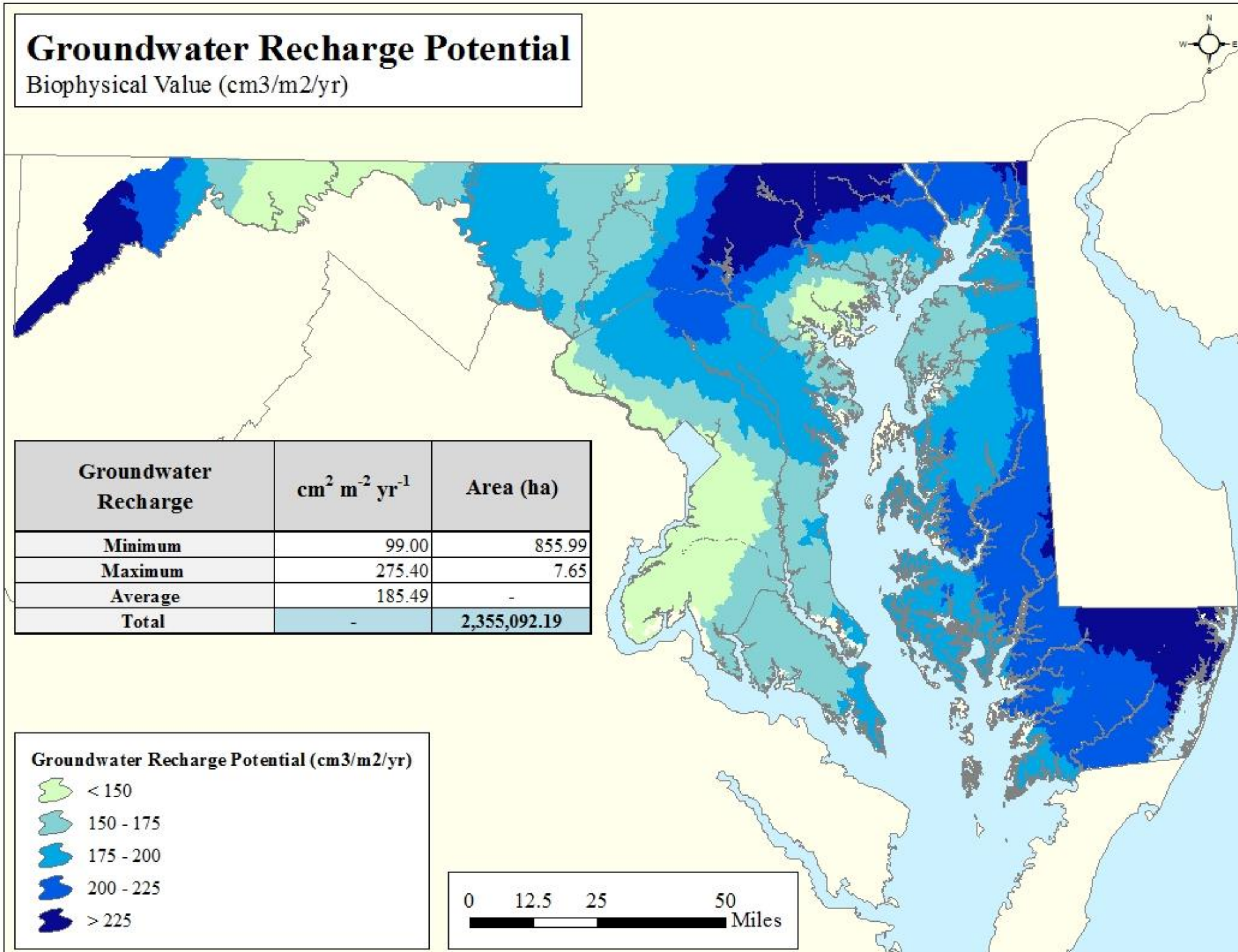


USGS science for a changing world
Water Resources NSDI Node

https://water.usgs.gov/GIS/metadata/usgswrd/XML/mrb_e2rf1_recharge.xml

Groundwater Recharge Potential

Biophysical Value (cm3/m2/yr)



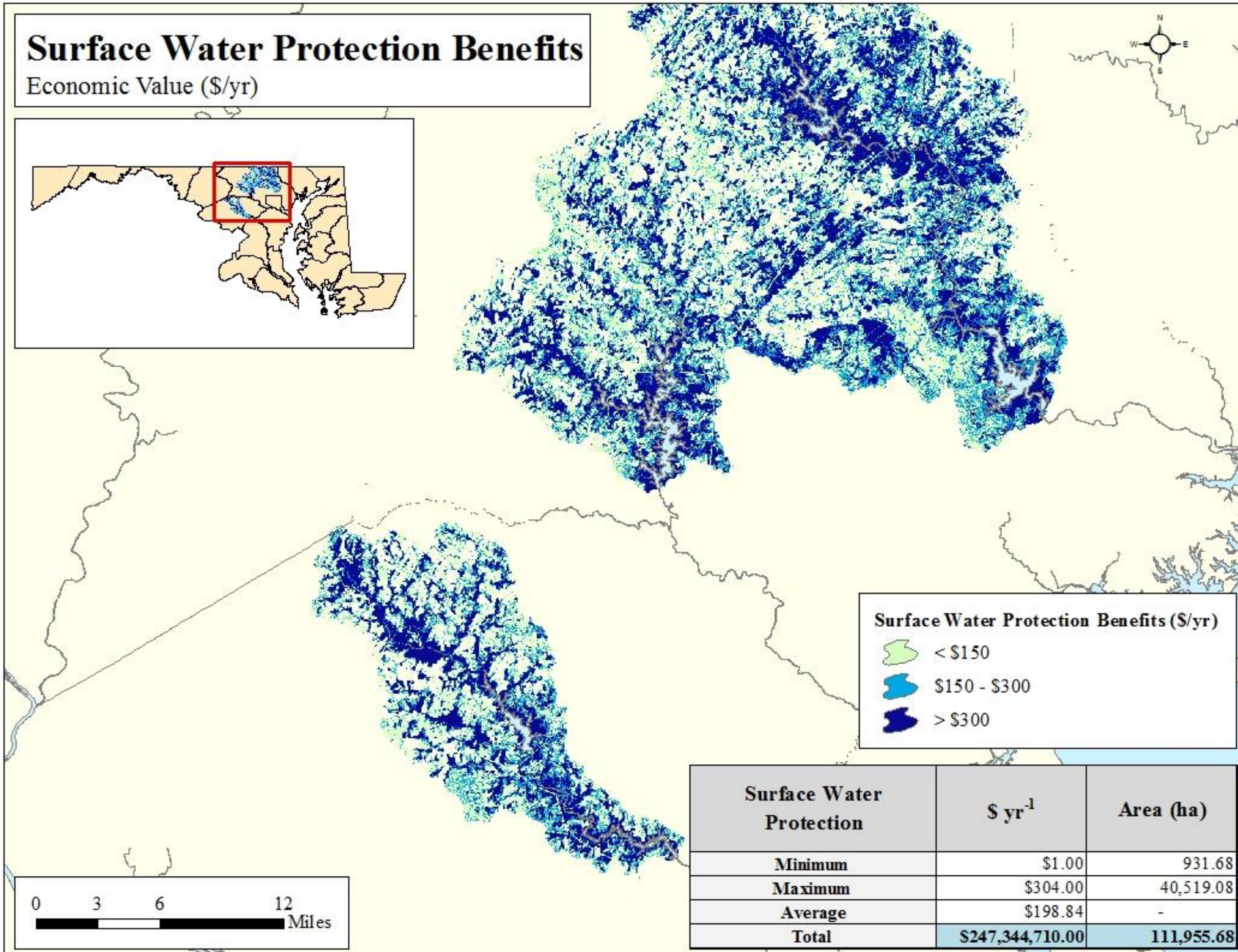
Groundwater Recharge	$cm^2\ m^{-2}\ yr^{-1}$	Area (ha)
Minimum	99.00	855.99
Maximum	275.40	7.65
Average	185.49	-
Total	-	2,355,092.19

Groundwater Recharge Eco-Price

Biophysical Category and Measure	Eco-Price	Units	Exchange Classification	
Municipal water supply	0.79	$ per m^3	Market Price	WSSC 2014
Investment in Watershed Protection	0.084	$/$m^3$ of water supply	Investment	NYC 2014, BCDPW 2015
Average for recreation	0.073	$ per m^3	Non-market Analysis	Reardon 2007, Roland, unpub
Average for Groundwater	$0.35	$ per m^3	•	

Surface Water Protection

- Half of the water supply in Maryland is sourced from reservoirs.
- Natural lands reduce the cost to treat water from reservoirs to water supply standards
- Five major reservoirs in Maryland: Loch Raven, Liberty, Pretty Boy, Tridelphia, and Rocky Gorge



Surface Water Protection	$ yr^{-1}	Area (ha)
Minimum	$1.00	931.68
Maximum	$304.00	40,519.08
Average	$198.84	-
Total	$247,344,710.00	111,955.68

Surface Water Protection Eco-Price

	Eco-Price	Units	Exchange Classification	Reference
Water treatment costs reduced	$0.02	$/m^3	avoided cost	Elias et al. 2013, Warzniak 2016
Provision of municipal water in MD	$0.79	$/m^3 water supplied	market price	WSSC 2014
Costs avoided of upgrading to advanced treatment facility	$3.76	$/m^3	avoided cost	HDR 2013
Average for Surface water protection	$1.52	$/m^3		

Flood Prevention and Stormwater Mitigation

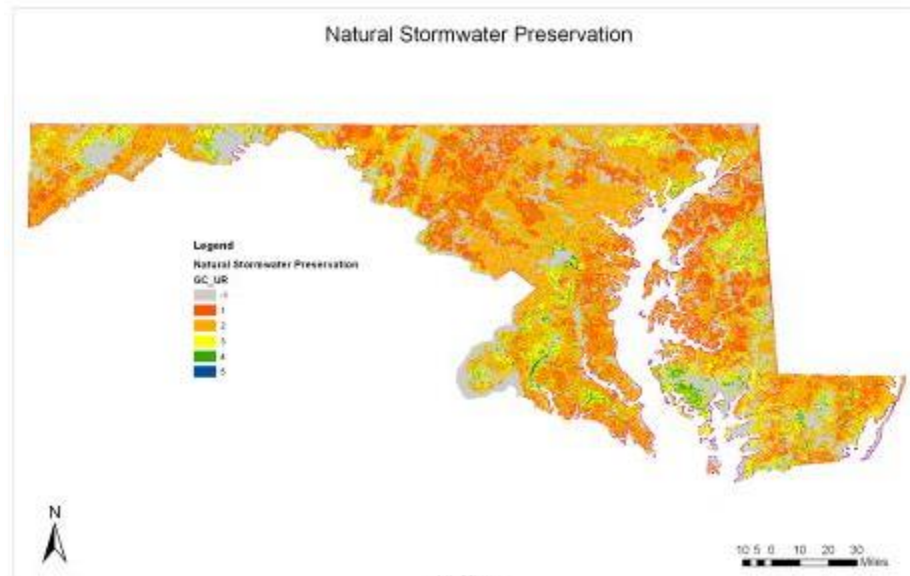
- Created an index that ranks areas based on the volume of storm water treated.

- Used a modified version of the Watershed Resource Registry Stormwater Preservation model to rank the relative capacity and stormwater load across the landscape from 1-5

- The model ranking algorithm was modified by removing targeting classifications from the model (targeted ecological areas, stronghold watershed, etc.) and adding a factor for slope of the landscape.

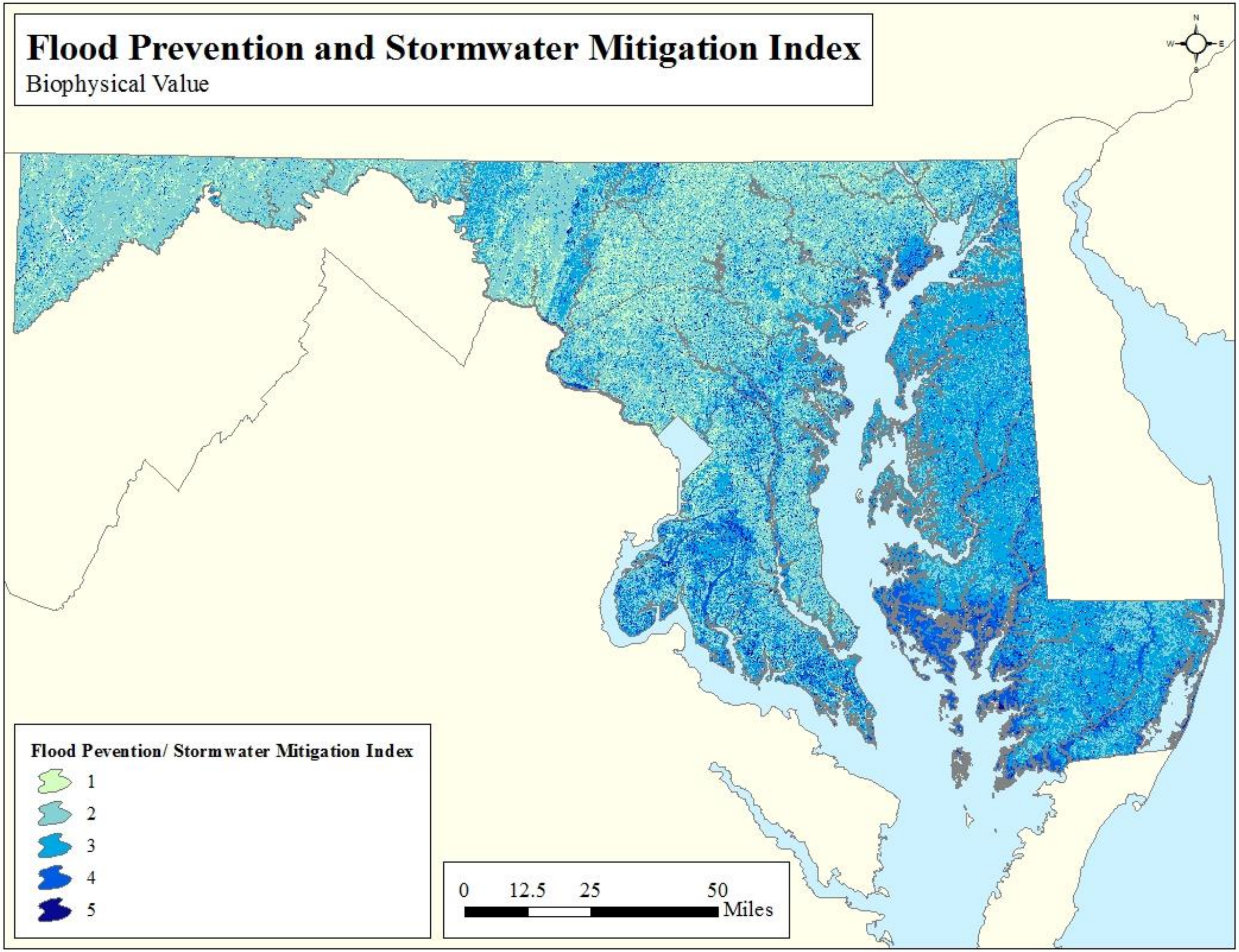
- The range of stormwater volumes treated was estimated using the Maryland Stormwater Design Manual and the Virginia Stormwater Management Handbook.

- Riparian areas, forests, and wetlands in watersheds with high impervious area upstream receive larger amounts of stormwater runoff. The type of soil, presence of floodplain, whether in a riparian area, type of wetland, and the impervious surface percentage of the surrounding watershed all factor into how much water runs off into the area and the ability of the area to absorb that water.



watershed resources registry

http://watershedresourcesregistry.com/detailsHp.html



Flood Prevention and Stormwater Mitigation Index
Biophysical Value
Flood Pevention/ Stormwater Mitigation Index
1
2
3
4
5
0
12.5
25
50
Miles
N
S
E
W

Stormwater Eco-Price

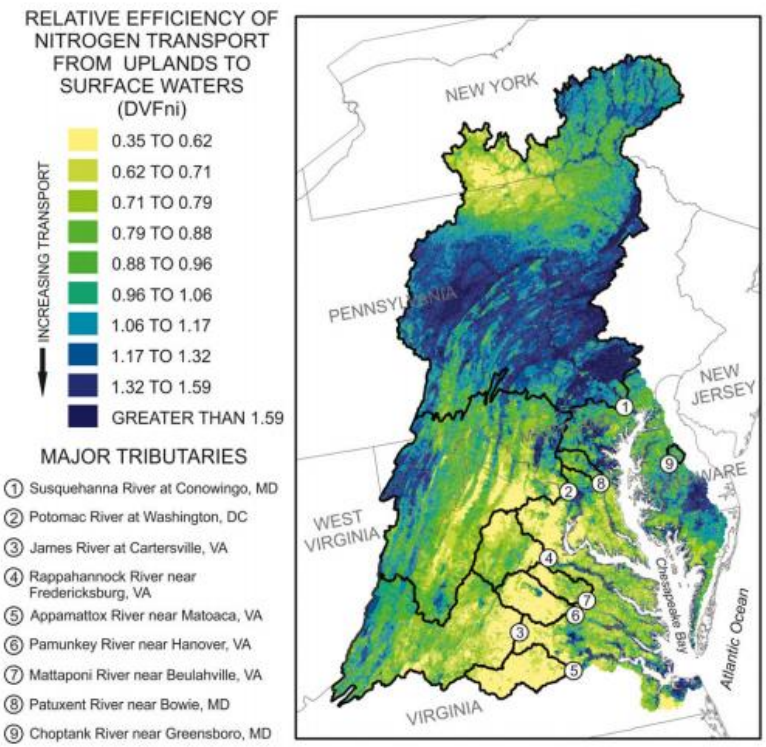
Biophysical Category and Measure	Eco-Price	Units	Exchange Classification
Flood insurance benefits	\$0.05	\$/m^3 runoff avoided	Cost Savings
Average Stormwater Remediation fee	\$0.18	\$/cubic meter (m^3) runoff	Tax
Average Replacement Cost Using BMPS	\$0.48	\$/m^3 stormwater	•
Average of Tax, Cost Savings, and Replacement Cost	\$0.33	\$/m^3 stormwater	•

Nitrogen Removal

• Used the USGS SPARROW (Spatially Referenced Regression on Watershed Attributes) model, which simulates the loading of nitrogen and phosphorus across the Chesapeake Bay watershed based on land-use, incoming nutrients from other watersheds, and atmospheric deposition.

• Classified catchments as having low, med, or high nitrogen loading.

• Calculated nitrogen uptake rates using average rates for low, medium, and high loading rates and landcover type based on published scientific literature. (Ator, 2011)



Ator and Garcia, 2016

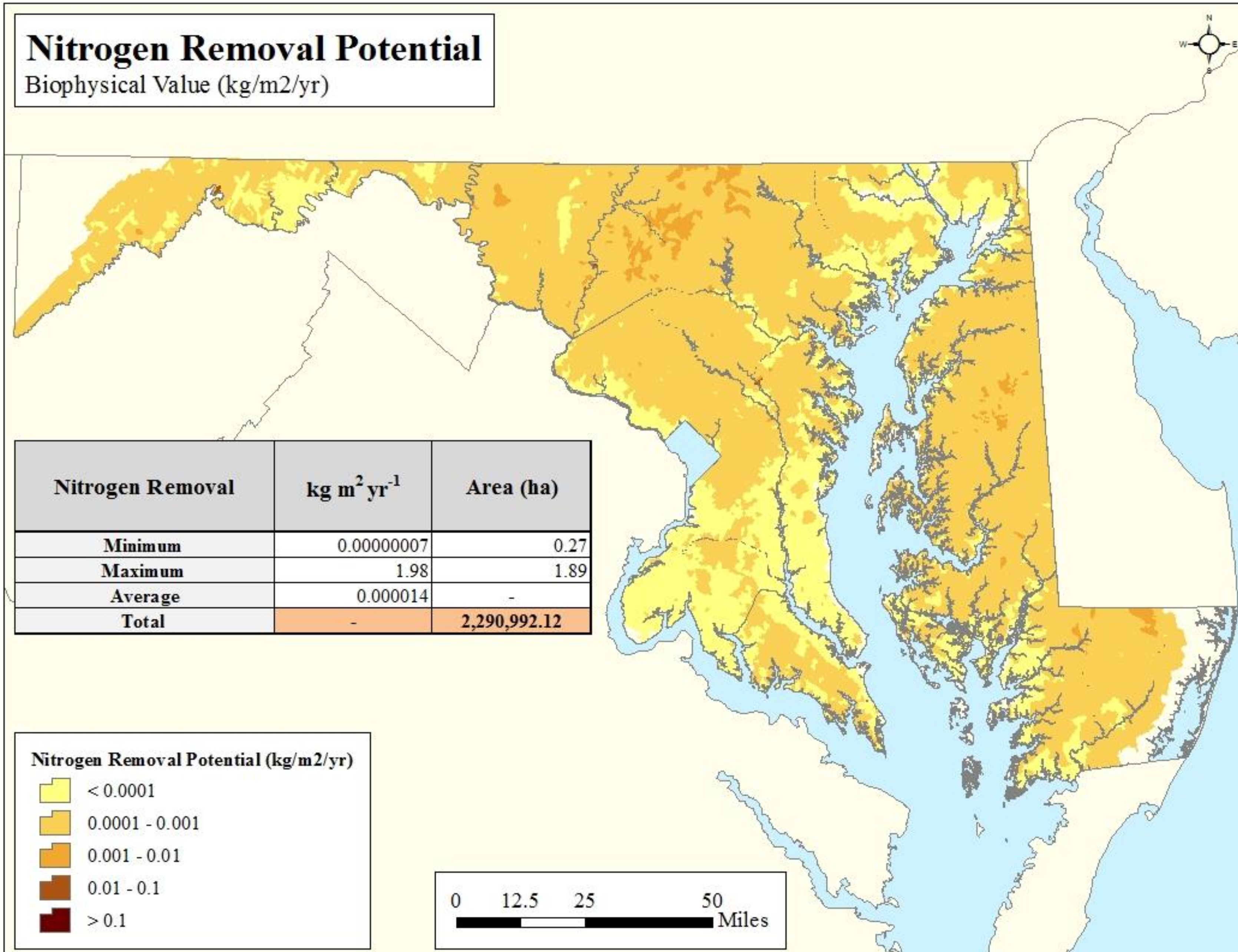
https://water.usgs.gov/nawqa/sparrow/#

Nitrogen Removal

- In palustrine wetlands, floodplains process and store higher quantities of nitrogen than isolated wetlands.

- In estuarine wetlands, salinity is a significant factor in the ability to process and store nitrogen, with more saline wetlands tending to be more efficient in nitrogen removal.

Ecosystem Type	Nitrogen Removal Rate	Reference
	kg/ha/yr	
Forest		
Low N Loading Watershed	5	CBP 2008[54]
Mid N Loading Watershed	10	CBP 2008
High N Loading Watershed	12	CBP 2008
Floodplains Wetlands		
Low N Loading Watershed	30	CBP 2008
Mid N Loading Watershed	80	CBP 2008
High N Loading Watershed	150	CBP 2008
Depressional Wetlands		
Low N Loading Watershed	10	CBP 2008
Mid N Loading Watershed	25	CBP 2008
High N Loading Watershed	50	CBP 2008
Estuarine Wetlands		
Tidal Fresh (0-2.5 ppt)	1750	Merrill & Cornwell 2000[55]
Brackish (2.5-18 ppt)	300	Merrill & Cornwell 2000, Kemp 2006[56]
Salt (18+ ppt)	900	Thomas & Christian 2001[57]



Nitrogen Removal	kg m^2 yr^{-1}	Area (ha)
Minimum	0.00000007	0.27
Maximum	1.98	1.89
Average	0.000014	-
Total	-	**2,290,992.12**

Nitrogen Removal Eco-Price

Biophysical Category and Measure	Eco-Price	Units	Exchange Classification
MD BMP Cost-Share Program	$3.67	$/kg N	Cost of regulation
Nutrient Trading in Chesapeake Bay Watershed	$8.38	$/kg N	Market price
Average for Nutrient Management BMPS	$31.97	Costs/kg N	Avoidance cost
Average for Nutrients	$18.34	$/kg N	

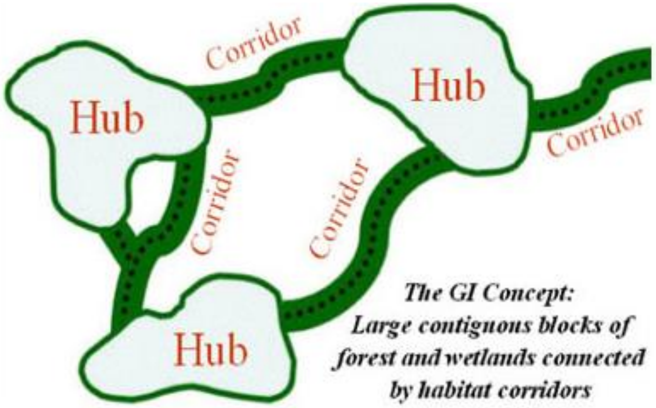
Wildlife Habitat and Biodiversity

- Created an index showing the wildlife habitat and biodiversity potential of each 30m pixel.

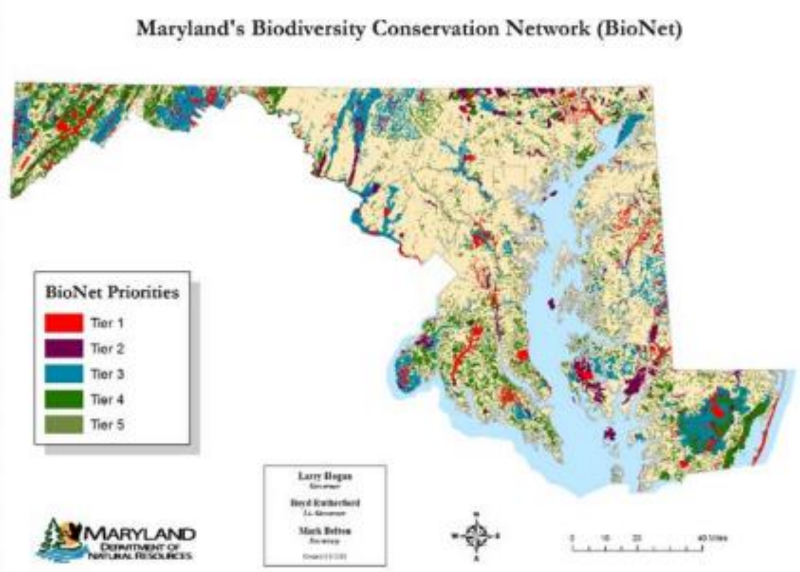
- Considered the size of habitats and the degree of habitat connectivity using the MD Green Infrastructure (GI) Model.
  - Land in the Green Infrastructure was assigned into quintiles based upon their score, and assigned corresponding values.

- Considered the presence of rare species or rare species habitats using the MD BioNet Model.
  - Land in the top two ranks of MD BioNet was assigned the 1st and 2nd quintile of value, respectively.

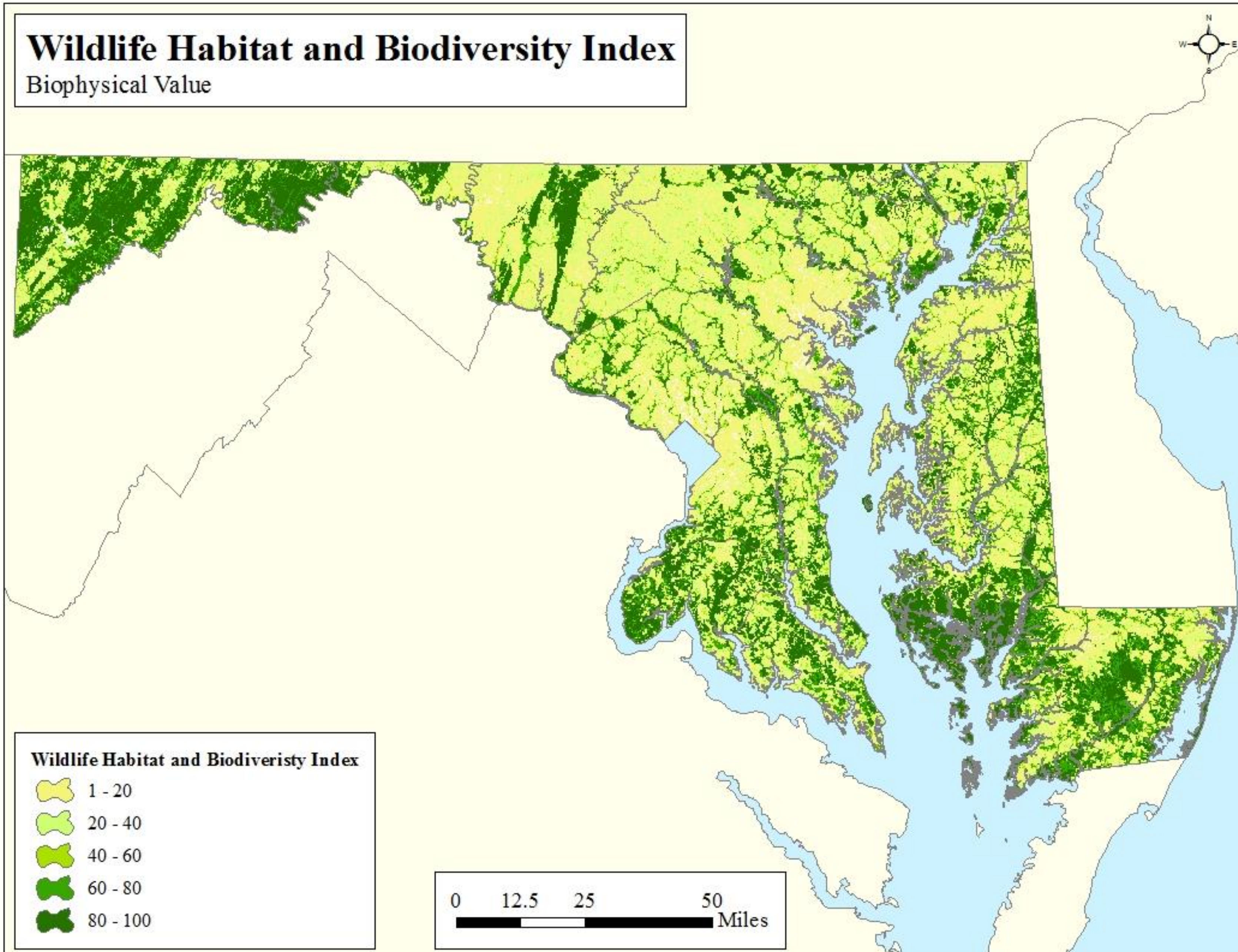
- Forests and wetlands occurring outside both models were given the lowest quintile value.



http://dnr.maryland.gov/land/Pages/Green-Infrastructure.aspx



http://dnr.maryland.gov/wildlife/Documents/BIONET_FactSheet.pdf


Wildlife Habitat and Biodiversity Index
Biophysical Value
N
W
E
S
Wildlife Habitat and Biodiveristy Index
1 - 20
20 - 40
40 - 60
60 - 80
80 - 100
0
12.5
25
50
Miles

Wildlife Habitat Eco-Price

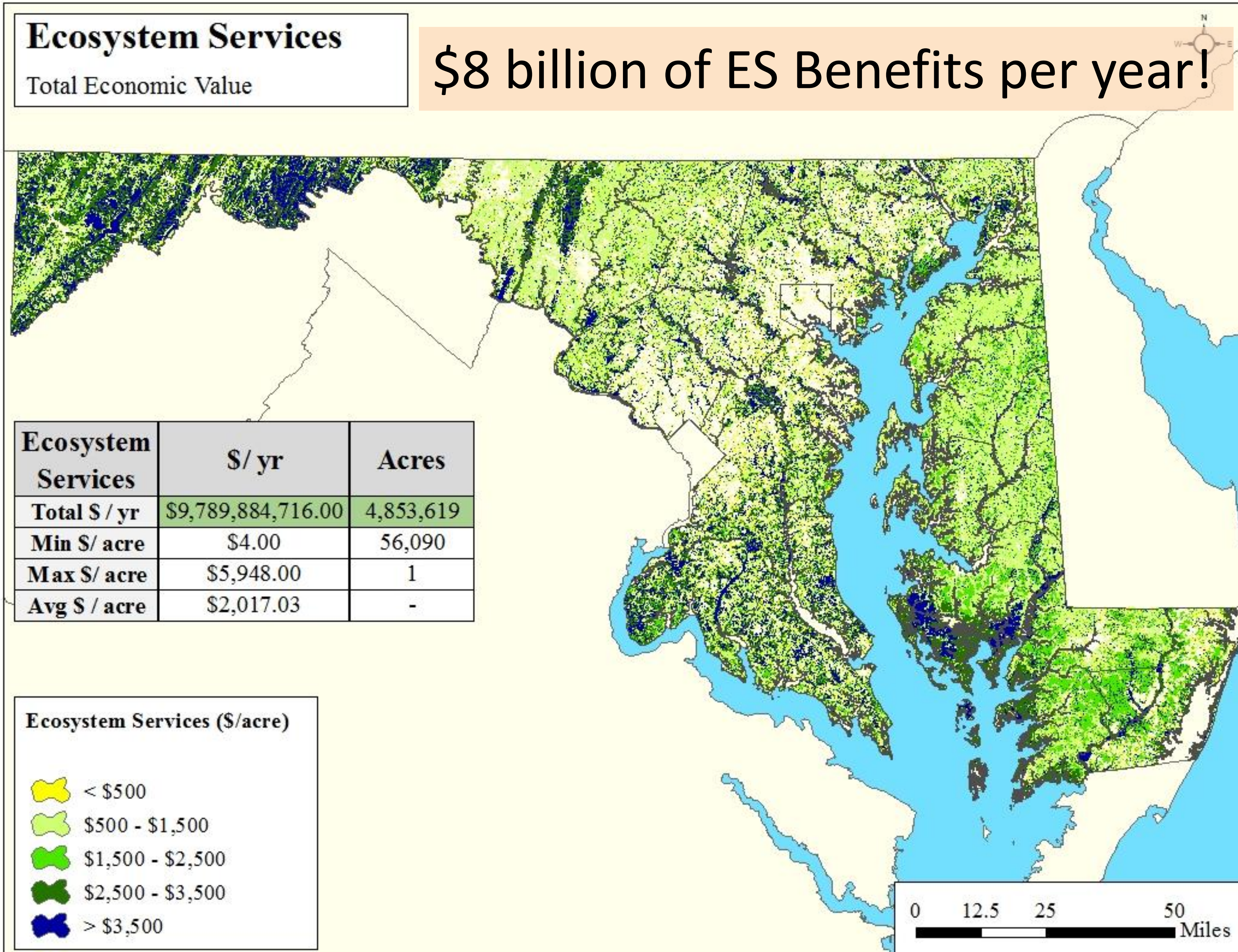
Biophysical Category and Measure	Eco-Price	Units	Exchange Classification
Wetland Reserve Program	$1,125	$/acre	Investment
Ducks Unlimited	$1,223	$/acre	Investment
Mid-Atlantic Conservation Fund	$1,726	$/acre	Investment
Habitat banking: Trout Conservation average	$3,499	$/acre	Cost of Regulation
Habitat banking: Delmarva Fox Squirrel Habitat	$5,748	$/acre	Cost of Regulation
Habitat Banking: Puritan Tiger Beetle	$6,025	$/acre	Cost of Regulation
Tax Benefit Conservation Enrollment in MD	$933	$/acre/yr	Tax benefit
Average Yearly Benefit (15 year time horizon, yearly tax benefit)	$1,023	$/acre/yr	
High Estimate (Tax benefit + Habitat Banking)	$1,282	$/acre/yr	•

Ecosystem Services

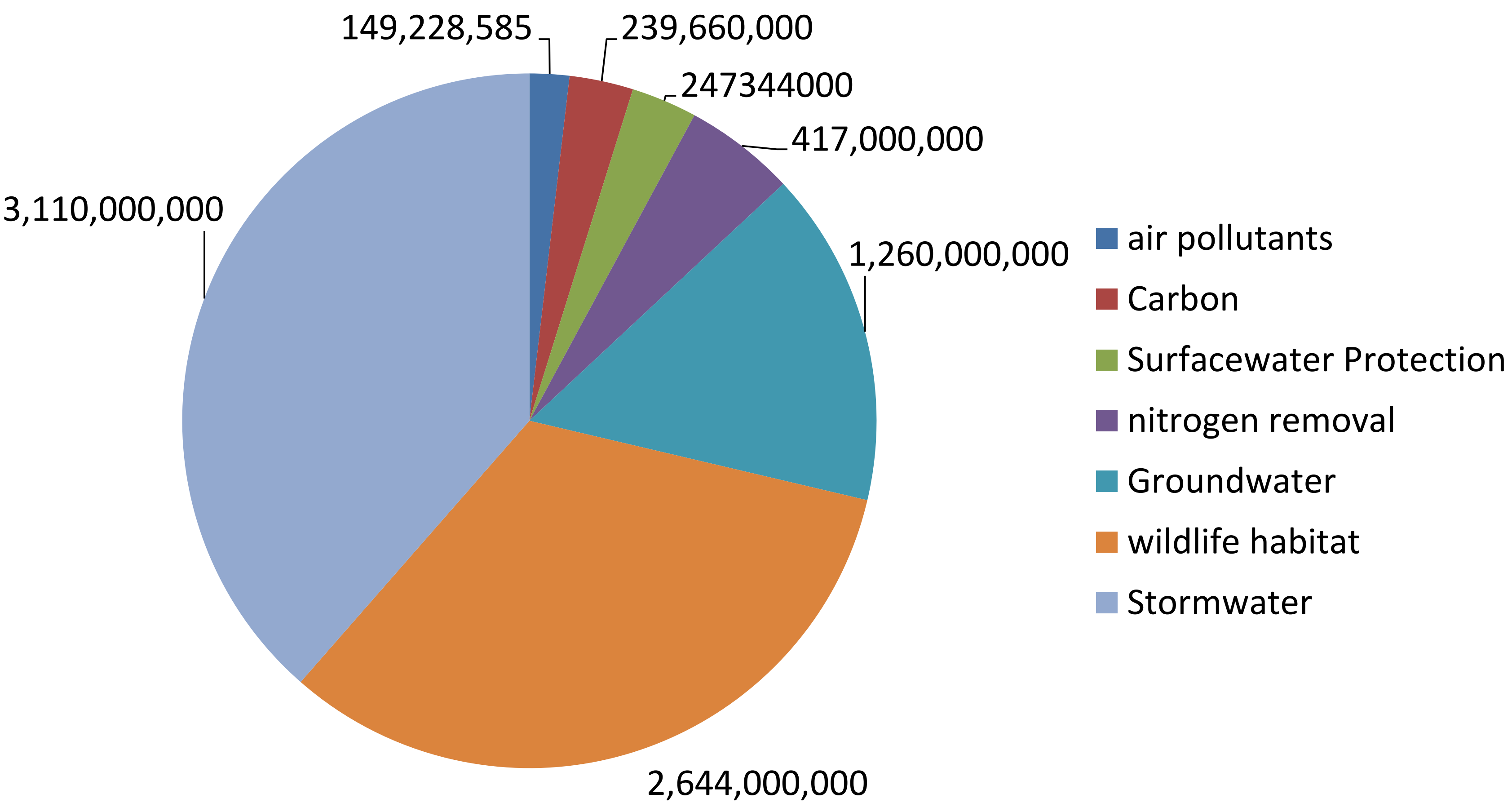
Total Economic Value

$8 billion of ES Benefits per year!

Ecosystem Services	$/ yr	Acres
Total $ / yr	$9,789,884,716.00	4,853,619
Min $/ acre	$4.00	56,090
Max $/ acre	$5,948.00	1
Avg $ / acre	$2,017.03	-

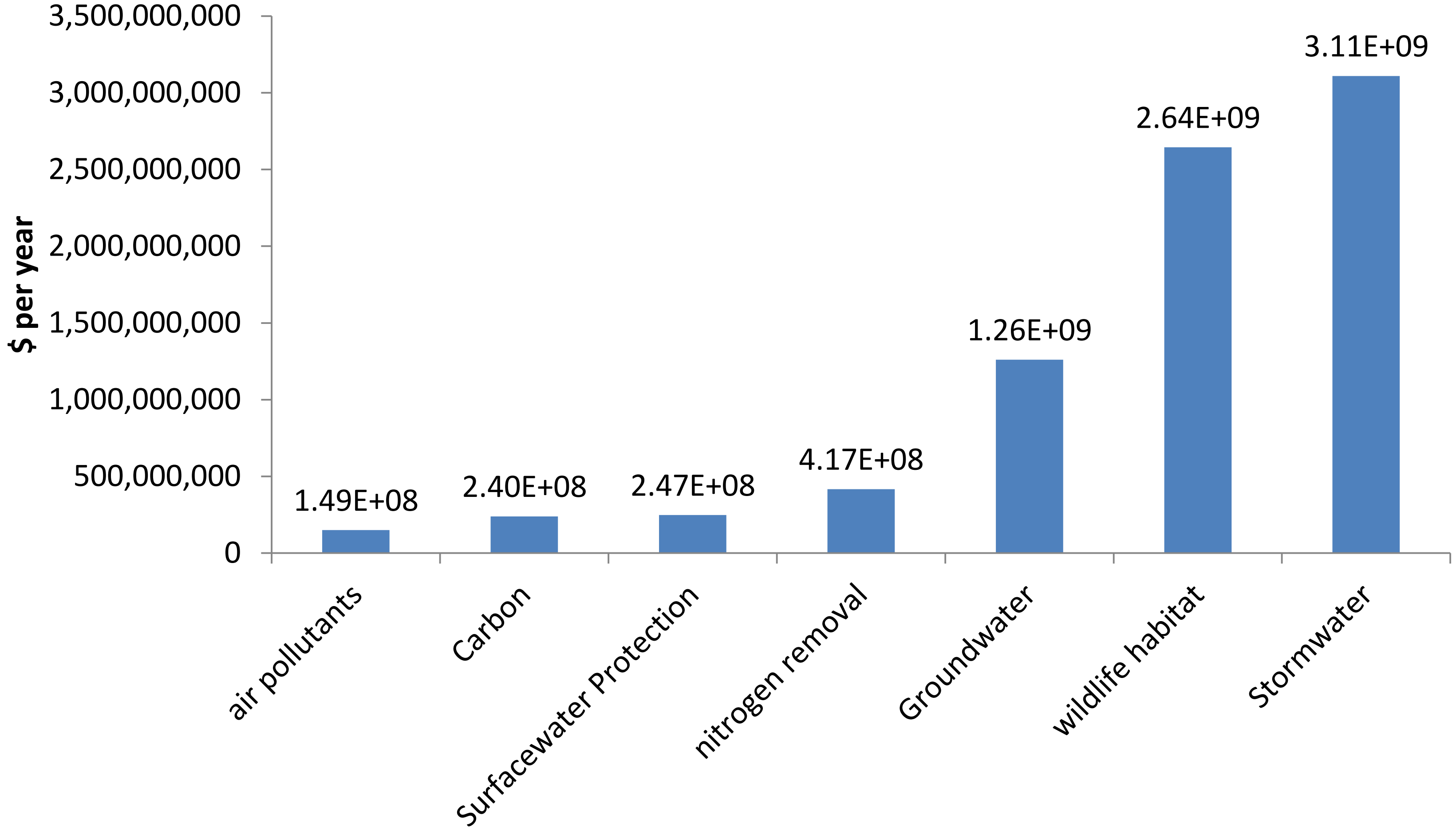


Ecosystem Service Totals

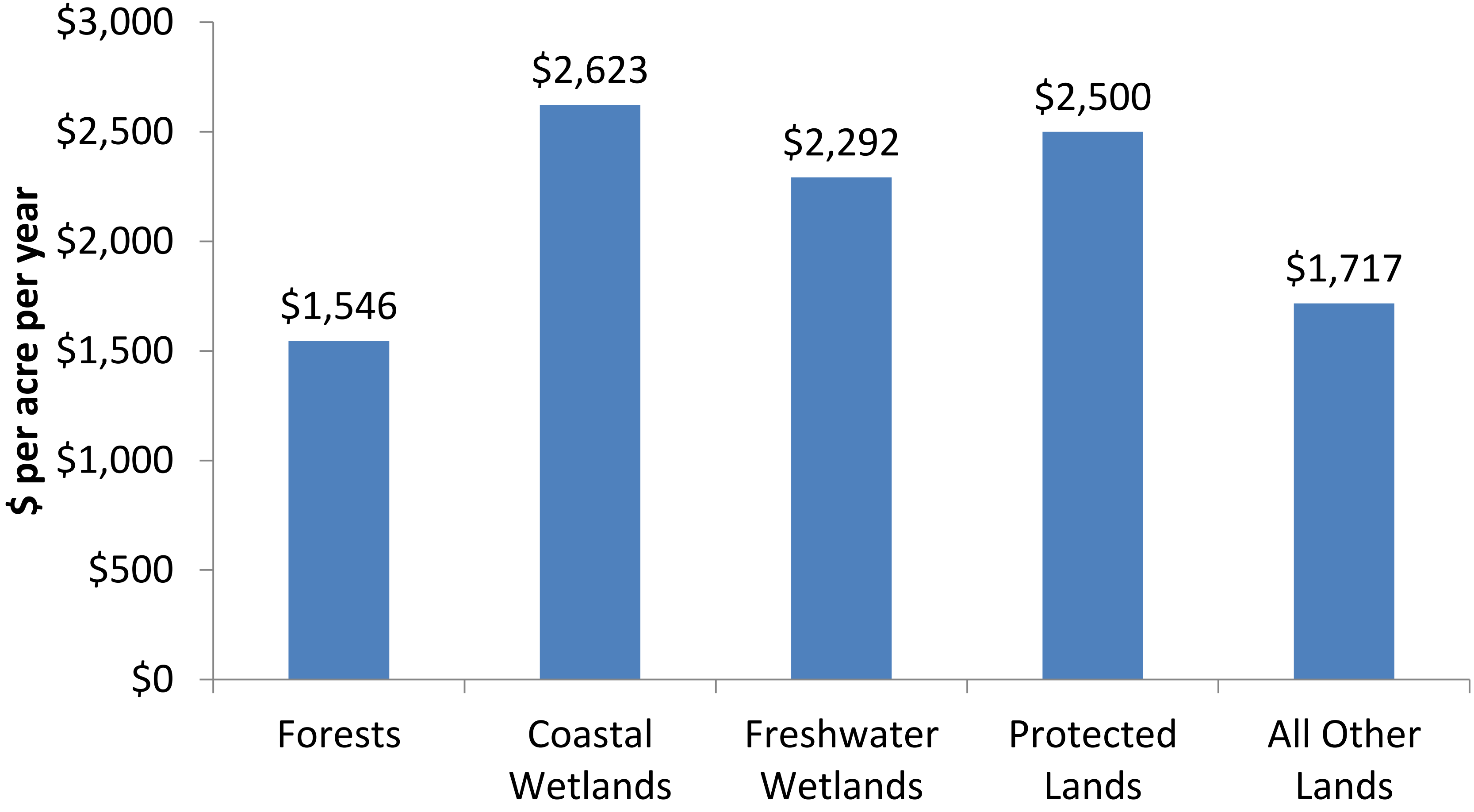


Units= $ per year

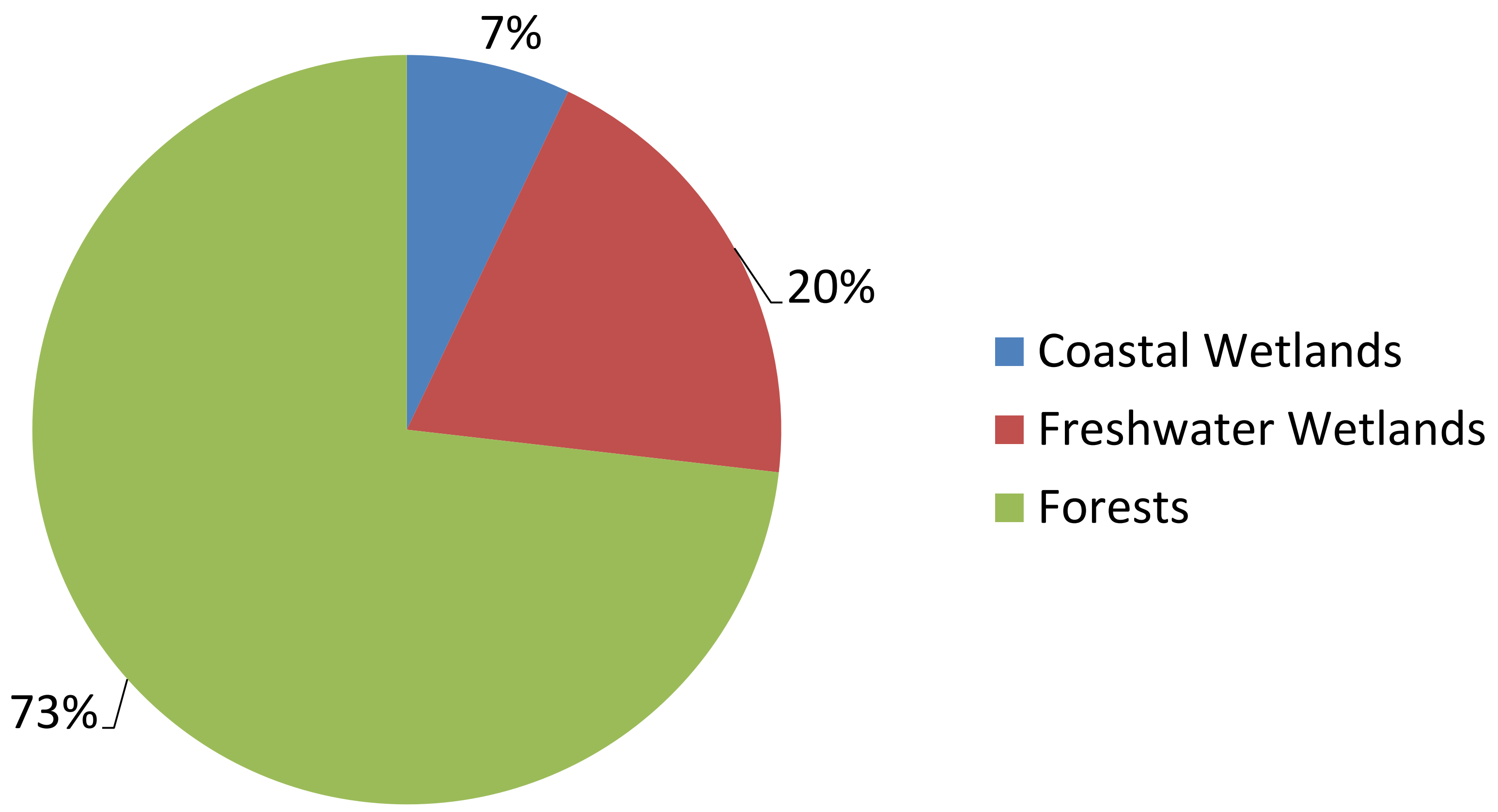
Ecosystem Service Totals



Land Use Comparisons

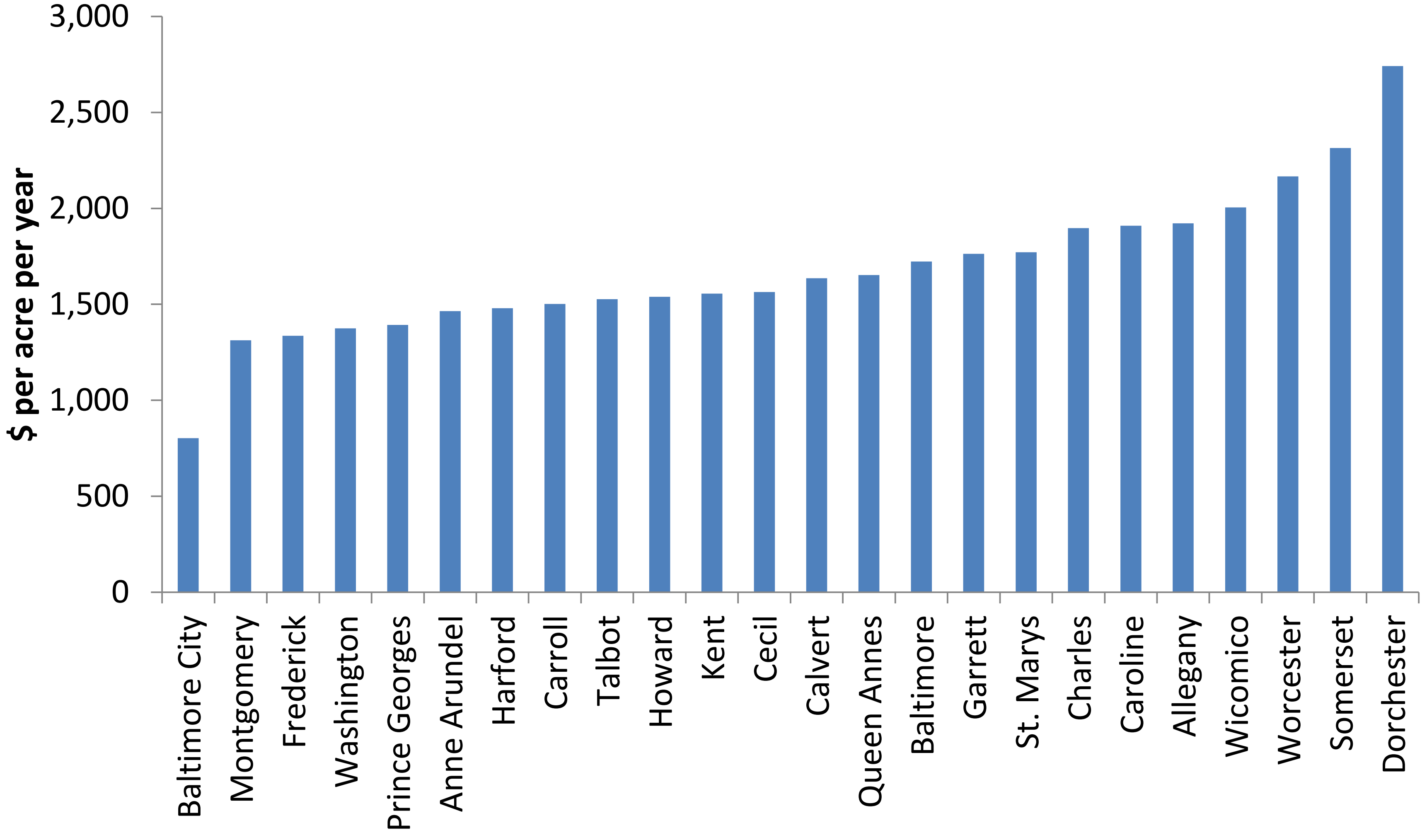


Percent Contribution



Wetlands ~ 20% of the area, contribute 27% of the ES value

County Comparison



ES Applications by the MD DNR

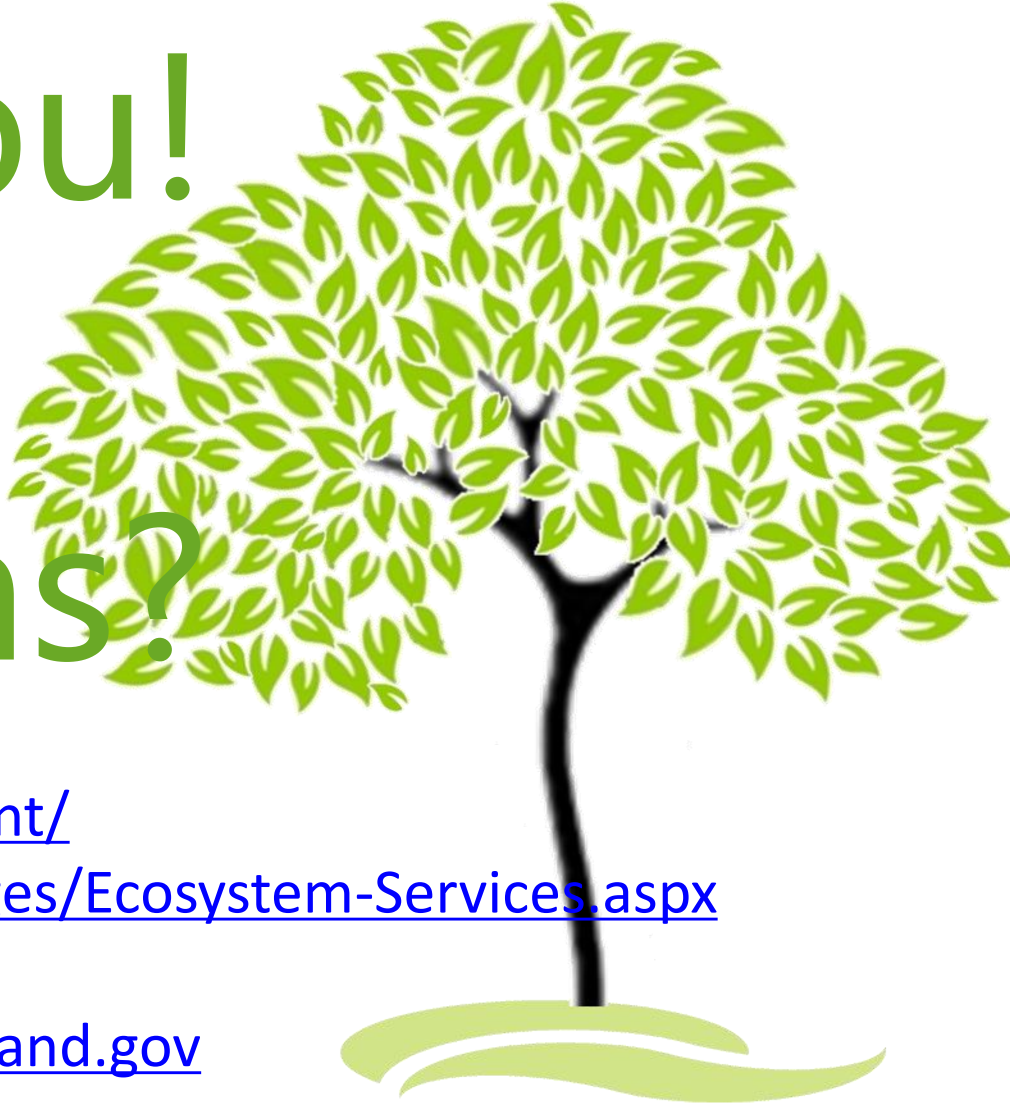
- Consider ES Value When Selecting Projects and Investments, Evaluating ROI, suggesting compensation
  - Conservation- Program Open Space Investments –Totaled >$100 million for FY2018. We evaluated the ES of the Stump Property Acquisition in 2017. Parcel Evaluator Tool with ES information will be used for prioritizations of future acquisitions.
  - Restoration- Creating a tool to evaluate the ES benefits of restoration work done through the DNR Trust Fund, Restoration through Resiliency for 2018 pilot. Investments of > $25 million per year
  - Worked with the Maryland Park Service to evaluate impact to the park of a NG pipeline, suggested fair compensatory value that was accepted in the agreement

Future Work

- Include Services from the Chesapeake Bay
  - Oyster beds
  - Submerged Aquatic Vegetation (SAV)
- Include Services from Agriculture
  - Certain Best Management Practices increase ES
- Incorporate new data
  - Wetland mapping
  - Higher resolution forest cover
  - New models of BRI's
  - New eco-prices
- Collaborate with instate, interstate, and federal partners- PA, Ches. Bay Program, EPA Reg. 3

Thank you!

Questions?



Websites:
http://geodata.md.gov/greenprint/
http://dnr.maryland.gov/ccs/Pages/Ecosystem-Services.aspx

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Rachel.Marks@maryland.gov