Accounting for Ecosystem Services In Charles County, Maryland

MARYLAND
DEPARTMENT OF NATURAL RESOURCES

CHARLES COUNTY Maryland

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Executive Summary

This report was prepared at the request of the Charles County Planning Commission. The Commissioners recognized that the natural resources of the county provide tremendous benefits to society that are not consistently accounted for in county government decision making. Leading the State of Maryland, the county has elected to consider new and innovative information for valuing the contributions of the environment, termed ecosystem services, with the goal of informing decision making in the county.

Ecosystem services can be broadly defined as any benefit that people receive from the environment. The ecosystem services we consider in this report are those that have quantifiable monetary value. We assess that monetary value by looking at how people pay for an ecosystem service in a market, or what they would have to pay to replace or conserve the service. By looking at multiple instances of economic preference we estimate the "social value" of ecosystem services.

For example, we value reductions in carbon emissions in many different ways; Maryland participates in the Regional Greenhouse Gas Initiative (RGGI) where carbon is traded in a market, the Environmental Protection Agency (EPA) calculates the social cost of carbon (an estimate of the economic cost per ton of carbon emissions), and there is an associated cost of implementing carbon emission reduction technologies at power plants. When considered together, these carbon payments represent how society values carbon. This same exercise is repeated for each ecosystem.

When ecosystem services are lost they must be replaced through restoration or with manmade alternatives, or the public must do without those benefits. If they are not replaced we will eventually suffer the consequences, be it through human health impacts due to poor air or water quality or a decrease in opportunities to enjoy a healthy ecosystem through wildlife watching, hunting, or fishing. In both of those cases there are real consequences to both our quality of life economy in Maryland.

The values contained in this report are intended for evaluating tradeoffs and informing decision making, but do not indicate market value or compensatory value. While in some cases we consider market values as part of the value equation, the assessment broadly quantifies the many ways people value the natural environment, yielding a "social" or "public" value of ecosystem services in Charles County.

The economic value of ecosystem services in Charles County is significant, totaling $577 million every year. For comparison, the total economic activity in the County totals approximately $4 billion per year. Stormwater mitigation is the largest service from natural systems, totaling $371 million, followed by wildlife habitat at $134 million. Groundwater recharge, carbon sequestration, nutrient uptake, and air pollutant removal total $12 million, $9 million, $7 million, and $1.2 million of benefits per year, respectfully. Ecosystem services from agricultural lands in the county provide $41.6 million of benefits per year. These values are in addition to the marketed economic contributions from outdoor recreation and resource extraction.

Kim Hernandez, Mallows Bay

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CHARLES COUNTY'S NATURAL RESOURCES

The people of Maryland benefit from the natural environment in many different ways. Forests clean the air, wetlands clean the water, and the Bay provides fish and crabs. These benefits people gain from the environment can be collectively referred to as **Ecosystem Services**. Though ecosystem services can be categorized in different ways[1,2], they are commonly divided into four major categories: **provisioning services** (e.g. timber, firewood, food), **regulating services** (e.g. water purification, wildlife habitat), **supporting services** (e.g. nutrient cycling, soil formation) and **cultural services** (e.g. recreation, spiritual benefits).

Charles County has one of the greatest abundance of natural resources, and corresponding ecosystem services, of all Maryland counties. Examples of ecosystem services provided by natural lands are summarized in **Table 1** and **Figure 1**. As of 2010, forests comprised 164,424 acres, or 64%, of the land area of the county, making Charles the third most forested county in the state behind the Western Maryland counties of Allegany and Garrett. Additionally, the western and southern portions of the county are bordered by the Potomac River, and several other rivers and creeks run through Charles. The county has 6,780 acres of wetland, comprising 2.3% of its land area.

Table 1. Ecosystem Services in Maryland**;** *the + symbol indicates that the ecosystem type provides the service, the +/ – symbol indicates that the system can either have a positive or negative effect on the service.*

Ecosystem Service	Forest	Freshwater Wetlands	Coastal Wetlands	Chesapeake Bay	Crop Agriculture
Reduce Stormwater Runoff	+	+			+
Control Flooding	+	+	+		+
Recharge Groundwater	+	+			+/-
Uptake Nutrients	+	+	+		-
Reduce Air Pollutants	+				
Sequester Carbon	+	+	+	+	+/-
Wildlife Habitat	+	+	+	+	
Food Provision	+			+	+
Recreation	+	+	+	+	
Timber	+				

[1] Millennium Ecosystem Assessment (2005)

[2] Boyd and Banzhaff (2007)

Figure 1. Natural resources provide benefits, subject to drivers of change (from US EPA Enviroatlas, 2016)

While Charles County possesses a large amount of natural areas, it also has one of the highest population growth rates of any MD county, growing 21.5% from 2000 to 2010, growing by 1.4% per year from 2005-2015, and conservatively projected to grow by 37,000 people (1% annual growth rate) by 2040 from the current population[3]. This growth has corresponded to a high degree of land-use change over the past 40 years. From 1973 to 2010, the Maryland Department of the Environment estimates that developed areas increased 178%, with 8% of that increase occurring between 2002 and 2010 (Figure 2). These dates were chosen for reporting because they coincide with the earliest and most recent National Land Cover Dataset mapping done by the US Geological Survey[4]. During the entire period, forested areas decreased 10%, while agricultural areas decreased by 23%. From 2002 to 2010, the majority of land converted to development was agricultural area, while forested land exhibited a slight increase of 258 acres.

Wetland area increased slightly between 1973 to 2002, and remained relatively constant from 2002 to 2010. It is important to note that small differences in acreage measured may be due to errors inherent in each individual land use map, as well as differences in the mapping methods and data used between years, thus definitive conclusions on wetland change should not be made from this analysis. The percent of land area in Charles County comprised of impervious (developed), forest, agriculture, and other land use are summarized in Figure 2, while the spatial distribution of land use change is illustrated in Figure 3.

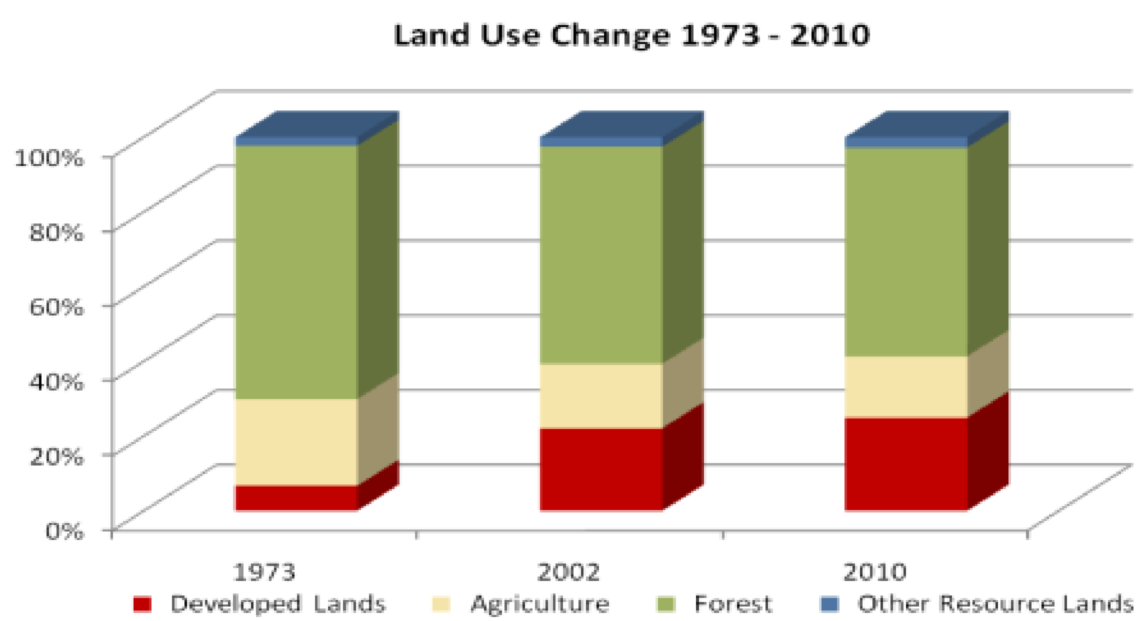
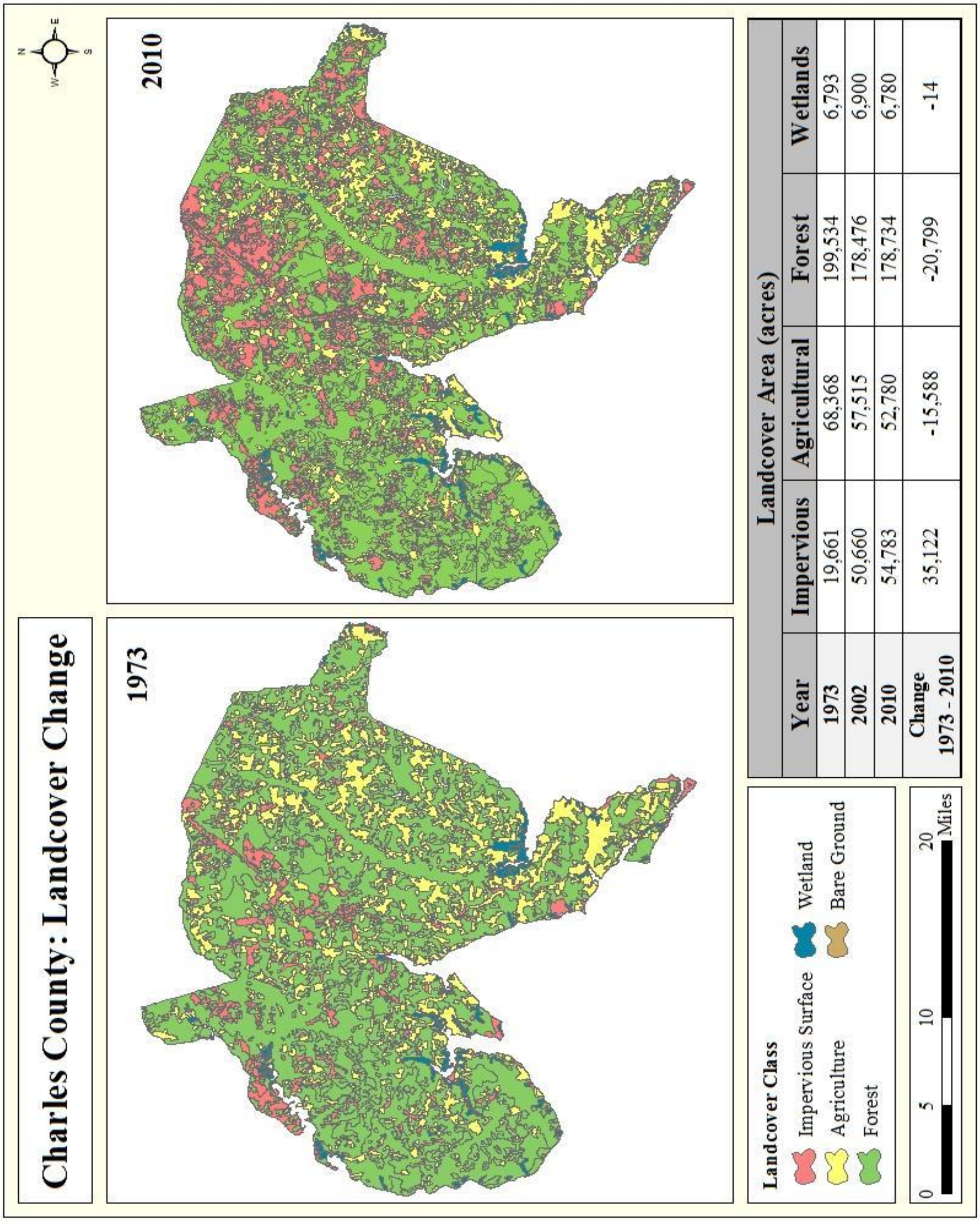


Figure 2. Landcover change in Charles County, 1973 - 2010

[3] Charles County Comprehensive Plan, 2016

[4] Homer et al. 2015

Figure 3. Spatial distribution of landcover change in Charles County from 1973 to 2010



Landcover Area (acres)				
Year	Impervious	Agricultural	Forest	Wetlands
1973	19,661	68,368	199,534	6,793
2002	50,660	57,515	178,476	6,900
2010	54,783	52,780	178,734	6,780
Change 1973 - 2010	35,122	-15,588	-20,799	-14

The abundant natural features of Charles County are large draws for both residents and visitors, with county parks servicing 940,000 people per year. 175,000 of those visitors use trails in the parks. State parks in the county serve 100,000 visitors every year[5]. 14,530 acres of public land are open to hunting and 3,123 deer were harvested during the 2015-16 season. There are eight public boat ramps from which approximately 21,000 boats are launched every year. In 2015, 4,000 people participated in 96 fishing tournaments in Charles County[6]. Natural beauty and rural nature are big parts of the $187 million dollar tourism industry in Charles. Agri-tourism (tourism centered on farms) is a growing source of revenue for farms in the county .The forestry industry in Charles County was estimated to have a direct economic impact of $50 million in 2005[7]. The spatial distribution of publically accessible natural areas across Charles County, along with highlights on several popular parks, is illustrated in Figure 4.

The fast growing population of Charles County, combined with the associated development of natural lands, makes consideration of the economic value of ecosystem services a crucial component of future land use decisions. Incorporating this value into decision making can help support choices that accommodate the growing population while preserving the highest possible environmental value. In this report, we describe a method for quantifying and valuing ecosystem services across the state of Maryland, and provide a detailed accounting of the current distribution and value of ecosystem services within Charles County.

Cedarville State Forest, Stephen Badger, 2015

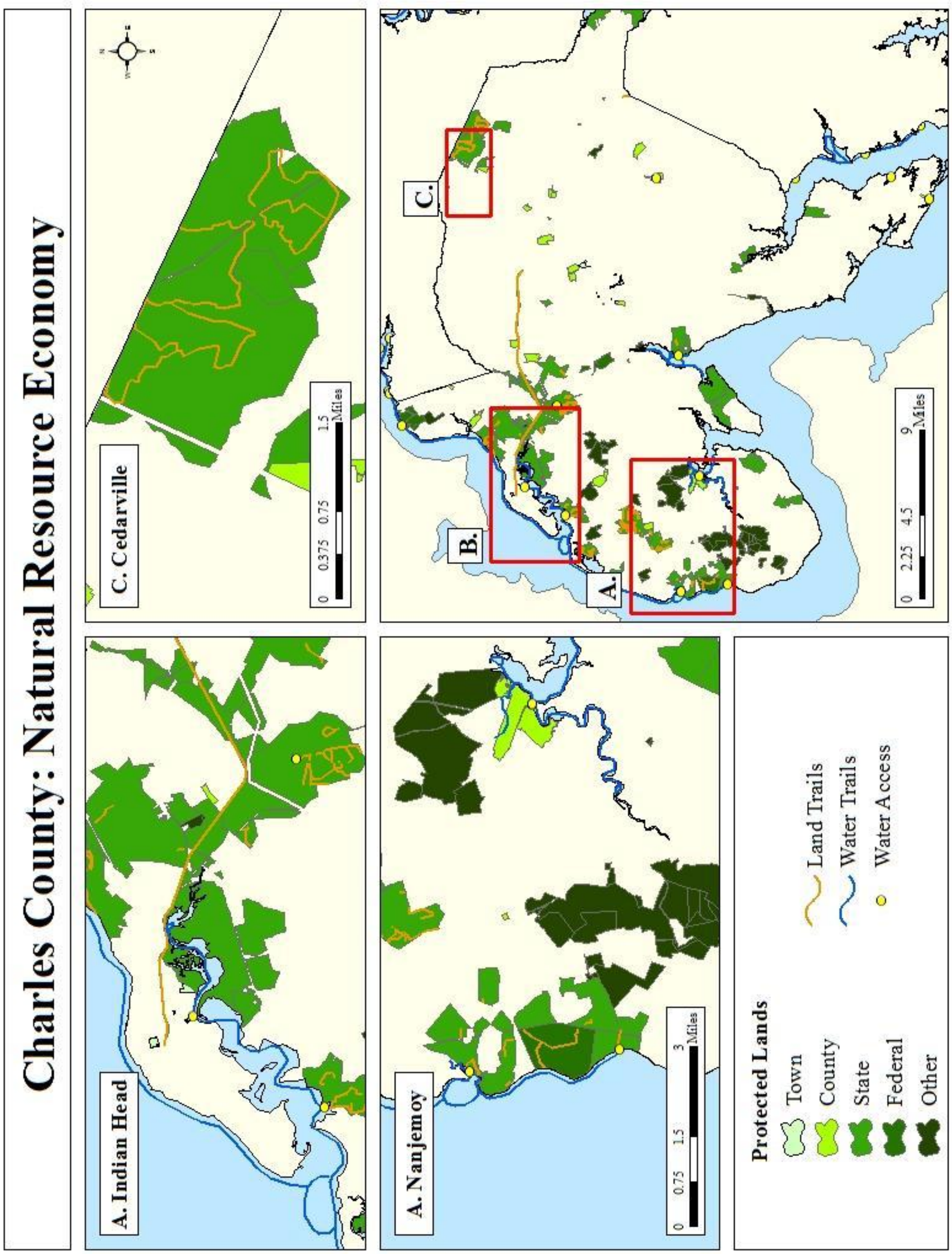
Potomac River, Department Photo

[5] Charles County Parks and Recreation (2016)

[6] Maryland DNR Wildlife and Heritage (2016)

[7] Beacon (2005)

Figure 4. Spatial distribution of publically accessible natural areas across Charles County, including land trails, water trails**,** and water access points in the areas of **A.** Nanjemoy, **B.** Indian Head and **C.** Cedarville State Forest



THE VALUE OF NATURAL LANDS

Calculating the Return on Environment

If society is to preserve ecosystem services fundamental to human life, we must be able to accurately measure their ecological outputs, as well as their economic value. Even though each of these services benefits society economically, they are not all currently represented in economic markets across Maryland. While the value of provisioning and cultural services, such as fish, crabs, timber, and recreation are well understood and accounted for within our economic system, the value of regulating and supporting services, such as stormwater management and nutrient uptake, are more difficult to quantify, and thus more difficult to incorporate into an economic market. In the absence of known economic values, these services are treated as free subsidies for society (termed a **positive market externality** in economics). Society and individuals benefit from their existence, but are not typically held financially responsible for the management or protection of these non-market benefits.

In a market system, land use decisions are often driven by opportunity cost, favoring the most profitable option given the constraints of governmental regulation and policy. When the economic value of ecosystem services are not explicitly included in resource management decisions, there is an increased risk of natural lands being lost, which threatens ecosystem health and natural productivity, potentially impairing the well-being of current and future generations. In order to better preserve the integrity of ecosystem services provided by Maryland's natural lands, it is critical to develop mechanisms which quantify and incorporate the economic value of these services, thereby creating an additional incentive for responsible land stewardship and informing decision making by state and local governments.

Beyond their intrinsic value, natural systems provide millions of dollars of social and economic benefits every year—a triple bottom line to communities and residents. Triple bottom line refers to accounting for social and environmental costs and benefits on the same balance sheet as economic ones. Just as financial analysts express return on investments, new methods are now available to express nature's annual value to the economy in terms of **Return on Environment (ROE)**. ROE estimates the value that people place on the work of the environment through consideration of observed financial patterns, such as costs avoided, market prices, the cost of regulations, or premiums for real estate value based on proximity to open spaces. Such estimation of economic benefits of ecosystem services to society allows policy makers, businesses and residents to view natural systems as a portfolio of financial assets rather than a commodity. Accounting for ecosystem services, and understanding the "Return on Environment" of a region, can serve the interests of conservation, the economy and society as a whole. The benefits of using an ROE valuation system are summarized in Table 2.

Table 2. Benefits of a Return on Environment Valuation System

Benefits of a Return on Environment Valuation System	
1	Nature's complex system is conveyed in a simple bottom line which is understandable to a broad audience.
2	Dollars, as a financial measure, underscore nature's connection to our quality of life, health, cost of living, economy and sense of place.
3	Dollars also convey a level of significance or priority to allow for better trade-off analysis.
4	Monetary estimates of the value of natural system services can be applied within decision frameworks related to land use, tourism and economic development.
5	Discussion of natural system cover types, services, and their values can engage key stakeholders in an educational process that can help other organizations in their missions.
6	While any numeric model will engender healthy skeptics, the discussion about nature's value finally puts this issue on the table in full view so policy makers and citizens are aware of its relative importance.

Natural systems work 24 hours a day, 365 days a year without cost to taxpayers, and may generate economic benefits for a single function or for a function that provides several services. Beyond these continuous services, like mitigating air pollution or providing wildlife habitat, nature also provides a form of insurance or risk management. Natural systems increase the resilience of an area to the effects of climate change, decreasing the risk of flooding and allowing more rapid recovery after severe weather events. In contrast to residential, commercial and industrial areas which require public or private investment for services, intact natural areas require little more than protection. Though ecosystem services are inherently renewable, continuation of benefits requires ecosystem productivity and biological diversity. Once ecosystem integrity is lost, these services must replaced, typically at the taxpayers' expense, or society will go without the former ecosystem services being provided. Unlike economic assets which typically recover value relatively quickly after losses, this ecologically-based portfolio of assets can take 50 to 100 years to recover its full set of services.

Zekiah Swamp, Department Photo

Through explicit economic valuation of ecosystem services and biodiversity, the relative value of protecting certain natural system services can be clearly conveyed to policy makers, investors and homeowners, highlighting ecosystem conservation as a practical long-term business strategy. It is almost always a better economic decision to conserve natural lands than restore them at a later date, as the future investments necessary to replace what is lost will likely be more expensive than employing smart growth development policy that preserves natural lands.

A variety of recent studies have demonstrated that in the long term, it is often less costly to preserve a forest buffer along a river or stream compared to remediating the water either downstream or when it is extracted for use.

- Riley (2009)[8] found that costs of riparian buffer restoration in the San Francisco Bay region of California were less than a quarter of building and maintaining a stormwater/urban runoff treatment plant to perform the same nutrient reduction function. In fact, this underestimates the difference in costs given the different time horizons of the options (the natural buffer will last in perpetuity while the treatment plant will only last ~50 years).

- Kramer et al. (2006)[9] compared forested buffers near Wisconsin lakes with septic upgrades for reducing nutrient loading to the lakes. In the 25 instances studied the forested buffer was found to be the more affordable option for nutrient reduction in all but one case.

- Keystone Conservation Trust evaluated ecosystem service benefits in 5 PA counties[10], finding that for every dollar invested in conservation seven dollars of ecosystem service value is returned. These findings influenced the Northhampton Co. (PA) Commissioners in increasing their open space budget by $2.2 million for FY2016.

- New York City invested $1.5 billion in land preservation in the watershed of their drinking water source, ensuring the high quality of their drinking water. This investment avoided having to build a $10 billion water treatment plant[11].

Types of Economic Value

The type of value we most often consider is ***market value,*** which is the price of a good or service in a market. From the market price economists calculate ***consumer surplus***, the difference between what someone paid for a good or service and the most they would have been willing to pay. However, for most ecosystem services a market does not exist. Many different ***non-market valuation*** methods have been proposed. They range from asking a sample of people what they would pay for an ecosystem service (***contingent valuation***) to using the price of proximal homes to estimate the value people place on being near natural areas (***hedonic pricing)***, evaluating what it costs to visit a natural area (***travel cost analysis****).* However, all of these methods have well known flaws. For example, contingent valuation is subject to hypothetical bias, meaning that people are likely to over-or-understate what they would actually pay for something. Hedonic pricing and travel cost analyses do not actually measure the ecosystem service (ES) and can easily conflate benefits from the ecosystem with other values. These methods are typically biased towards measuring immediate economic well-being, discounting longer term values, such as intergenerational equity.

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[8] Riley (2009)

[9] Kramer et al. (2006)

[10] Lehigh Valley Planning Commission (2014)

[11] New York State Department of Environmental Conservation (2015)

Social Value measures the benefit of something not just at the level of the individual (i.e. someone's willingness to pay for a good or service), but the benefit to a group of people. This type of valuation is particularly appropriate for valuing ecosystem services, as very often benefit the public as a whole (i.e. a ***public value***) and do not have traditional markets. This analysis calculates the social value of ecosystem services, where society overall is benefiting from the work of the environment. It is important to note that while social value is an inclusive measure of the benefits that the public gain from the work of the environment, it is not the same as market or compensatory value, and the values presented here are not meant for that purpose. Social value is intended to be used to inform decision making and trade-offs, rather than market exchanges.

Pricing the Environment: The "Eco-Price"

One mechanism which has been developed to put an social economic value on the work performed by the environment is the **eco-price**. The eco-price is defined as the ratio of dollar amount that has been paid to preserve or restore ecosystem services, or cost avoided, to the change in ecological function, where dollar amounts based on current trends in society's payment for and valuation of these services[12]. Again, this is necessary because these services largely exist outside of traditional markets. The eco-price reconciles the biophysical value of the environment with economic value and extends the capability to suggest monetary values for the work of the environment to be used when evaluating management alternatives, ecosystem service markets, or formulating policy. The value generated through the eco-price is not the same as market value and is not meant to imply landowner compensation for services provided.

As an example of the utility of the eco-price, consider nutrient management activities carried out by a private land owner in Maryland. This private landowner can plant a riparian forest buffer on their land that will take up a certain estimated amount of nitrogen. This quantity of nitrogen can then be sold on the MD nutrient marketplace to municipalities needing to meet their mandated water quality goals for a certain dollar amount. Another example is payment made for reducing nitrogen loads to the Chesapeake Bay through the Maryland Bay Restoration Fund, where water users pay a fee used to retro-fit water treatment plants in the state, and through installation of best management practices for nutrient reduction (riparian buffers, wetland restoration, etc.) in the watershed. The amount paid per pound of nitrogen is calculated for each instance of society investing in nutrient reduction, and then averaged in order to estimate how society values nitrogen reduction, overall.

[12] Campbell and Tilley (2014)

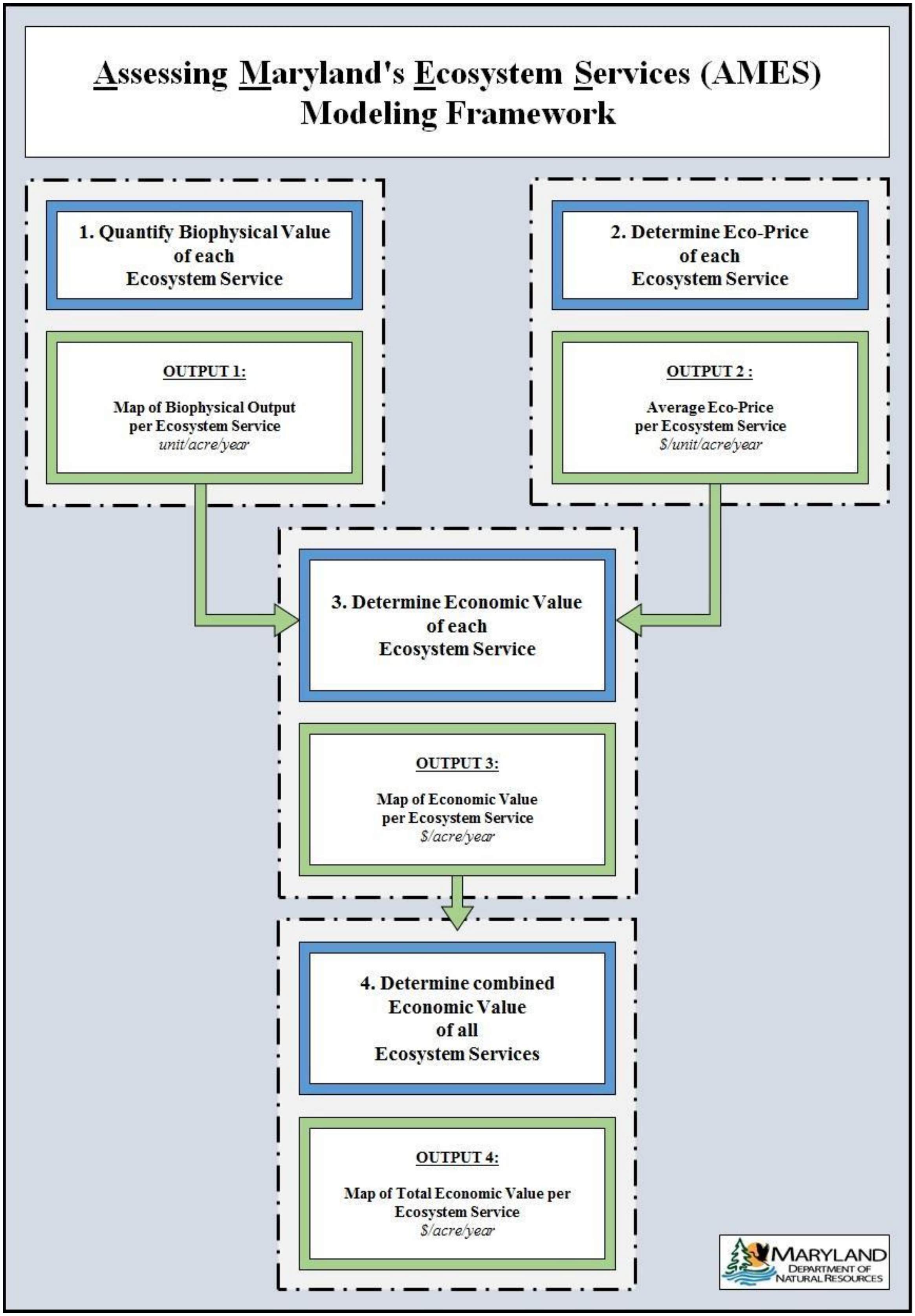
ASSESSING MARYLAND'S ECOSYSTEM SERVICES (AMES)

To address the need for better economic valuation of the ecosystem services provided by Maryland's natural resources, the **Chesapeake and Coastal Service's Center for Economics and Social Sciences** has developed a new modeling framework, **"Assessing Maryland's Ecosystem Services"** (AMES). The goal of the AMES model framework is two-fold: **1)** to quantify the biophysical value of work performed by the environment, and **2)** to estimate the economic value, or eco-price, of this work. We rely upon existing spatial maps of the biophysical supply of ecosystem services (i.e. metric tons (mt) of carbon sequestered, cubic meters (m^3) of groundwater recharge, etc.) from federal and state agencies. The model outputs a series of spatially explicit maps, which capture variation in the biophysical and economic value of individual ecosystem services performed in forest and wetland areas, as well as the total value of all co-occurring ecosystem services across the state of Maryland. AMES currently incorporates six ecosystem services: **carbon sequestration, wildlife habitat and biodiversity, storm water mitigation, groundwater recharge, nutrient uptake** and **agricultural benefits**. Figure 5 illustrates the AMES model framework.

Forest and wetland areas across Maryland were identified using a combination of two datasets: the Landsat-based National Land Cover Database (NLCD) and Maryland Department of Planning (MDP) Land Use/Land Cover. The biophysical value of individual ecosystem services within these forest and wetland areas was then quantified using a set of unique ecological sub-models. For some services, the AMES framework leverages the power of existing external ecological models, while other services are modeled internally using a combination of GIS data inputs and published ecological thresholds. Each sub-model produces a per-pixel estimate of the biophysical output produced by a given service across the state.

The economic value of each ecosystem services was derived from the work of Campbell (in press) which analyzed 60 instances in which money has been exchanged for the work of the environment. These instances spanned a range of payment types, including regulatory programs (e.g. Maryland's Bay restoration fee, stormwater management fee), NGO investments (e.g. purchases by the Conservation Fund, Ducks Unlimited), market exchange (e.g. Regional Greenhouse Gas Initiative purchases, nutrient trading in Pennsylvania), or tax incentives (e.g. benefit of enrolling land in conservation programs). Because society places different value on different ecosystem services, observed dollar amounts paid were categorized by relevant ecosystem service. For each service, an average was calculated for each payment type. Mapped biophysical output values were then multiplied by the average eco-price, to produce per-pixel estimates of the eco-price of each service across the state of Maryland. Finally, per-pixel eco-prices for each individual service were summed, to produce an estimate of the economic value of all ecosystem services occurring in a given area.

Figure 5. AMES Model Framework



Cedarville State Forest, Department Photo

CHARLES COUNTY ECOSYSTEM SERVICES ASSESSMENT

The following section outlines the data and models used to assess each ecosystem service, as well as an estimate of the spatial distribution and economic value of these services across Charles County. The map of the spatial distribution of each ecosystem service also contains a table summarizing the annual economic value of the service, the minimum value, the maximum value, the average value, and the acreage in the county that was included.

Sunset on Mallows Bay, Kim Hernandez 2016

Carbon Sequestration

Carbon dioxide (CO_2) is a naturally occurring greenhouse gas (GHG) found in the Earth's atmosphere which plays a critical role in maintaining a climate suitable for life on this planet. Though beneficial to life, rising atmospheric concentrations of CO_2 over the past century have been linked to increases in climate variability and change at local, regional, and global scales. Over the past 30 years, climate researchers have worked to quantify the flux of carbon between sources and sinks in the carbon cycle. Forested areas have been identified as one of the major carbon sinks existing on Earth. During the process of photosynthesis, trees remove CO_2 from the atmosphere, releasing oxygen and converting carbon to long term storage as carbohydrates within the woody biomass of their trunks. The world's forests hold an immense amount of carbon in standing trees, and have the potential to continue sequestering carbon as they grow. Wetlands also have a large capacity to sequester carbon, particularly coastal wetlands which have high primary production and produce less methane (a gas which contributes to warming), than freshwater wetlands.

In 2009, The Green House Gas Emissions Reduction Act (GGRA) was signed into law, requiring Maryland to reduce statewide GHG emissions by a minimum of 25% by 2020. Expansion of forested area is one of the most straightforward and economical ways to mitigate CO_2 emissions. Increasing forested area across the state could thus play a significant role in meeting state implemented GHG reduction goals.

Quantifying Carbon Sequestration across the Landscape

Forest extent across Maryland was delineated using the NLCD 2011 land cover dataset, which identifies forests as deciduous, evergreen, mixed forest, and shrubland at a 30 m resolution. Wetland extent was delineated using a DNR dataset, which identifies palustrine and estuarine wetlands as forested, shrubland, or emergent. The rate and amount of carbon sequestration within forests and wetlands varies spatially across Maryland. The primary source of variation in forested areas is tree species composition, with deciduous trees such as oaks and hickories sequestering more carbon than do evergreen trees such as pines and hemlocks. Carbon sequestration rates for hardwoods (deciduous), softwoods (evergreen), mixed forest, and shrubland were calculated using output from the US Forest Service Carbon Online Estimator (COLE). Across wetland areas, forested wetlands (swamps) and coastal wetlands tend to sequester higher amounts of carbon than do freshwater wetlands with emergent vegetation. Average sequestration rates for each wetland type were determined based on scientific literature[13]. Average sequestration rates for each cover type were applied to calculated carbon sequestration potential per unit area across the landscape. Sequestration rates for forests and wetlands are summarized in Table 3.

[13] Versar (2002)

Table 3. Carbon sequestration rates by ecosystem type

	Ecosystem Type	C Sequestration Rate (MT C/ ha/ year)	Reference
Forests	**Scrub shrub**	1	USFS COLE Model[14]
	Mixed forest	1.4	USFS COLE Model
	Softwoods	1.6	USFS COLE Model
	Hardwoods	1.9	USFS COLE Model
Wetlands	**Emergent freshwater**	0.81	Hupp and Noe 2008[15], Fenstermacher 2012[16]
	Forested freshwater	1.9	Hupp and Noe 2008, Fenstermacher 2013
	Emergent coastal	3.4	Needelman et al. 2012[17]

Valuing Carbon Sequestration

We used several ways of valuing carbon to assess the economic preference that society places on reducing carbon emissions. These included the Social Cost of Carbon[18] (estimate of the costs of climate change), the price of carbon through the Regional Greenhouse Gas Initiative (RGGI)[19] market, and estimated costs to comply with the Clean Power Plan (CPP)[20,21], a law that requires power plants to limit the amount of carbon emitted. When averaged, these estimates yield a value of $77 per mt of carbon. Table 4 summarizes the instances of payment for carbon reduction used to calculate the average eco-price. The spatial distribution of carbon sequestration and associated economic values across Charles County is illustrated in Figure 6.

14 Van Deusen, P., and L.S. Heath (2015)

15 Noe and Hupp (2008)

16 Fenstermacher (2012)

17 Needelman et al. (2012)

18 IWSCC (2013)

19 RGGI (2014)

20 Brattle Group (2014)

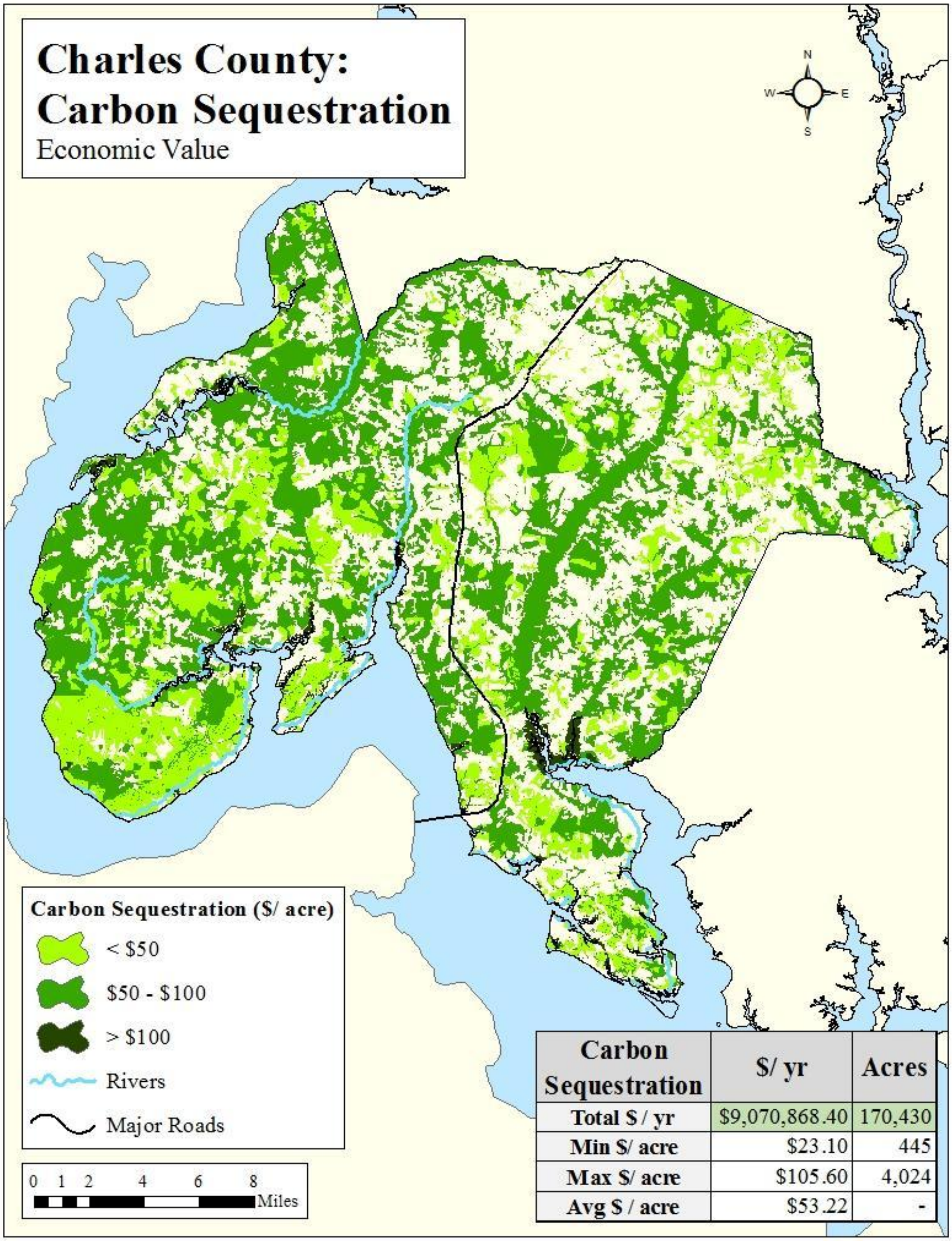
21 USEPA (2015)

Table 4. Eco-prices used to calculate the carbon sequestration ecosystem service value

Biophysical Category and Measure	Eco-Price	Units	Exchange Classification
RGGI Trading Price in 2014	$19.73	$/mt C	Market price
Estimated Cost to Comply with Clean Power Plan	$51.34	$/mt C	Cost of regulation
Average Cost per Ton C Reduction, Clean Power Plan	$85.24	$/mt C	Cost of regulation
Clean Power Plan Average	$68.29	$/mt C	•
Social Cost of Carbon, EPA	$143.00	$/mt C	Cost of damages
Average	**$77.01**	**$/mt C**	

Mallows Bay, Marine Robotics & Remote Sensing, Duke University 2016

Figure 6. Spatial distribution of carbon sequestration ecosystem service values



Wildlife Habitat and Biodiversity

Forests in Maryland support a variety of plants and animals. Some of which are important for hunting such as deer, turkey, or bear and others that are rare or endemic species like the Delmarva Fox Squirrel or Short Eared Owl. A healthy, biologically diverse ecosystem is essential to providing habitat for wildlife, and ultimately, through maintaining the ability of the ecosystem to function, all of the other ecosystem services being provided by natural lands. Without the linkages and interactions that different species convey to the system many of the ecosystem services considered would be lessened, or not exist at all. For example, a diverse system is key to developing healthy soils, which in turn supports a higher capacity to recharge groundwater, store water on the landscape to reduce runoff, and store carbon.

Quantifying Wildlife Habitat and Biodiversity across the Landscape

We looked at the size of habitat, degree of connection to other habitats (scored through the MD Green Infrastructure model)[22], and presence of rare species or habitats (scored through the MD BioNet model)[23]. Land in the top two ranks of MD Bionet were assigned the 1st and 2nd quantile of value, respectively. Lands in the Green Infrastructure were assigned into quintiles based upon their score, and assigned corresponding values. Forests and wetlands occurring outside both models were given the lowest quintile value.

Valuing Wildlife Habitat and Biodiversity

Cost to preserve natural land (i.e. Ducks Unlimited, Conservation Fund, habitat banking)[24,25,26,27,28], annualized over 15 years, period that tax benefit can be spread. This averages $1023 per acre of natural land. Instances of payment used to calculate the average eco-price of wildlife habitat and biodiversity are summarized in Table 5, along with the estimated tax benefit. The spatial distribution of the economic value associated with wildlife habitat and biodiversity across Charles County is illustrated in Figure 7.

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[22] Weber (2003); Maryland DNR's Green Infrastructure assessment

[23] MD DNR (2016) DNR's BioNet

[24] NRCS (2009)

[25] Ducks Unlimited (2014)

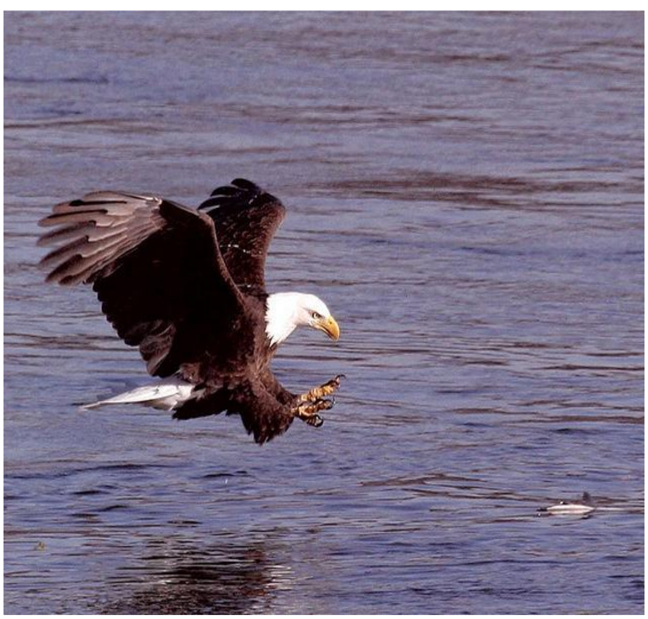
[26] Conservation Fund (2014)

[27] The Baybank (2012)

[28] MD DNR (2016)

Table 5. Eco-prices used to calculate the biodiversity and wildlife habitat ecosystem service value

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 avgerage	$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	•



Bald Eagle, 2012 MD DNR Photo Contest by Bill Miles

Salamander, Department Photo

Figure 7. Spatial distribution of wildlife habitat and biodiversity ecosystem service values across Charles County

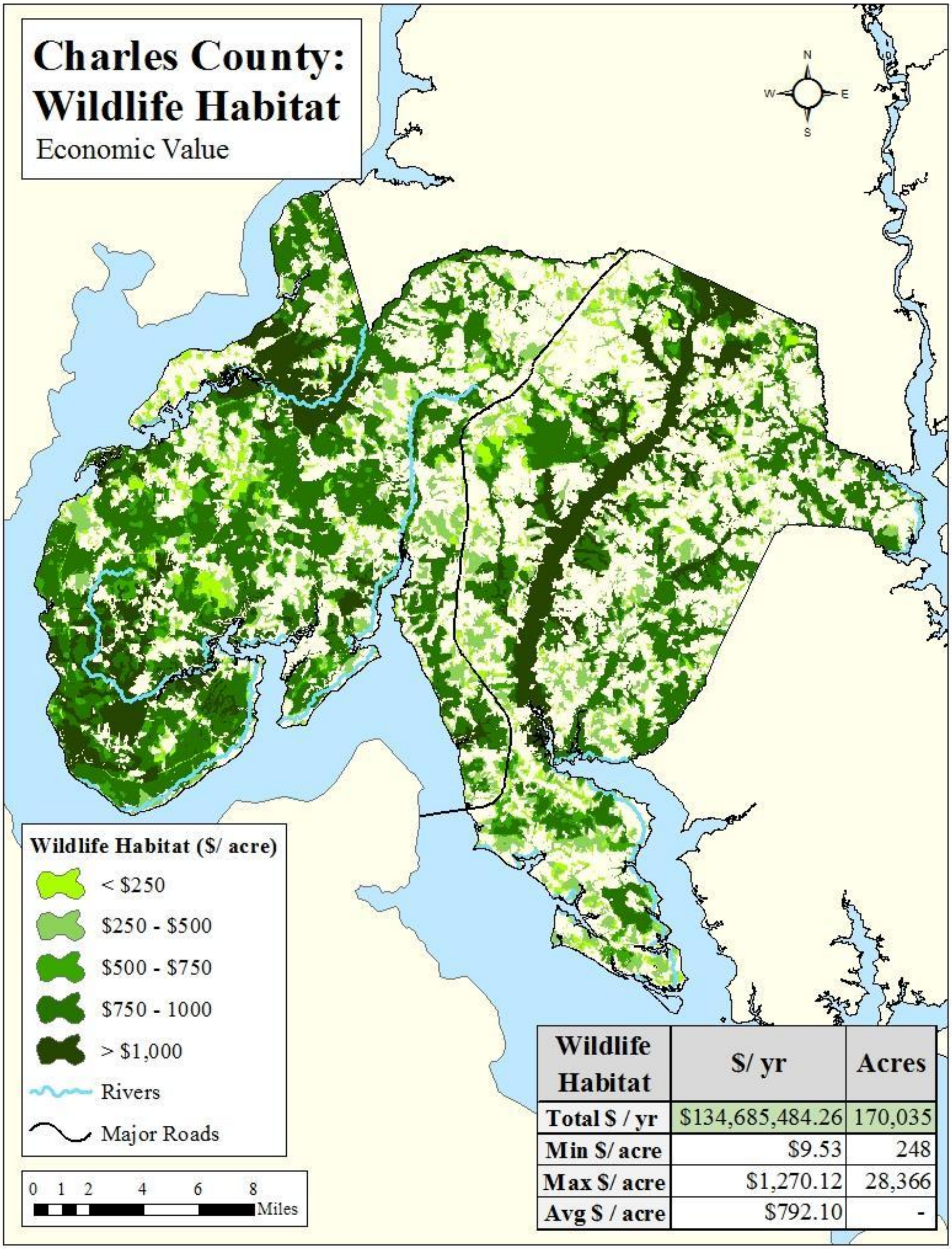


Photo Credits: American Beaver, Melissa McCeney;
Beaver activity in Cedarville State Forest, Stephen Badger 2015;
Heron, 2016 MD DNR Photo Contest, Duane Tucker;
Frog, 2015 MD DNR Photo Contest, Marie -Ann D'Aloia,

Air Pollutant Removal

The forests of Maryland play an important role in reducing air pollution in the state. Trees remove pollutants from the air by absorption through leaf stomata and interception by leaves. The forest soil is also a large and important sink for air pollutants like carbon monoxide. This ecosystem service is especially important due to its effect on human health. The pollutants taken up by trees can have many negative effects on human health, causing or exacerbating bronchitis, cardiovascular stress, and asthma. A study led by David Nowak of the US Forest Service (USFS)[29] found that forests remove over 17 million tons of air pollutants in the United States, avoiding nearly $7 billion in air pollutant caused medical costs.

Air Pollutant Removal across the Landscape

Trees remove more air pollutants with a greater impact on human health in urban areas. The study done by the USFS looked at the reduction of both human mortality and respiratory ailments due to fewer air pollutants, finding the effect was much more pronounced in urban areas than rural ones. This is due to the combination of there being more people to benefit and worse air pollution in urban areas. Urban areas are defined as having a population density greater than 2,500 people in the census area.

Valuing Air Pollutant Removal

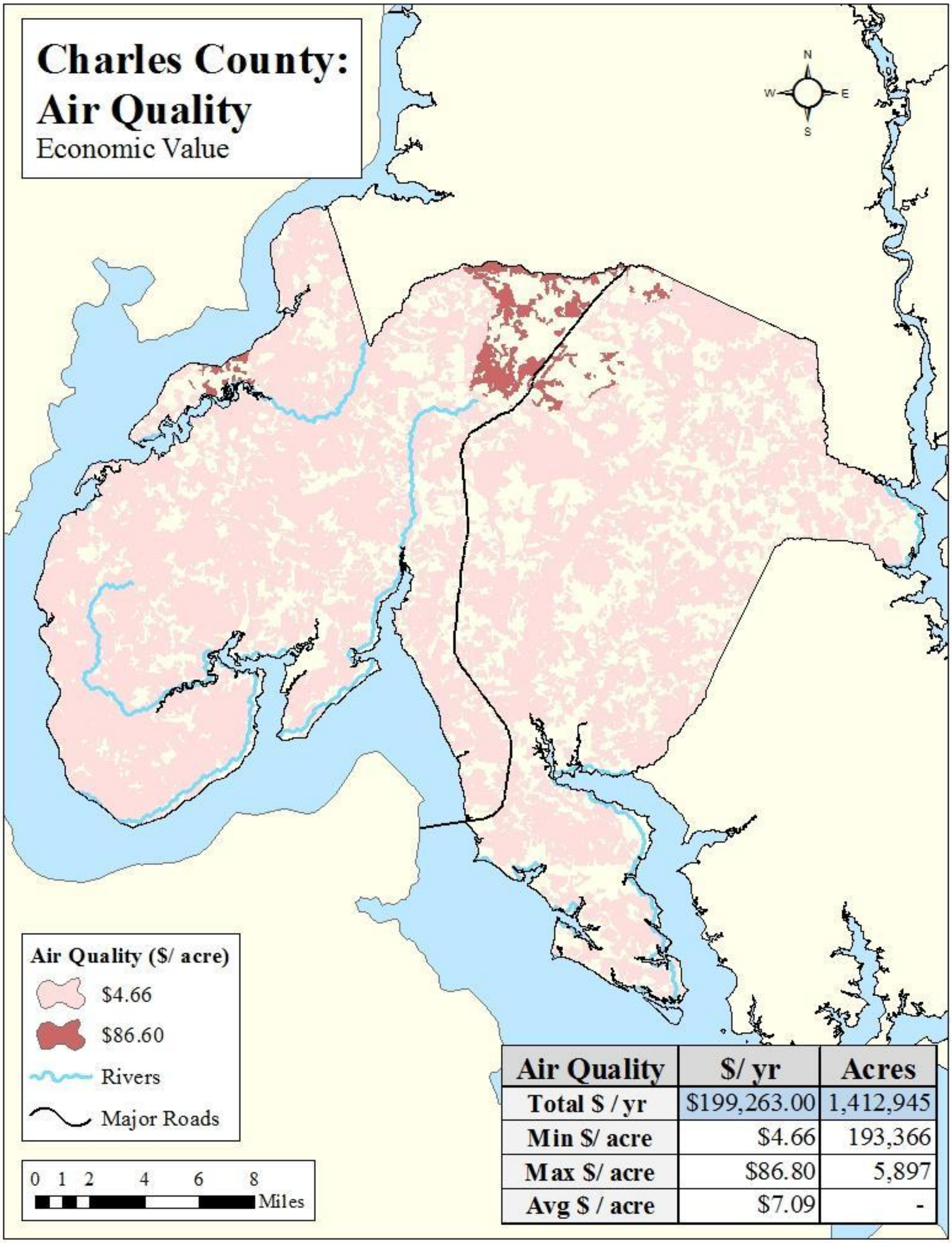
We use the economic impact that tree air pollution removal has on health costs. The air pollutants taken up by trees would otherwise cause health ailments in the populace at a certain known rate, with a certain known cost. For Maryland, Nowak et al. (2014) estimated that the decrease in air pollution related health costs due to trees was ~$4 per acre of forest in rural areas and ~$86 per acre in urban regions. Instances of payment used to calculate air pollution removal values by individual pollutants are summarized in Table 6. The spatial distribution of air pollution removal and associated economic values across Charles County is illustrated in Figure 8.

Table 6. Eco-prices used to calculate the air pollution removal ecosystem service value (Conterminous US values)

	Conterminous US		Urban areas		Rural areas	
	$ / t	$ / ha	$ / t	$ / ha	$ / t	$ / ha
NO2	27	0.15	436	3.05	7	0.04
O3	155	8.5	2864	154.76	52	2.87
PM2.5	6587	17.54	117,106	323.14	2169	5.78
SO2	8	0.03	148	0.51	3	0.01
Total		26.22		481.47		8.69

[29] Nowak et al. (2014)

Figure 8. Spatial distribution of the air pollution removal ecosystem service values across Charles County



Stormwater Mitigation

Forest canopies intercepts a portion of precipitation during rainfall events, while ground vegetation and pervious soil in forests and wetlands further slows the surface flow of water, allowing for a portion to infiltrate into the soil. Together, these ecosystems function to decrease the rate and volume of rainfall discharge into waterways, decreasing flood risk during storm events. Increasing urbanization of the state of Maryland is resulting in a state covered by an increasing amount of impervious surface, yielding more runoff when it rains. This creates several problems; the runoff carries pollutants with it, decreasing water quality, high volumes of water can erode the banks of streams and rivers, and less land is available for water to seep into the ground to recharge drinking water aquifers. Forests help to mitigate all of these problems; comparatively little water runs off forest land in an average storm, much of it seeps into the ground and what does runoff does not carry the nutrient and sediment load that urban runoff does. Increasing the amount of forest land in a watershed can help decrease the cost of treating polluted water and protects this precious resource for future generations.

Quantifying Stormwater Mitigation across the Landscape

Several factors determine the amount of stormwater runoff that is stored on the landscape. Riparian areas and 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, and type of wetland all factor into how much water runs off into the area and the ability of the area to absorb that water. All of these factors were considered when ranking the ability of forests and wetlands in Maryland to reduce stormwater runoff. This rank was related to the stormwater ecosystem service by observing the range of stormwater volumes treated by forests or wetlands.

The Watershed Resource Registry Stormwater Preservation model[30] was used to rank the relative capacity and stormwater load across the landscape from 1-5, with the modification of removal of targeting classifications from the model (targeted ecological areas, stronghold watershed, etc.). We used the Maryland Stormwater Design Manual[31] and the Virginia Stormwater Management Handbook[32] to estimate the range of stormwater volumes treated.

[30] Water Resources Registry (2016)

[31] MDE (2009)

[32] VA DEQ (2013)

Valuing Stormwater Mitigation

Instances of payment used to calculate the average eco-price of stormwater mitigation are summarized in Table 7. We considered the Charles County Stormwater Remediation fee[33]and numerous cost estimates for stormwater infrastructure, as prepared by King and Hagan for the State of Maryland in 2011[34].

The spatial distribution of stormwater mitigation and associated economic values across Charles County is illustrated in Figure 9. Additionally, Figure 10 highlights two specific regions within the county, The Mattawoman Watershed and the Waldorf unincorporated area. Both areas have some high values, but for different reasons. Mattawoman has many riparian forests, with the capacity to avoid flooding, while forests and wetlands in Waldorf receive more runoff from impervious surfaces. This highlights the importance of having natural lands across the landscape.

Table 7. Eco-price used to calculate the stormwater mitigation ecosystem service value

Biophysical Category and Measure	Eco-Price	Units	Exchange Classification
Charles County Stormwater Remediation fee	\$0.18	\$/cubic meter (m^3) runoff	Tax
Erosion and Sediment Control	\$0.22	\$/m^3 stormwater treated	Replacement cost
Vegetated Open Channels	\$0.35	\$/m^3 stormwater treated	Replacement cost
Wet Ponds and Wetlands (New)	\$0.38	\$/m^3 stormwater treated	Replacement cost
Urban Grass Buffers	\$0.38	\$/m^3 stormwater treated	Replacement cost
Urban Nutrient Management	\$0.52	\$/m^3 stormwater treated	Replacement cost
Urban Forest Buffers	\$0.54	\$/m^3 stormwater treated	Replacement cost
Bioswale (new)	\$0.57	\$/m^3 stormwater treated	Replacement cost
Dry Detention Ponds (new)	\$0.63	\$/m^3 stormwater treated	Replacement cost
Dry Extended Detention Ponds (new)	\$0.63	\$/m^3 stormwater treated	Replacement cost
Wet Ponds and Wetlands (Retrofit)	\$0.71	\$/m^3 stormwater treated	Replacement cost
Infiltration Practices w/o Sand, Veg. (New)	\$0.71	\$/m^3 stormwater treated	Replacement cost
Average Replacement Cost	\$0.48	\$/m^3 stormwater	•
Average of Tax and Replacement Cost	\$0.33	\$/m^3 stormwater	•

[33] MD (2014)

[34] King and Hagan (2011)

Figure 9. Spatial distribution of stormwater mitigation ecosystem service values across Charles County

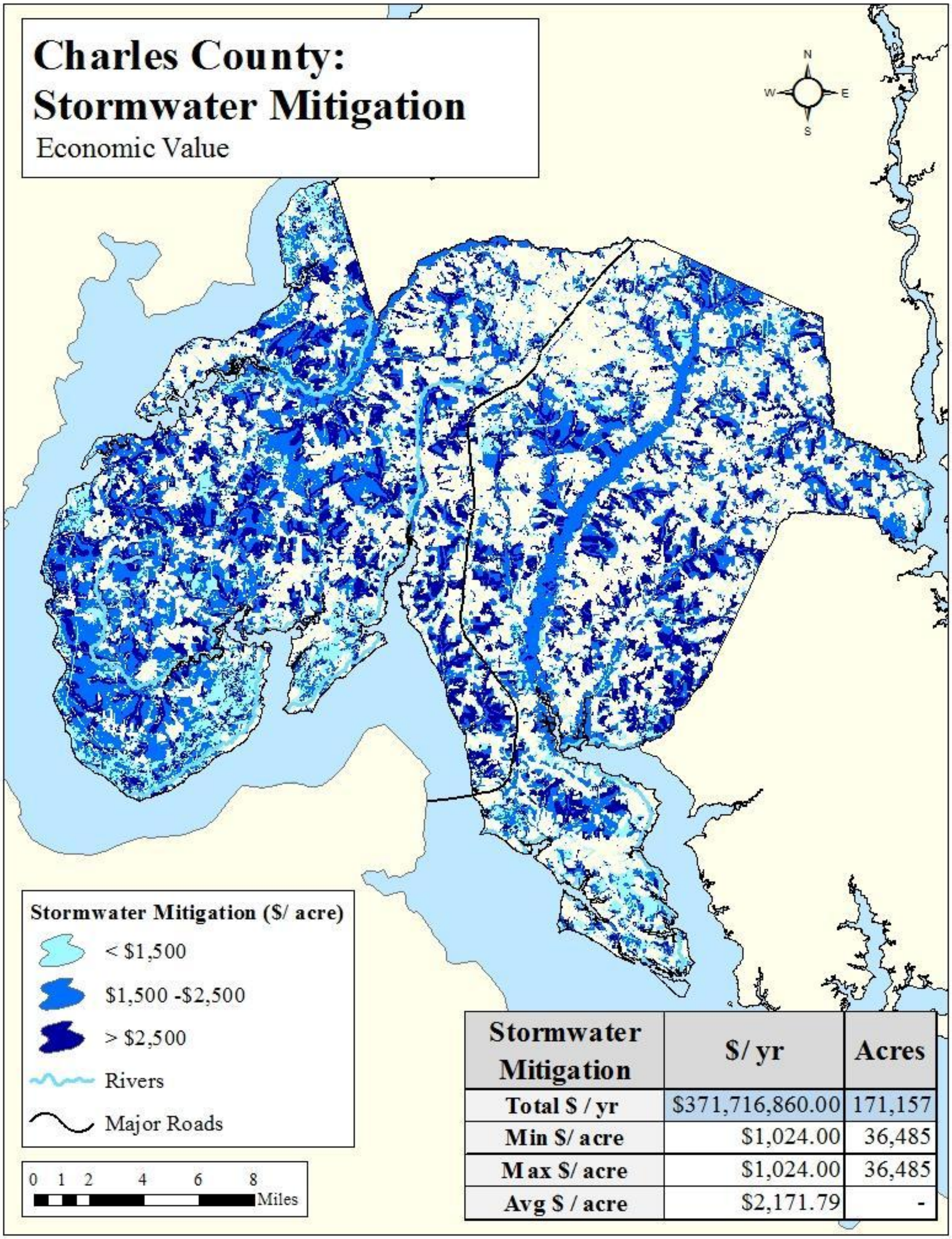
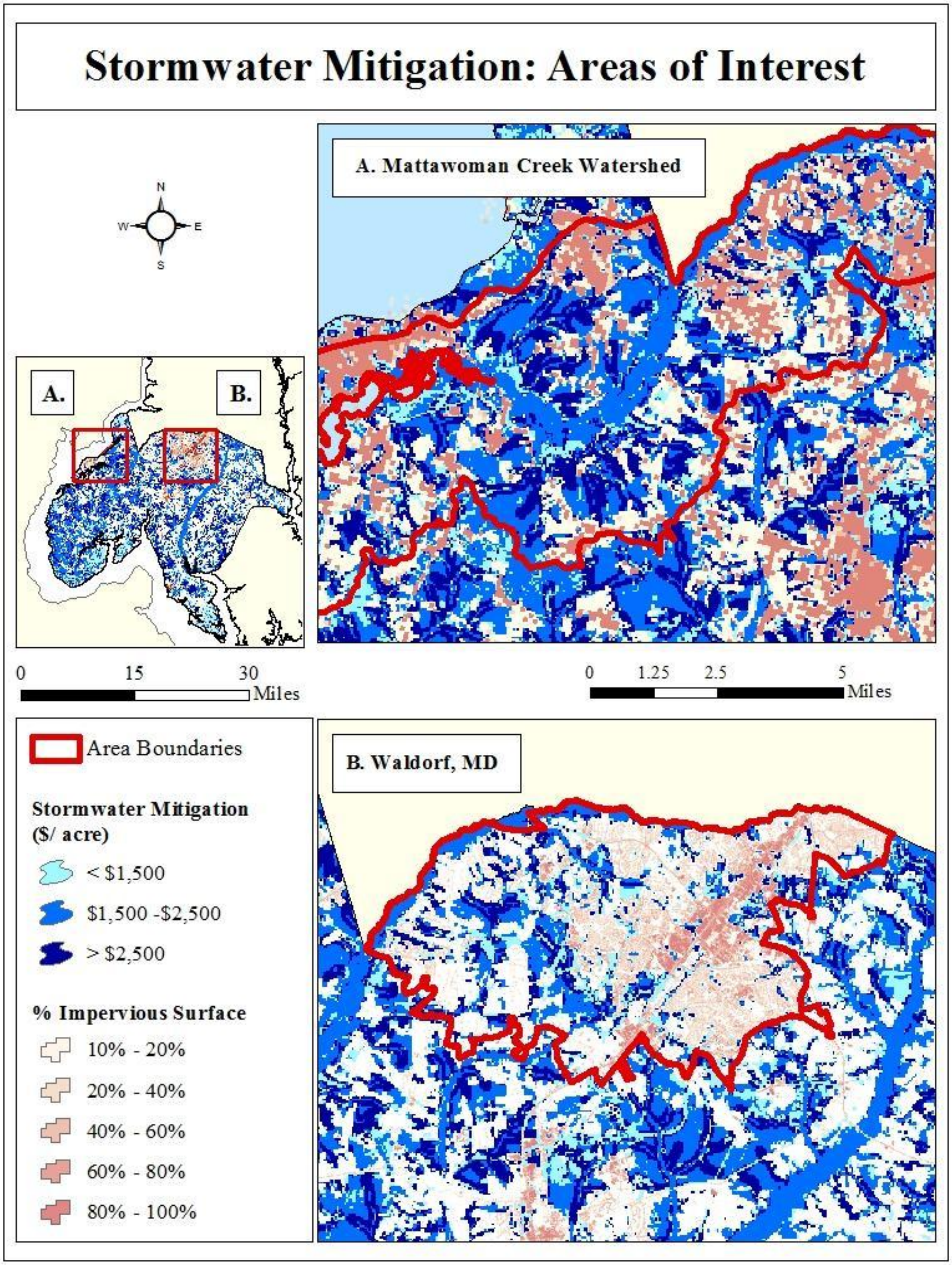


Figure 10. Stormwater mitigation in **A.** Mattawoman Watershed and **B.** the Waldorf unincorporated area, with percent impervious surface show in shades of red, and economic value of storm water management ecosystem services shown in shade.



Groundwater Recharge

Groundwater recharge represents the portion of precipitation that percolates through the soil and enters underground aquifers. Approximately 50% of Maryland residents rely on groundwater as a drinking water source, particularly in Southern Maryland and on the Eastern Shore. While water scarcity is not currently as critical of an issue in Maryland as it is in other parts of the United States, groundwater recharge is a vital component of securing the water supply of the state, particularly in the face of a growing population. Charles County relies on the Patapsco and Magothy Aquifers (groundwater), and the Washington Suburban Sanitary Commission (surface water) for their municipal water supply. Both aquifers have been identified by MDE as Water Management Strategy areas due to excessive drawdown and potential saltwater intrusion, implying that Charles County is one of Maryland's areas greatest concern for groundwater resources.

Quantifying Groundwater Recharge across the Landscape

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. The USGS National Hydrography Database (NHD) spatial assessment of groundwater recharge[35] is the data source on which we rely for our assessment.

Valuing Groundwater Recharge

The value of groundwater recharge includes the average municipal price of water in Charles County[36], value of water for recreation[37,38], and the cost of investment in watershed protection[12]. Instances of payment used to calculate the average eco-price of groundwater recharge are summarized in Table 8. The spatial distribution of stormwater mitigation and associated economic values across Charles County is illustrated in Figure 11.

Table 8. Eco-prices used to calculate the groundwater recharge ecosystem service value

Biophysical Category and Measure	Eco-Price	Units	Exchange Classification
CC municipal water	0.88	$ per m^3	Market Price
Investment in NYC Watershed Protection	0.084	$/m^3 of water supply	Investment
Average for recreation	0.073	$ per m^3	Non-market Analysis
Average for Groundwater	$0.35	$ per m^3	•

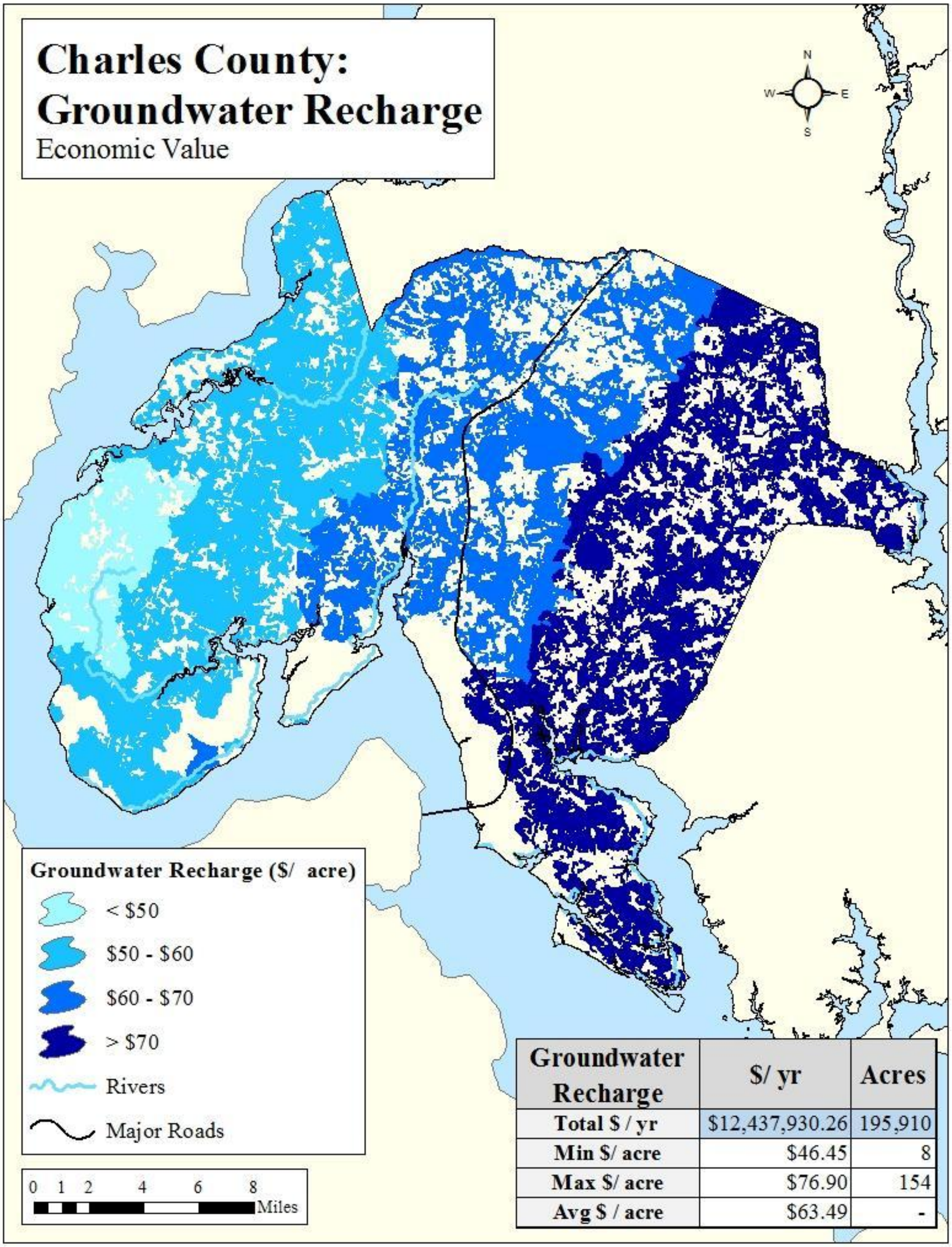
[35] National Hydrography Dataset

[36] Charles County Gov.(2016)

[37] Reardon (2007)

[38] Roland, unpub.

Figure 11. Spatial distribution of groundwater recharge ecosystem service values across Charles County



Groundwater Recharge	$/ yr	Acres
Total $ / yr	$12,437,930.26	195,910
Min $/ acre	$46.45	8
Max $/ acre	$76.90	154
Avg $ / acre	$63.49	-

Nutrient Uptake

Addressing the impacts of nutrient pollution is critically important to the Chesapeake Bay watershed. The Chesapeake Bay is a classic example of an overexploited resource, with impacts from overfishing being compounded by nutrient pollution. Historically, the forests and wetlands of the Chesapeake Bay watershed absorbed nutrient loads resulting from agriculture, urban land use, and waste products. However, in the past century, the capacity of our natural lands to absorb excess nutrient loads has been exceeded due to population growth coupled with forest and wetland loss. This has led to excess nutrients entering the Chesapeake Bay. Excess nutrients in waterways cause harmful algal blooms, which then decompose and deplete oxygen levels in the water, leading to increased dead zones and poor water quality. This process, known as eutrophication, negatively impacts the health of the Bay and impedesthe ability of fisheries to be productive. In order to restore the Bay from its degraded state, we must replace the services that were being performed by ecosystem services by either restoring natural lands or implementing nutrient removal technologies, both costly options.

Quantifying Nutrient Uptake across the Landscape

Forests and wetlands in watersheds with high amounts of urban or agricultural land-uses receive and take-up higher quantities of nutrients. Forests and wetlands have a finite ability to take up nutrient inputs and a number of factors work to determine the quantity of nutrients absorbed, including the type of forest or wetland and the timing of nutrient inputs (more nutrients will be taken up during the growing season).

The USGS SPARROW (Spatially Referenced Regression on Watershed Attributes)[39] model simulates the loading of nitrogen and phosphorus across the Chesapeake Bay watershed based on land-use, incoming nutrients from other watersheds, and atmospheric deposition. Loading rates are then used to assign low, medium, and high nutrient uptake rates based on a range of uptake rates for forests and wetlands taken from the academic literature. Average nutrient uptake rates for each forest and wetland category are summarized in Table 9.

[39] Ator (2011)

Table 9. Nitrogen and phosphorus uptake rates for forests and wetlands in Maryland

Nitrogen				Phosphorus		
Category		Range (kg)	Value ($ha)	Category	Range (kg)	Value ($/ha)
Forest	Low	< 5	15.89	Low	< 5	83.87
	Medium	15 - 5	31.78	Medium	15 - 5	100.64
	High	15 +	47.67	High	15 +	251.60
Wetland	Low	< 50	95.35	Low	< 3	61.22
	Medium	50 - 100	143.02	Medium	3 - 6	83.87
	High	> 100	190.70	High	6 +	100.64

Coastal Bay, Department Photo

Valuing Nutrient Uptake

We value nutrient uptake by observing the average cost to remove nutrients using best management practices[40], what the state provides for the BMP cost share program[41] and through the Bay Restoration Fund[42], and the price on nutrient trading markets[43]. This averages $8.36 per lbs nitrogen or phosphorus. Instances of payment used to calculate the average eco-price of nutrient uptake are summarized in Table 10. The spatial distribution of stormwater mitigation and associated economic values across Charles County is illustrated in Figure 12. Urban lands are particularly important nutrient sources, as evidenced by the Waldorf region of Charles County (see inset of Figure 12).

Table 10. Eco-prices used to calculate the nutrient uptake ecosystem service value

Biophysical Category and Measure	Eco-Price	Units	Exchange Classification
MD BMP Cost-Share Program	$3.67	$/kg N	Cost of regulation
BMP, Conservation planning	$4.64	Costs/kg N+P	Avoidance cost
BMP, Grass buffers	$5.26	Costs/kg N+P	Avoidance cost
BMP, Forest buffers	$6.95	Costs/kg N+P	Avoidance cost
Nutrient Trading in Chesapeake Bay Watershed	$8.38	$/kg N	Market price
BMP, Conservation tillage	$15.49	Costs/kg N+P	Avoidance cost
BMP, Cover crops	$15.53	Costs/kg N+P	Avoidance cost
BMP, Wetland restoration	$24.20	Costs/kg N+P	Avoidance cost
Bay Restoration Fund	$29.33	$/kg N	Cost of regulation
BMP, Enhanced nutrient management	$37.93	Costs/kg N+P	Avoidance cost
BMP, Barnyard runoff control	$38.46	Costs/kg N+P	Avoidance cost
BMP, Pasture fencing	$59.16	Costs/kg N+P	Avoidance cost
BMP, Nutrient management	$60.70	Costs/kg N+P	Avoidance cost
BMP, Prescribed grazing	$83.34	Costs/kg N+P	Avoidance cost
Average for Nutrient Management BMPS	$31.97	Costs/kg N+P	Avoidance cost
Average for Nutrients	**$18.34**	$/kg N+P	

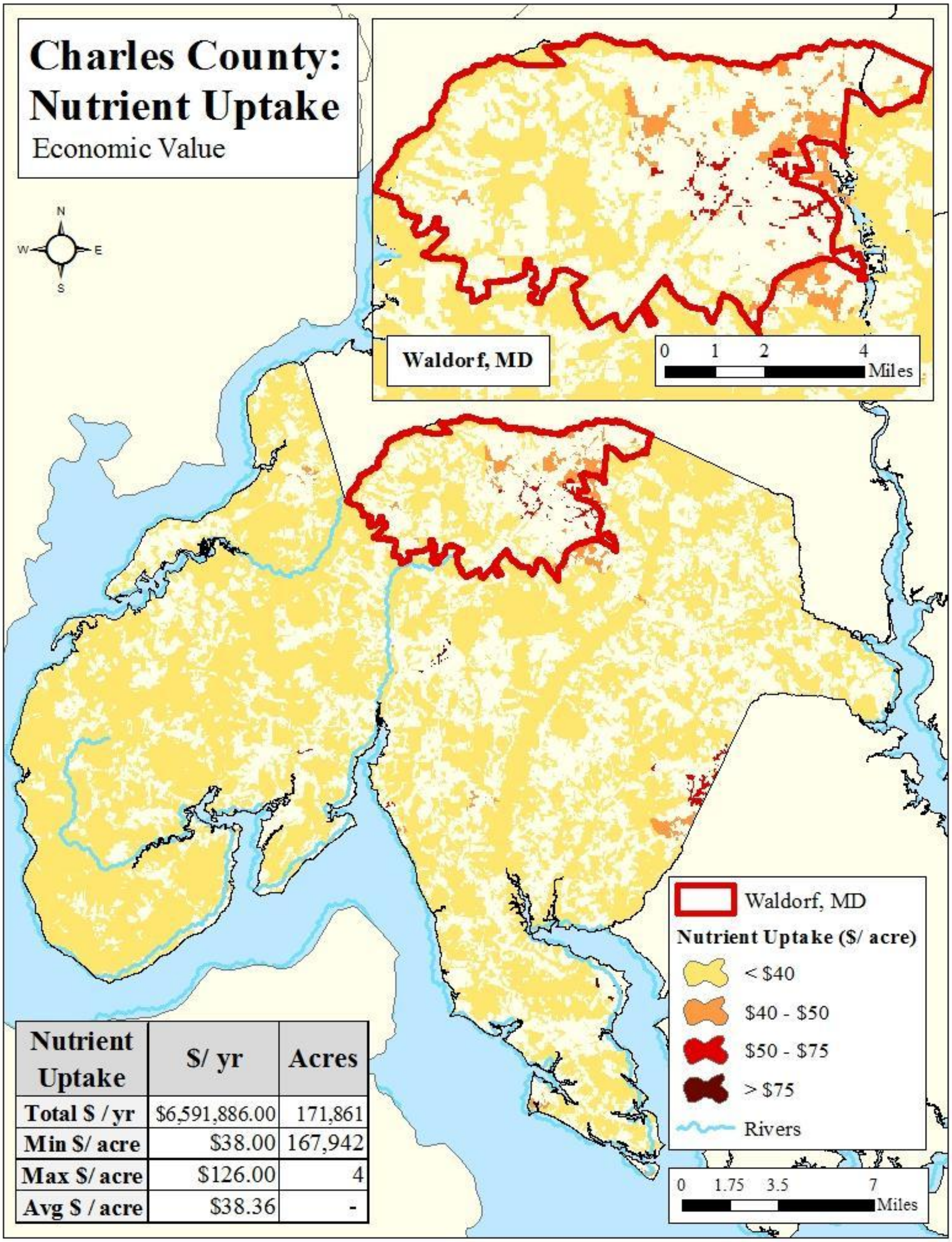
[40] Talberth et al. (2015)

[41] MDA (2015)

[42] MDE (2015)

[43] PA DEP (2014)

Figure 12. Spatial distribution of nutrient uptake ecosystem service values across Charles County



Nutrient Uptake	$/ yr	Acres
Total $ / yr	$6,591,886.00	171,861
Min $/ acre	$38.00	167,942
Max $/ acre	$126.00	4
Avg $ / acre	$38.36	-

Agricultural Benefits

Agriculture is a vital land-use for the obvious reason of providing the food we eat, but in many cases there are other benefits that come along with food provision. From a hydrology perspective agricultural land generates less stormwater runoff than suburban or urban lands and allows more groundwater recharge. However, depending on the amount of irrigation used, and its source, agriculture can be a net drain on groundwater. Agricultural land has the potential to either be a net benefit or cost for carbon sequestration, depending on the practices used. Standard agriculture is typically carbon neutral, but when conservation tillage or cover crops are used, net carbon sequestration in the soil tends to occur. Nutrient and sediment loading are ecosystem disservices or costs associated with agriculture, although they can be decreased through incorporating best management practices.

Quantifying Agricultural Benefits across the Landscape

Corn/soybean rotation agriculture is the most common in Maryland, approximately 60% of all cropland is planted with either corn or soybeans in a given year. We went to the academic literature to assess ecosystem services in conventional agriculture and with conservation tillage/cover crops. The Maryland Department of Agriculture collects data on the acres using these best management practices in each county, but not the location due to privacy concerns. 70% of cropland in Charles County is in conventional agriculture, compared to 52% for the state as a whole.

The Maryland Department of Agriculture (MDA) provided much of the data used for the analysis, including the acreage in Charles Co. using conservation tillage or cover crops and the average crop yield. Literature sources were used to estimate the impact that BMP's have on ecosystem services[44,45,46,47,48].

[44] Olson et al. (2014)

[45] Yeo et al. (2014)

[46] Kaspar et al. (2006)

[47] Kaspar (2001)

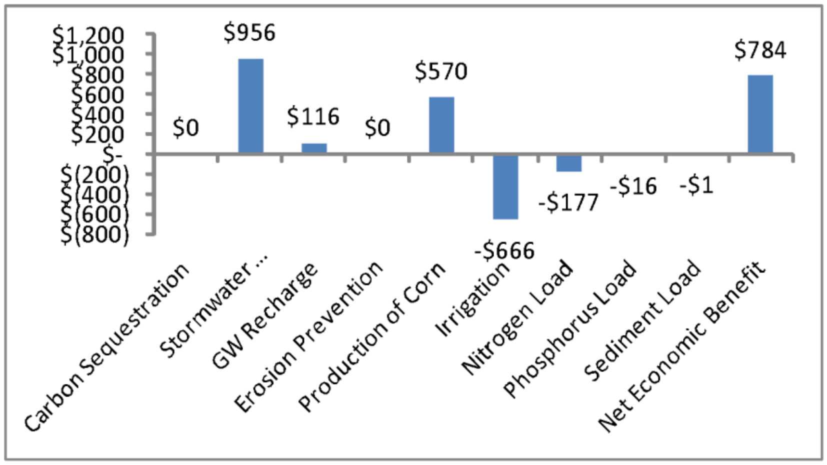
[48] Langdale et al. (1991)

Valuing Agricultural Benefits

We calculated the average value of ecosystem services in Charles Co. by taking a weighted average of conventional agriculture ($784 per acre per year, see figure 13A) and agriculture with best management practices ($1,482 per acre per year, see figure 13B). The categorical eco-prices for agricultural benefits are the same as those used for the previous ecosystem services. The breakdown of conventional agricultural practices and conservation agriculture is 70%-30%, respectively. Using these percentages, there is a weighted average for ecosystem services from agriculture in Charles County of $962 per acre per year. The spatial distribution of agricultural land across Charles County is illustrated in Figure 14.

Farmland,, Karen Lowry

A.



B.

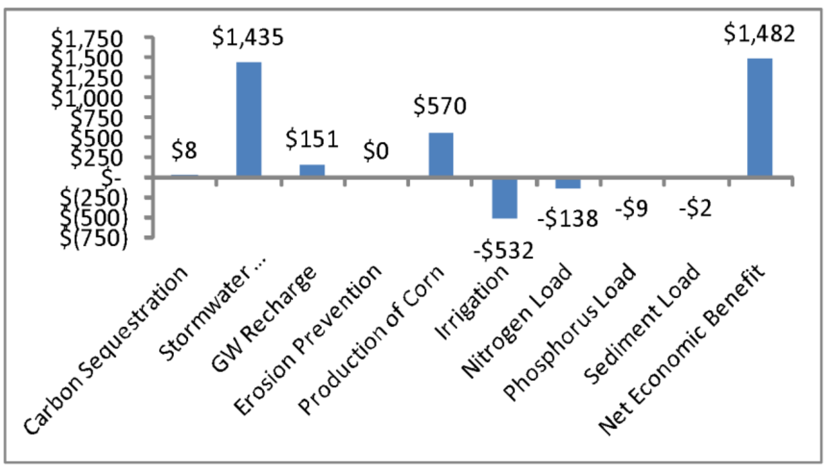
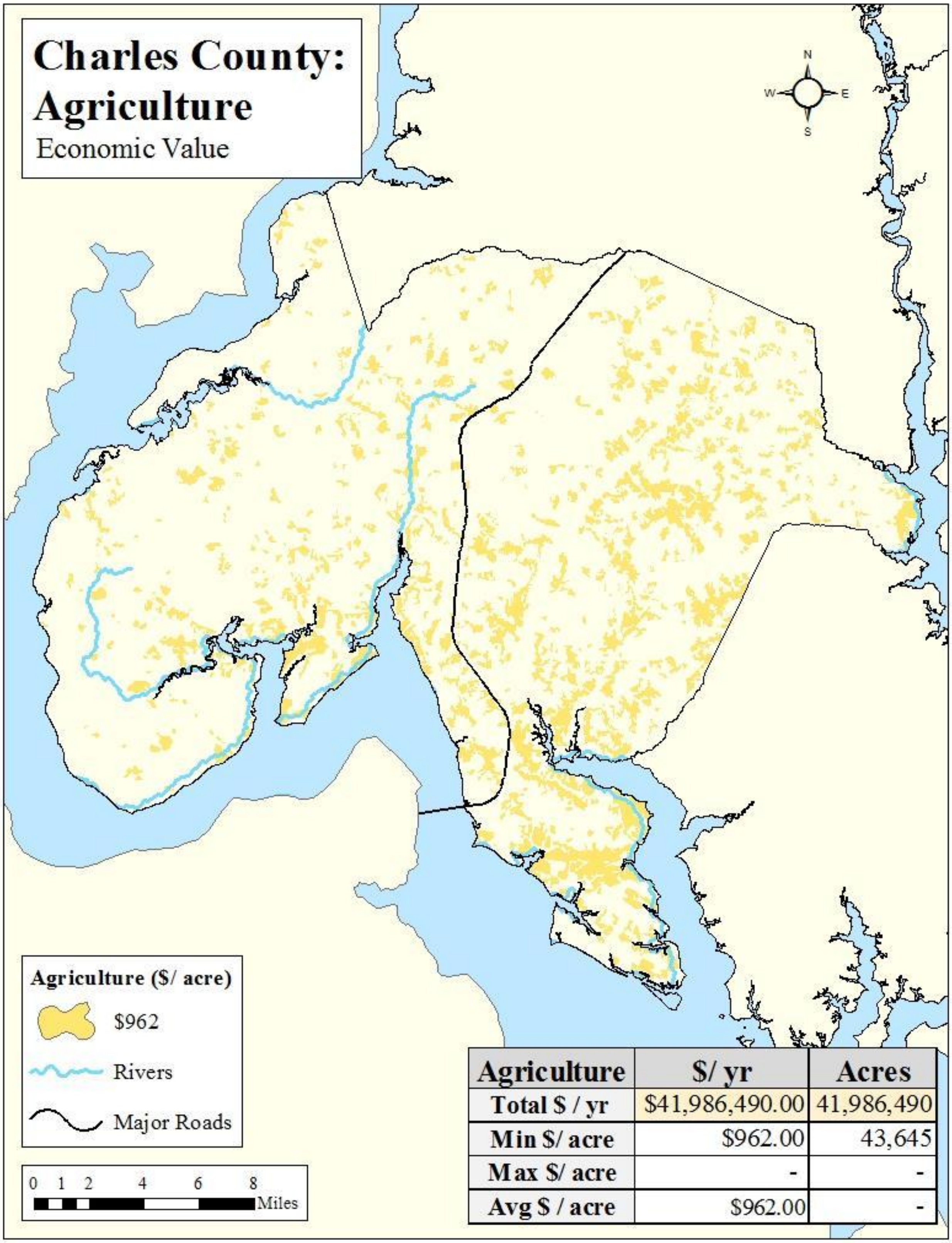


Figure 13. The value of agricultural ecosystem services when land is managed using **A.** standard agriculture methods versus **B.** Best Management Practices, including conservation tillage and cover crops

Figure 14. Spatial distribution of agricultural land ecosystem service values across Charles County



Agriculture	$/ yr	Acres
Total $ / yr	$41,986,490.00	41,986,490
Min $/ acre	$962.00	43,645
Max $/ acre	-	-
Avg $ / acre	$962.00	-

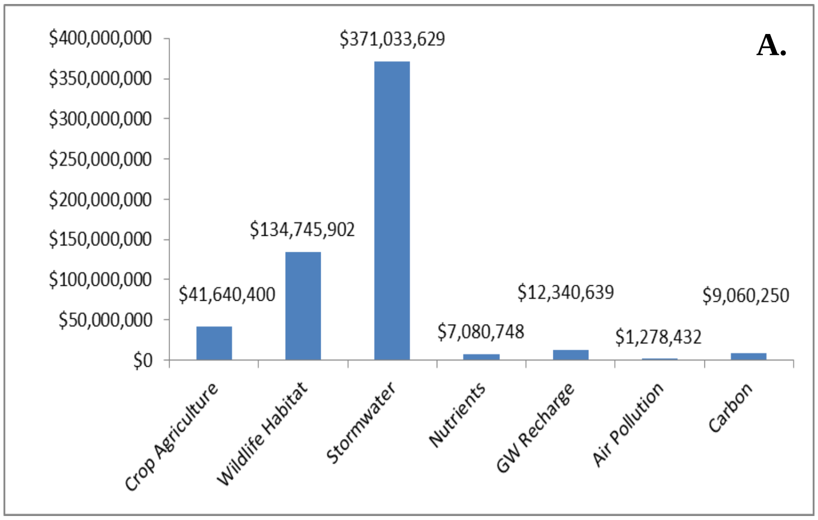
Corn and Grain Fields, Frank Tiralla III

CHARLES COUNTY ECOSYSTEM SERVICE SUMMARY

Value of Combined Ecosystem Services

Across forest and wetland areas in Charles County, the total value of all ecosystem services considered is $535.5 million dollars per year, with an average ecosystem service value per acre per year of $2,459. The total and average values for each individual ecosystem service are summarized in Figure 15. The spatial distribution of ecosystem services in across Charles County is illustrated in Figure 16.

The stormwater ecosystem service is the largest in the county, indicating the importance of natural lands in reducing the need for building stormwater grey infrastructure and reducing the risk of flood damage. Riparian forests and wetlands are the most important regions for providing this service, and consequently have the highest ecosystem service value of any region in the County. Wildlife habitat and biodiversity protection is the second largest ecosystem service, on average. Charles County has significant areas of large contiguous natural lands and presence of rare or threatened habits, contributing to the ES value.



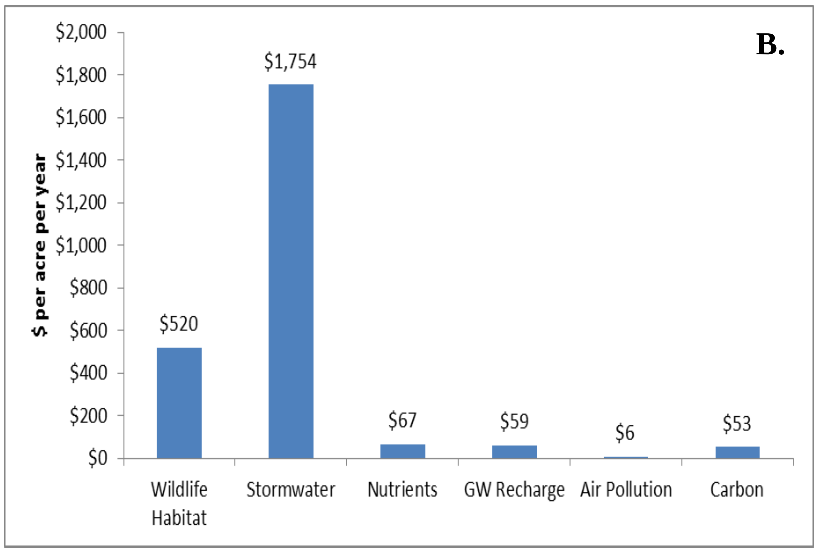
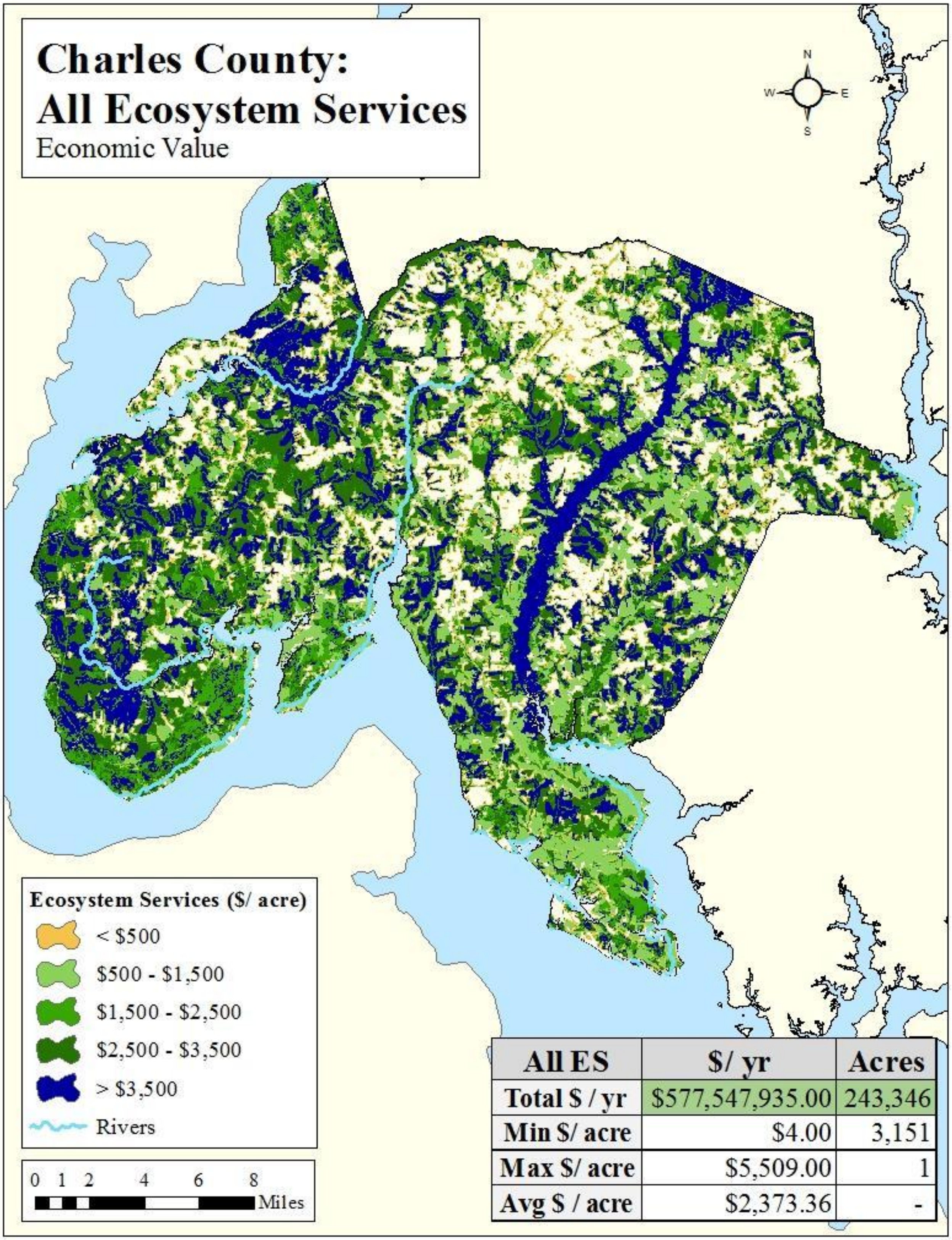


Figure 15. This figure shows **A.** the total value of each ecosystem service across Charles County, totaling $535.5 million per year and **B.** the average annual value per acre of each ecosystem service

Figure 16. Spatial distribution of combined ecosystem service values across Charles County

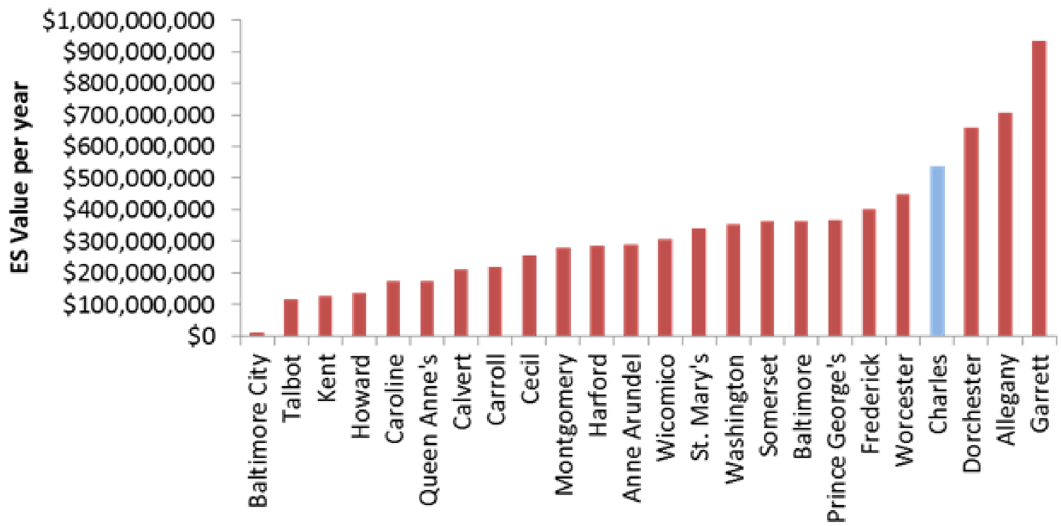


Comparison to Other Maryland Counties

Charles County has the fourth highest total for ecosystem services provided per year, and the third highest value per acre of forest or wetland (Figure 17 A and B, Figure 18). This is not unexpected, as Charles has the third highest percentage of forest cover in the State, behind Allegany and Garrett Counties. Dorchester County on the Eastern Shore of the state has the highest abundance of wetlands in Maryland, contributing to its high ranking in ecosystem services provided. Trends in ecosystem services across the state will be further explored in future work.

Figure 17. Comparison of ecosystem service values across Maryland counties; **A.** shows the total ES value per year, while **B.** shows the average dollar per acre per year

A.



B.

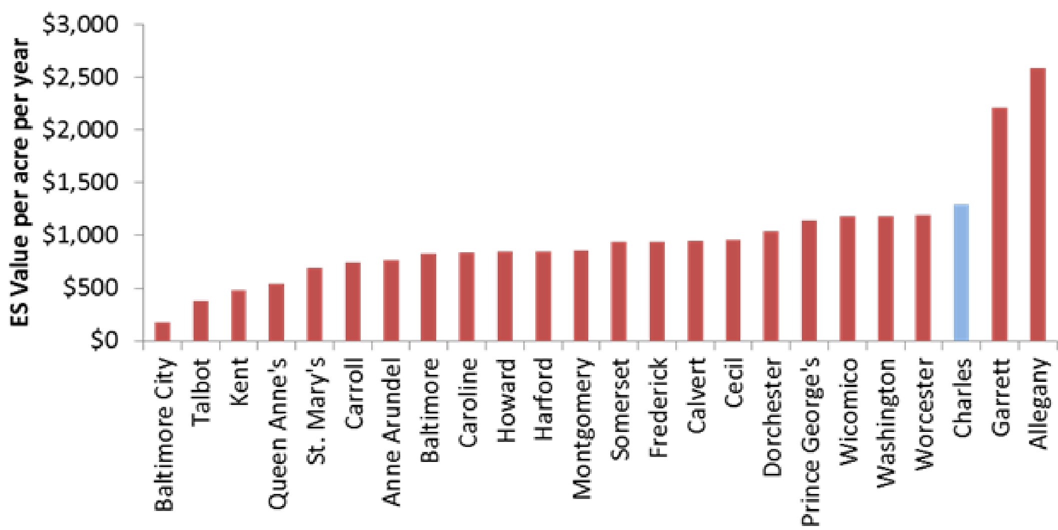
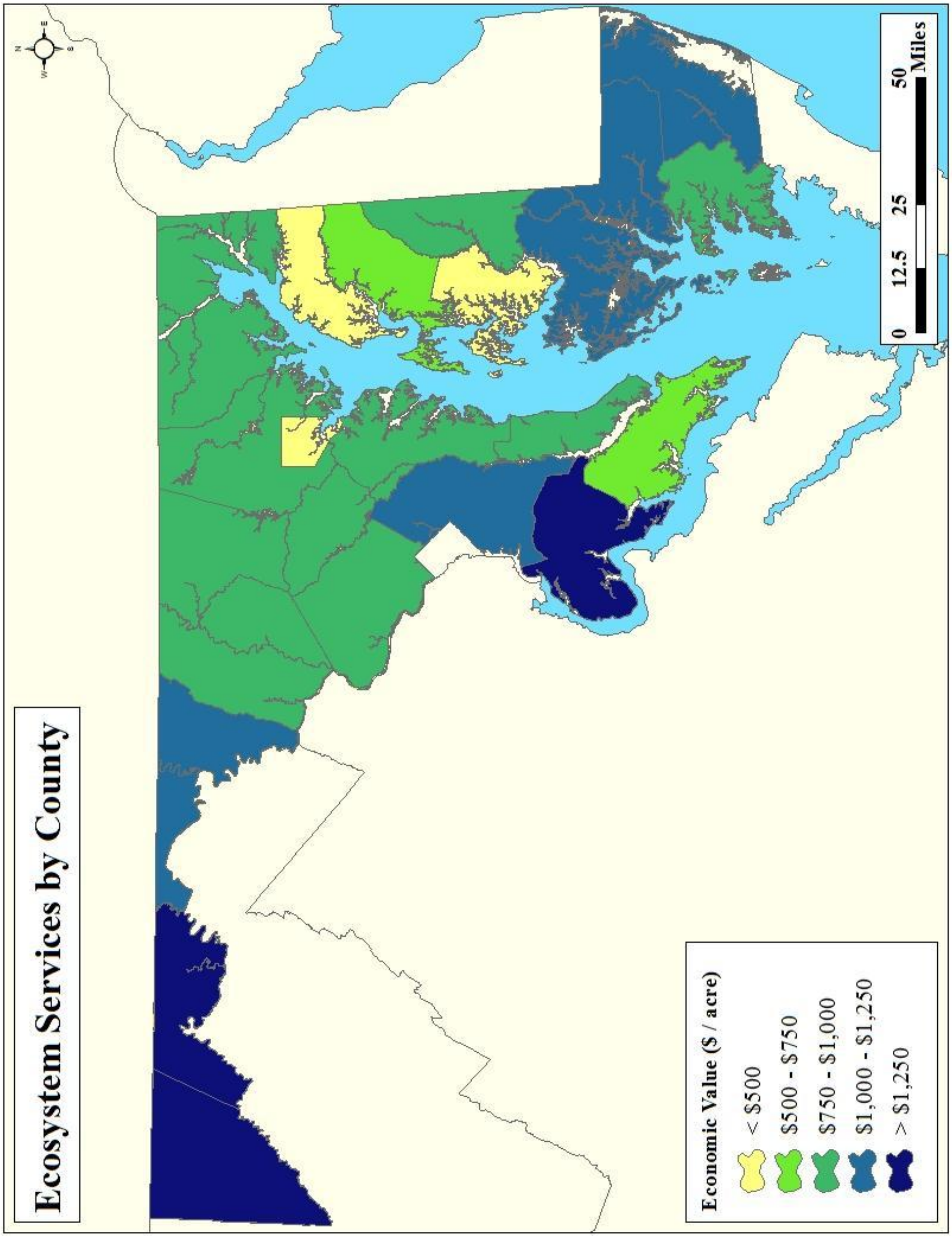


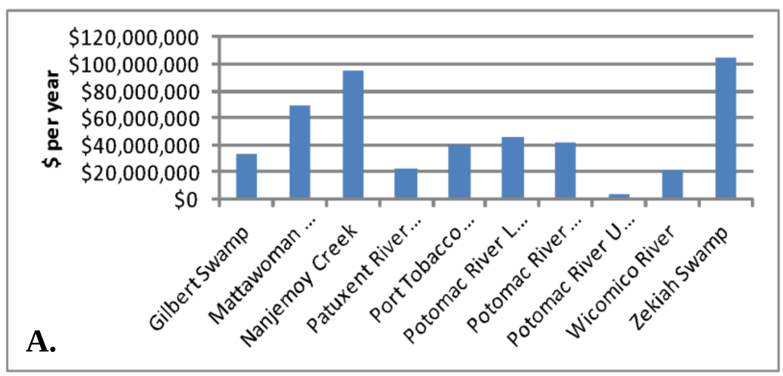
Figure 18. Average ecosystem service value per acre per year across Maryland counties



Ecosystem Services Value by County Watershed

Several watersheds within Charles County stand out as being particularly important for providing ecosystem services. In terms of biophysical value, Zekiah Swamp, Mattawoman Creek, and Gilbert Swamp exhibited the greatest amount of ecosystem services provided per acre per year. In terms of total economic value, Zekiah Swamp, Mattawoman Creek, and Nanjemoy Creek exhibited the highest eco-price per acre per year (Figure 19 A). Not coincidentally, these watersheds contain lands managed and protected by county, state, and federal agencies (Figure 4). Lands with high conservation value (and corresponding ecosystem service value) tend to be target for protection. The location and average economic value per acre per year of watershed across Charles County are illustrated in Figure 20. Across Charles County, the total ecosystem service value of forests and wetlands was found to be similar, with forests and wetlands providing $2,886 and $2,862 per acre per year respectively (Figure 19 B). These values are higher than the average of all natural lands in the County due to some land outside of the forest/wetland classification being included for certain ecosystem services in the county wide analysis. The high value of the Zekiah Swamp, Mattawoman Creek, and Gilbert Swamp watersheds indicates that particular care should be taken in protecting the ecological integrity of these watersheds, for this value to be preserved into the future

Zekiah Swamp, Department Photo



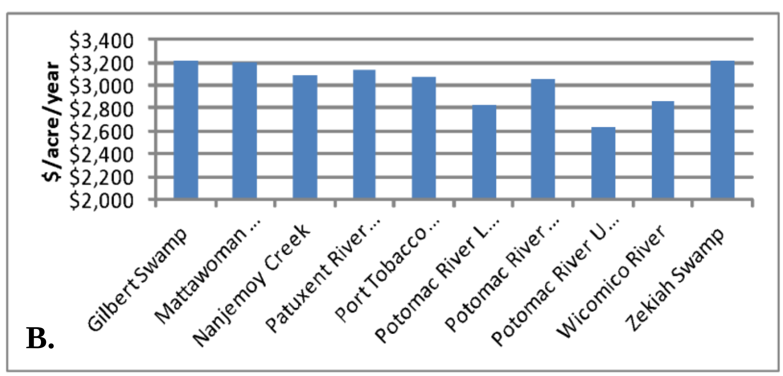
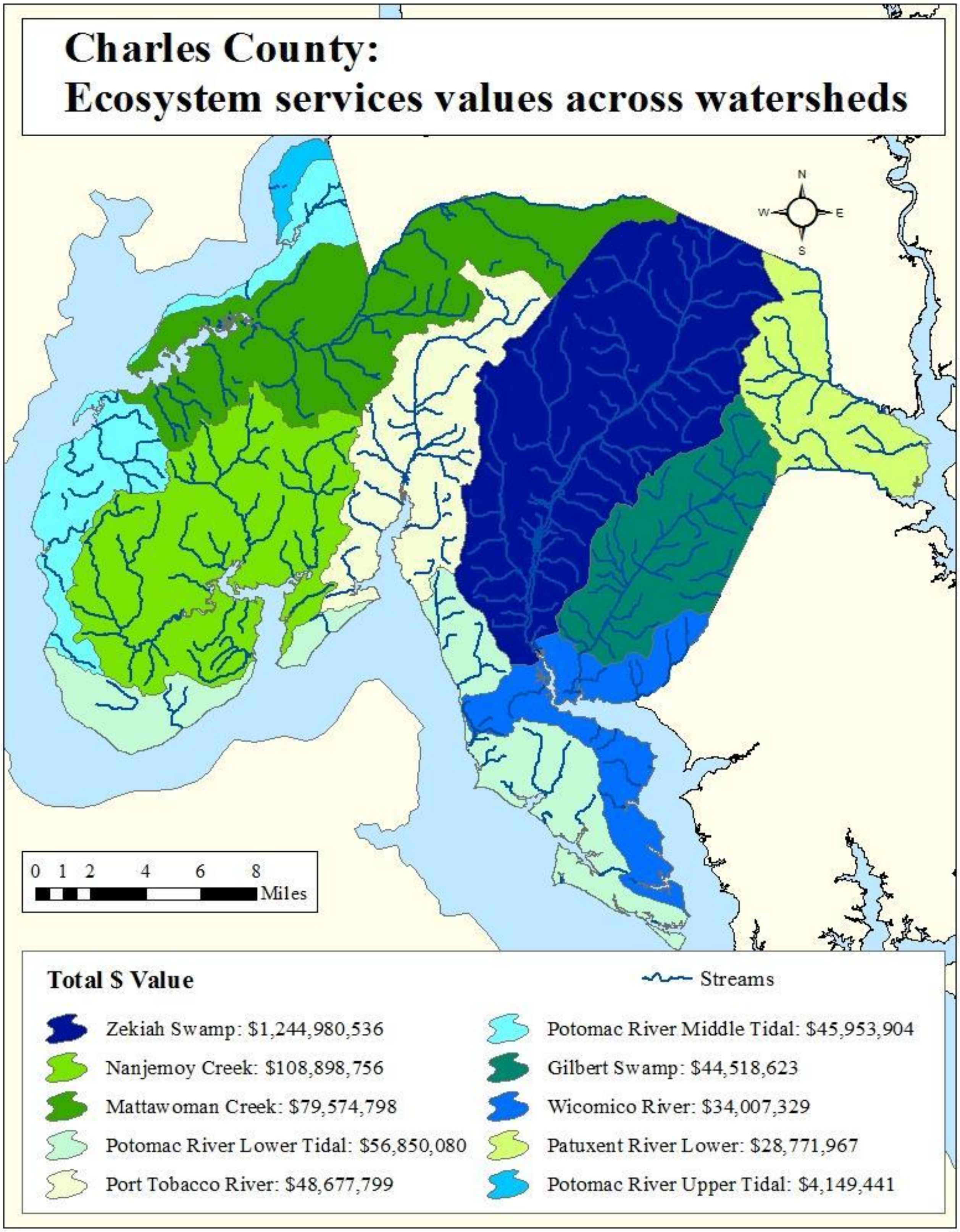


Figure 19. Ecosystem service totals by **A.** watershed in Charles County and **B.** average ES value per acre by watershed

Figure 20. Total ecosystem service values by 8 digit watershed across Charles County



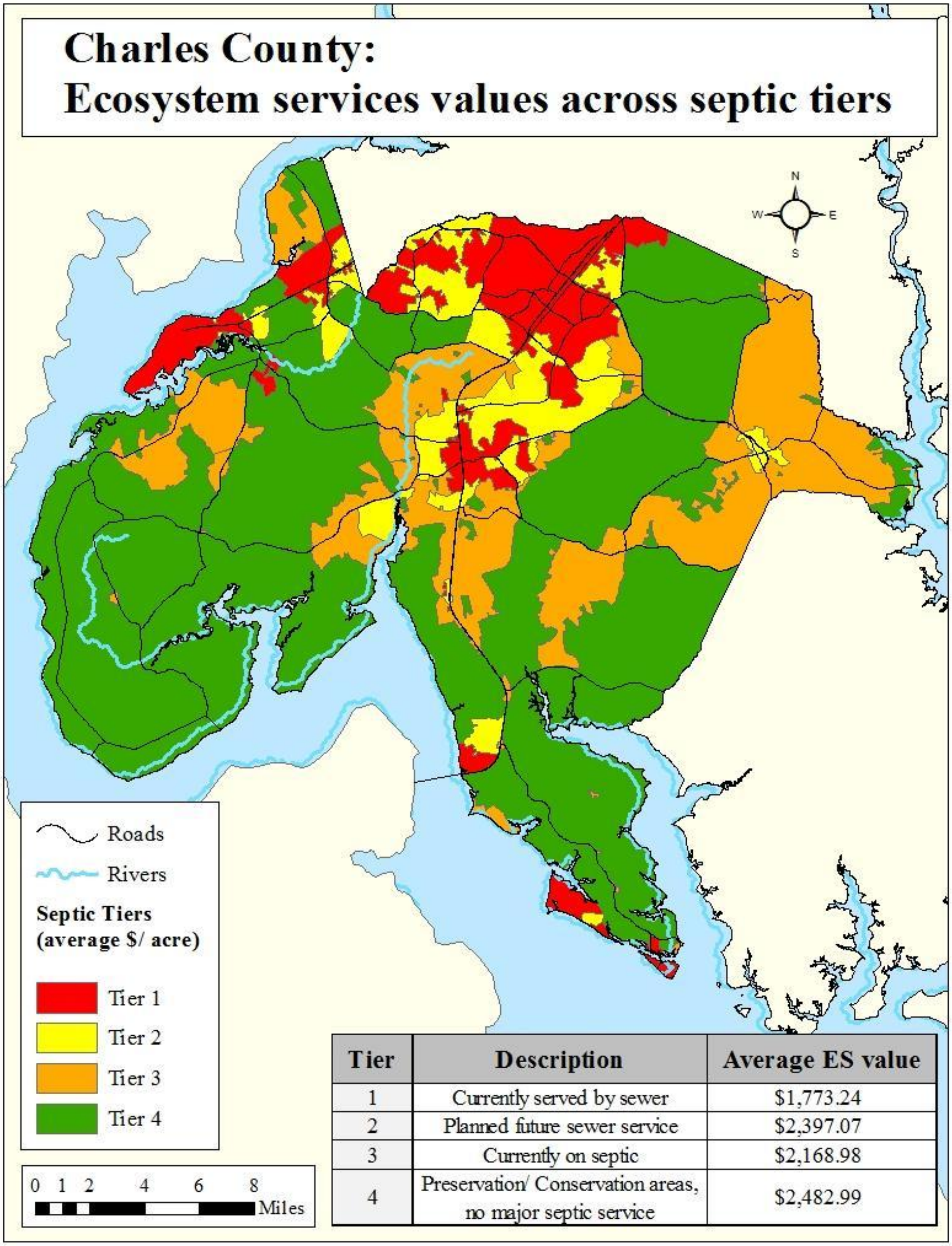
Ecosystem Services Value by Septic Tier

As part of the Sustainable Growth and Agricultural Preservation Act of 2012, Charles County has mapped its land area into a series of 4 septic tier designations: current sewer (1), future planned sewer (2), large lot septic (3), and preservation or conservation with limited use of septics (4) . The purpose of these designations is to limit the implementation of septic systems on large lot residential developments, as these systems are a major source of nitrogen pollution in the Chesapeake Bay. The spatial distribution of septic tier designations across the county illustrated in Figure 21, along with a table that provides a definition of each tier and the associated average economic value of ecosystem services across that tier per acre per year.

To understand how the value of ecosystem services varies between septic tiers, the average eco-price per acre per year for each tier was calculated. Tier 2 and Tier 4 areas exhibit high ecosystem service values, averaging $2,397.07 and $2,482.99 per acre per year respectively. This is because the Tier II areas remain undeveloped until sewer service is provided, and the Tier IV areas allow for the least overall amount of future development. The relatively low level of development in these areas has allowed natural systems to remain intact and retain their optimal functionality. Despite issues with nitrogen pollution, Tier 3 areas currently on septic exhibit higher average ecosystem service values than do Tier 1 areas currently serviced by sewer systems, averaging $2,168.98 and $1,773.24 per acre per year respectively. This is likely due to the lower level of development and impervious surfaces in largely rural Tier 3 areas, which retain more natural areas and associated ecosystem functionality than do more developed Tier 1 areas.

These results demonstrate several important concepts. First, the high value of ecosystem services in Tier 4 areas highlights the importance of protecting natural areas through preservation, conservation programs, and development density requirements. Second, while Tier 2 areas currently exhibit high ecosystem service values, the current low ecosystem service value of Tier 1 areas indicates that the future development planned in Tier 2 areas may result in a decrease in ecosystem service values. It is therefore important that future development plans explicitly value existing ecosystem services, and development is designed to minimize impacts to their functions. Finally, the current lower ecosystem service value per acre of Tier 1 and Tier 3 areas highlights an opportunity to improve ecosystem services through restoration of existing natural areas, or increases in tree canopy cover in developed areas.

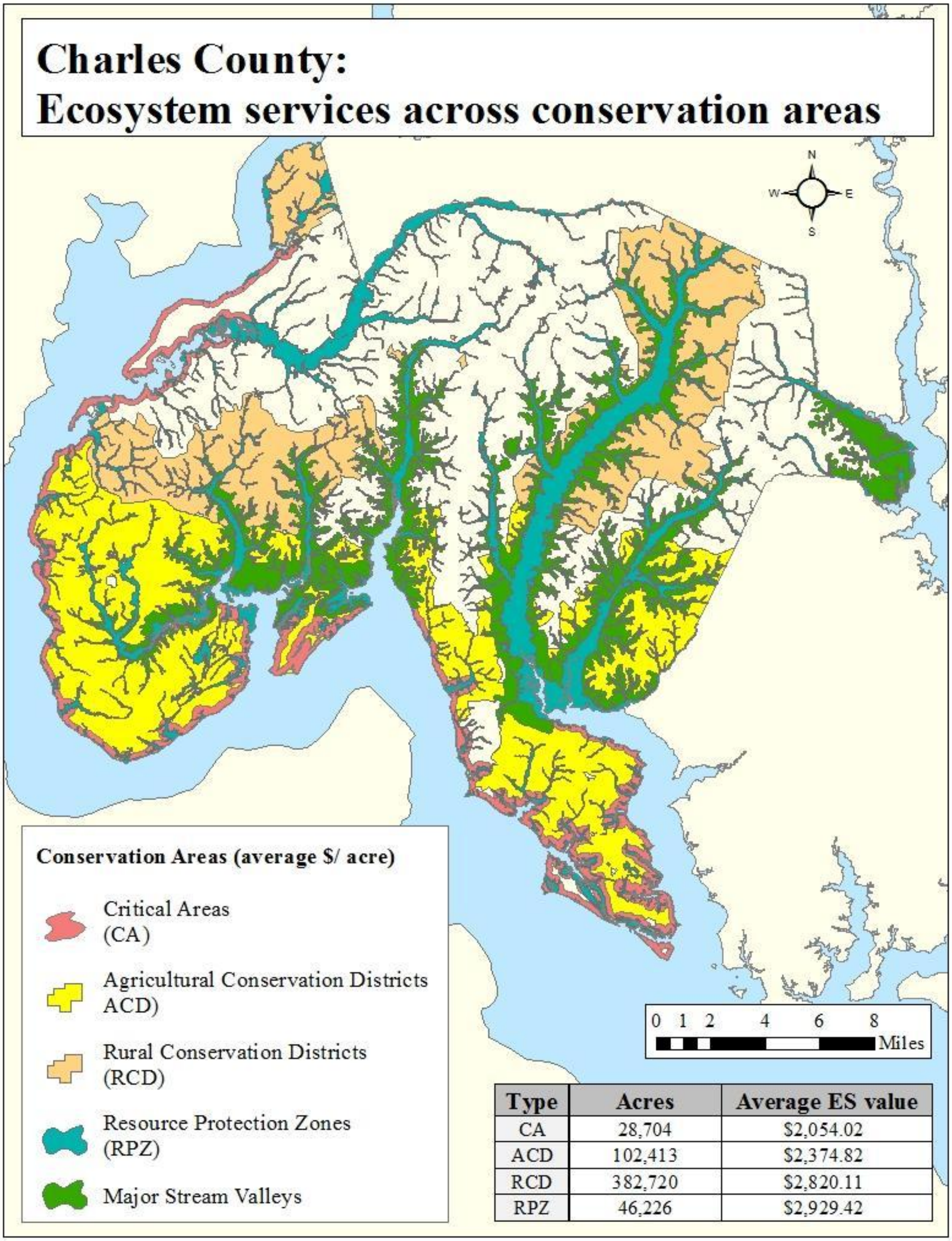
Figure 21. Average ecosystem service values by septic tiers across Charles County



Ecosystem Services Protection via Zoning

The zone, or overlay zone, in which parcels of land are placed, can be a catalyst of ecosystem service protection. The Critical Area Overlay Zone (CA) is restrictive on development as to protect the integrity and ES function of these sensitive areas. The regulations are written to reduce potential impacts that can arise from flooding, climate change induced sea level rise, storm surge, etc. This overlay zone protects the natural resources and protects property owners from property damage in these higher risk areas. Charles County currently has a Resource Protection Zone (RPZ), to "protect stream valley habitat and water quality." The RPZ is a minimum of 50 feet from the edge of the channel for a 1st or 2nd order stream and a minimum of 100 feet from the edge of the channel for a 3rd or 4th order stream. The RPZ is expanded 25 feet from the edge of associated wetlands within the designated Development District, and 50-100 feet from the edge of associated wetlands outside of the Development District. The Rural Conservation District is a low density zoning area, intended to preserve natural lands. These zones/overlay zones have effectively targeted high ecosystem service value regions, with the ES value being $2,758 per acre per year in the RPZ, and $2,158 in the Rural Conservation Zone (RC). Forests and wetlands surrounding rivers and streams tend to have the highest ecosystem service value, as evidenced by the exceptionally high value observed in the RPZ. The Resource Conservation Zone has a high ES value due to the high percentage of forests and wetlands the RPZ contains. These ES values indicate that zoning can effectively protect ecosystem services. The spatial distribution of these designations, as well as the average economic value of ecosystem services across each designation is illustrated in Figure 22.

Figure 22. Average ecosystem service values across various resource protection areas in Charles County



Type	Acres	Average ES value
CA	28,704	$2,054.02
ACD	102,413	$2,374.82
RCD	382,720	$2,820.11
RPZ	46,226	$2,929.42

IMPLICATIONS OF THE ECOSYSTEM SERVICE ASSESSMENT

There are several implications and potential applications of the ecosystem services assessment of Charles County. Ecosystem service values can be considered when deciding how municipalities or counties meet stormwater or nutrient reduction goals. Appendix 1 has an example of how these values could be used to compare the stormwater reduction options of green and grey infrastructure. The return on investment (ROI) is a commonly used economic metric to evaluate the net benefit of investing in something. Ecosystem services can be factored into the benefits of an investment decision in an activity that positively impacts the environment, like conserving natural land, restoring degraded lands to a more natural state, or instituting a regulation designed to improve or protect natural lands. The following are examples where the results of this study could be influential to these decisions.

Smallwood State Park, Department Photo

Conservation Return on Investment

The Mattawoman, Zekiah, and Gilbert watersheds have the highest per acre values of ecosystem services, indicating that these regions have the highest density of ecosystem service value in the County and that measures should be taken to minimize future degradation. The County and State should prioritize land acquisition in these regions and transfer of development rights (TDR) away from these watersheds.

Restoration Return on Investment

Comparison of the cost of implementing certain programs to the uplift in ecosystem services through expanding or restoring natural lands (e.g. reforestation, wetland restoration) could be done using the results of this analysis. The addition of ecosystem service value allows additional benefits of restoring natural lands to be realized, incentivizing restoration of degraded systems. Restoration activities are most appropriate in more impacted regions, such as the Waldorf unincorporated area of Charles, where ecosystem services like stormwater mitigation and nutrient removal will be higher.

Regulatory Return on Investment

Results could be applied to identify areas of high ecosystem service value, where regulatory action such as Critical Area protection or low density zoning could be used to support the maintenance or strengthening of services. Actions to limit impervious cover and development intensity can produce a high return of service values for a relatively low investment. This idea is demonstrated by the high ecosystem services values found within the county’s Watershed Conservation District and Resource Protection Zones.

Results could also be used to set mitigation targets that better compensate for the loss of ecosystem services following the conversion of natural lands, with the goal of no-net loss of services throughout the county. Initial analysis indicates that achievement of no-net loss would require mitigation ratios greater than what is currently required, as newly planted forests and restored wetlands lack the full function and service provisioning capacity of the original mature ecosystems they are meant to replace. Once the value of ecosystem services lost is quantified, mitigation targets can be set to achieve restoration of services to a value commensurate with that of the original system. The effectiveness of a direct no-net loss goal alone is limited, and should be used as part of a larger, holistic, long-term planning effort to project and avoid the impact of development on ecosystem function and services at the watershed scale. One important area for future research and policy debate is determination of the developmental threshold beyond which the natural resiliency of the ecosystem can no longer compensate for the rate or degree of degradation, and loss of ecosystem function and services becomes irreversible.

Potential Applications in Charles County

The wealth of data and information resulting from the Charles County ecosystem service assessment described here provides a detailed understanding of the distribution and value of services across the county. To leverage the full power of this assessment for the protection and preservation of ecosystem services, their values must be incorporated into existing implementation frameworks. At the local level, consideration of ecosystem service values should be integrated into Zoning and Subdivision regulations, which govern land use planning and development decisions. Beyond inclusion of ecosystem services values as a variable in the decision making process, an updated Zoning Ordinance could include several additional implementation considerations to address ecosystem services, including:

- Reduction of the uses permitted in the RPZ within the Zoning Ordinance;
- Creation of larger or wider RPZ and stream buffers in septic tiers 2-4, as tiers 2-4 were found to have the highest ecosystem service values in this study;
- Requirement of planting enhancements in RPZ when forested buffer is inadequate to counter effects of proposed development - specify stems/acres, larger plant stock to increase survivability, etc.;
- Revision of landscaping standards to require larger plant stock sizes, as larger trees and plants can absorb larger stormwater/pollutant loads, thereby decreasing pressure on ecosystem services.

Beyond modification of regulated Zoning Ordinances, there are number of management, decision making, and education/outreach strategies that could aid in the protection and preservation of ecosystem services, including:

- Focus stream and shoreline restoration in high ecosystem services areas, like septic tiers 2 and 4
- Facilitate land preservation and conservation easement programs in areas with high ecosystem service values
- Consider designating new Rural Legacy Areas that target properties with the highest ecosystem service value
- Launch outreach efforts to educate citizens about the value of ecosystem services, and garner support for strategic conservation land use planning in areas with high ecosystem service value.

Chapman State Park, Department Photo

CONCLUSIONS

- Ecosystem service valuation reveals the economic contributions of natural lands, which can be thought of as the "return on environment" that natural lands provide for County residents.

- When considering the value provided on a per capita basis, every citizen of Charles County benefits by $3,500 of ecosystem service value every year, or $290 per month. For context, that is more than double the average utility bill in the State in 2015[49].

- Charles County has abundant natural resources and associated ecosystem services, with the 4th highest total ES value in the state, and 3rd highest per acre value. Charles County has effectively targeted protection of many of their most important ecosystems, such as riparian areas through the Resource Protection Zone, the Watershed Conservation District and Rural Legacy Program.

- Agricultural lands using best management practices provide more ecosystem services than those using conventional agricultural practices. Charles Co. has the 4th lowest percentage of agricultural lands using BMPs of all MD counties; demonstration of added ecosystem service value may help to support future efforts to increase BMP implementation in the County.

- The information included in this report can be used to provide support for past preservation and conservation decisions and help to identify high value areas for additional conservation or preservation.

- Although there is an abundance of natural resources within Charles County, development pressure also exists in the County. This places particular importance in using information like ecosystem service assessments to prioritize where growth should be allowed, and which parts of the County are most important to protect as intact ecosystems for the benefit of the rural economy and future generations.

- The implementation of, and use of Ecosystem Services Assessment, is also a consideration for future policy debate which seeks to balance the sometimes competing interests between development and conservation. It can be used as a benchmark for understanding the economic costs of ecological impacts associated with human activities.

[49] US Energy Information Administration (2016)

REFERENCES

1. Millennium Ecosystem Assessment, 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC.

2. Boyd, James and Spencer Banzhaf . 2007. What are ecosystem services? The need for standardized environmental accounting units. ECOLOGICAL ECONOMICS 63 (2007) 616 – 626.

3. Charles County Board of Commissioners. 2016. Charles County Comprehensive Plan. https://www.charlescountymd.gov/pgm/planning/comprehensive-plan-2016

4. Homer, C.G., Dewitz, J.A., Yang, L., Jin, S., Danielson, P., Xian, G., Coulston, J., Herold, N.D., Wickham, J.D., and Megown, K., 2015, Completion of the 2011 National Land Cover Database for the conterminous United States-Representing a decade of land cover change information. Photogrammetric Engineering and Remote Sensing, v. 81, no. 5, p. 345-354.

5. Charles County Parks and Recreation. 2016. Information collected by Charles County Department of Planning.

6. Maryland DNR Wildlife and Heritage. 2016. Information collected by Charles County Department of Planning.

7. Beacon. 2005. The Impact of Resource Based Industries on the Maryland Economy. Report by the Business, Economic, and Community Outreach Network (BEACON), Salisbury University.

8. Riley, Ann. 2009. Putting A Price On Riparian Corridors As Water Treatment Facilities. Report for California Regional Water Quality Control Board San Francisco Bay Region.

9. Kramer, Daniel, Polasky, Stephen, Starfield, Anthony, Palik, Brian, Westphal, Lynne, Snyder, Stephanie, Jakes, Pamela, Hudson, Rachel, Gustafson, Eric.2006. A Comparison of Alternative Strategies for Cost-Effective Water Quality Management in Lakes. Environmental Management Vol. 38, No. 3, pp. 411–425.

10. Lehigh Valley Planning Commission. 2014. Lehigh Valley Return on Environment.

11. New York State Department of Environmental Conservation. 2015. New York City Water Supply. http://www.dec.ny.gov/lands/25599.html

12. Campbell, E.T. and D.R. Tilley. 2014. The Eco-Price: How environmental emergy equates to currency. Ecosystem Services. Vol. 7 130-141

13. Versar, Inc. 2002. Carbon Sequestration Potential in Maryland. Report for Maryland Department of Natural Resources, Power Plant Division.

14. Van Deusen, P., and L.S. Heath. 2015. COLE web applications suite. NCASI and USDA Forest Service, Northern Research Station. Available only on internet: http://www.ncasi2.org/COLE/ (Accessed January, 2015).

15. Noe, G.B. and Hupp, C.R. 2009. Retention of riverine sediment and nutrient loads by Coastal Plain floodplains: Ecosystems 12:728-746.

16. Fenstermacher, Daniel. 2012. CARBON STORAGE AND POTENTIAL CARBON SEQUESTRATION IN DEPRESSIONAL WETLANDS OF THE MID-ATLANTIC REGION. University of Maryland, Department of Environmental Science and Technology, Master's Thesis.

17. Needelman, B.A., and J.E. Hawkes. 2012. Mitigation of greenhouse gases through coastal habitat restoration. In B.A. Needelman, S. Bosak, S. Emmitt-Mattox, and C. Lyons (eds.) Creating Resilient Coasts: Coastal Habitat Restoration for Adaptation and Mitigation of Climate Change Impacts. Restore America's Estuaries, Washington, DC, p. 49-57.

18. Interagency Working Group on Social Cost of Carbon, United States Government. 2013. Technical Support Document: - Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis- Under Executive Order 12866. https://www.whitehouse.gov/sites/default/files/omb/assets/inforeg/technical-update-social-cost-of-carbon-for-regulator-impact-analysis.pdf

19. Regional Greenhouse Gas Inititave (RGGI) Inc. 2014. C02 Auctions. http://www.rggi.org/market/co2_auctions

20. The Brattle Group. 2014. EPA's Proposed Clean Power Plan Implications for States and the Electric Industry.http://brattle.com/system/publications/pdfs/000/005/025/original/EPA's_Proposed_Clean_Power_Plan_-_Implications_for_States_and_the_Electric_Industry.pdf?1403791723

21. United States Environmental Protection Agency. 2015. FACT SHEET: Clean Power Plan Framework. https://www.epa.gov/cleanpowerplan/fact-sheet-clean-power-plan-framework

22. Weber, Ted. 2003. Maryland's Green Infrastructure Assessment: A Comprehensive Strategy for Land Conservation and Restoration. Maryland Department of Natural Resources Report. http://dnr.maryland.gov/land/Pages/Green-Infrastructure-Mapping.aspx

23. Maryland Department of Natural Resources. Accessed 2016. BIONET: Biodiversity Conservation Network. http://dnr2.maryland.gov/wildlife/Documents/BIONET_FactSheet.pdf

24. United States Department of Agriculture- Natural Resource Conservation Service. 2014. Regulatory Impact Analysis (RIA) for the Environmental Quality Incentives Program (EQIP). https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=stelprdb1265716&ext=docx

25. Ducks Unlimited. 2014. Annual Report Fiscal Year 2013. http://www.ducks.org/resources/media/About%20DU/Annual%20Report/2013/2013AnnualReport_Full_FINAL.pdf

26. Conservation Fund Mid-Atlantic. 2014. http://www.conservationfund.org/where-we-work/maryland

27. Alliance for the Chesapeake Bay. 2012. Forests For the Bay. http://thebaybank.org/credits/14, http://thebaybank.org/credits/8

28. Maryland Department of Natural Resources. 2016. Tax Benefits of Land Enrollment. http://www.dnr.state.md.us/met/tax_benefits.asp

29. Nowak, David, Hirabayashi, Satoshi, Bodine, Allison, Greenfield, Eric. 2014. Tree and forest effects on air quality and human health in the United States. Environmental Pollution 193 pp. 119-129.

30. Watershed Resource Registry. 2016. Governmental Agency Partnership. http://watershedresourcesregistry.com/

31. Maryland Department of the Environment and Center for Watershed Protection. Revised 2009. 2000 Maryland Stormwater Design Manual, Vol. I and II. http://mde.maryland.gov/programs/water/stormwatermanagementprogram/marylandstormwaterdesignmanual/pages/programs/waterprograms/sedimentandstormwater/stormwater_design/index.aspx

32. Virginia Department of Environmental Quality. 2013. Virginia Stormwater Management Handbook. http://www.deq.virginia.gov/Programs/Water/StormwaterManagement/Publications.aspx

33. Maryland Department of the Environment. 2014. Watershed Protection Fee Rates. http://www.charlescountymd.gov/pgm/planning/watershed/stormwater-remediation-fee

34. King, Dennis and Patrick Hagan. 2011. Costs of Stormwater Management Practices In Maryland Counties. Ref. No. [UMCES] CBL 11- 043. Prepared for Maryland Department of the Environment Science Services Administration (MDESSA).

35. Coordinated effort between the United States Department of Agriculture-Natural Resources Conservation Service (USDA-NRCS), the United States Geological Survey (USGS), and the Environmental Protection Agency (EPA). The Watershed Boundary Dataset (WBD) was created from a variety of sources from each state and aggregated into a standard national layer for use in strategic planning and accountability. Watershed Boundary Dataset for Maryland]. Available URL: "http://datagateway.nrcs.usda.gov" [Accessed 2016]

36. Charles County Government. 2016. Water and Sewer Billing. https://www.charlescountymd.gov/fas/wsbilling/water-and-sewer-billing

37. Reardon, J. 2007. Fishing, boating drive county tourism. Maryland Independent. Charles County Economic Development Department

38. Roland, J. (unpublished). Referenced in Reardon 2007.

39. Ator, S.W., Brakebill, J.W., and Blomquist, J.D., 2011, Sources, fate, and transport of nitrogen and phosphorus in the Chesapeake Bay watershed—An empirical model: U.S. Geological Survey Scientific Investigations Report 2011–5167, 27 p. (Also available at http://pubs.usgs.gov/sir/2011/5167/.)

40. Talberth, John, Selman, Mindy, Walker , Sara, Gray, Erin. 2015. Pay for Performance: Optimizing public investments in agricultural best management practices in the Chesapeake Bay Watershed. Ecological Economics 118 (2015) 252–261.

41. Maryland Department of Agriculture. 2015. Maryland Agricultural Water Quality Cost-Share Program: Annual Report http://mda.maryland.gov/resource_conservation/counties/MACSAR2015FINAL.pdf

42. Maryland Department of the Environment. 2015. Bay Restoration Fund Advisory Committee Annual Status Report. http://www.mde.state.md.us/programs/Water/BayRestorationFund/Documents/2015%20BRF%20Report%20-%20Final.pdf

43. Pennsylvania Department of Environmental Protection (PA DEP). 2015. Nutrient Trading. http://www.dep.pa.gov/Business/Water/PointNonPointMgMT/NutrientTrading/Pages/default.aspx#.Vpau_PkrIgs
44. Olson, Kenneth, Al-Kaisib, Mahdi M., Lalc, Rattan, Lowery, Birl. 2014. Experimental Consideration, Treatments, and Methods in Determining Soil Organic Carbon Sequestration Rates. Soil Science Society of America Journal. Vol. 78 No. 2, p. 348-360

45. Yeo, I.-Y., Lee, S., Sadeghi, A.M., Beeson, P.C., Hively, W.D., McCarty, G.W., Lang, M.W. 2014. Assessing winter cover crop nutrient uptake efficiency using a water quality simulation model. Hydrol. Earth Syst. Sci., 18, 5239–5253

46. Kaspar, T.C., Kladivko, E.J., Singer, J.W., Morse, S., Mutch, D. 2006. POTENTIAL AND LIMITATIONS OF COVER CROPS, LIVING MULCHES, AND PERENNIALS TO REDUCE NUTRIENT LOSSES TO WATER SOURCES FROM AGRICULTURAL FIELDS. EPA Document. https://www.epa.gov/sites/production/files/2015-07/documents/2006_8_25_msbasin_10covercrops.pdf

47. Kaspar, T.C., J.K. Radke, and J.M. Laflen. 2001. “Small grain cover crops and wheel traffic effects on infiltration, runoff, and erosion.” J. Soil Water Conserv. 56:160-164.

48. Langdale, G. W., Blevins, R. L. Karlen, D. L. McCool, D. K. Nearing, M. A. Skidmore, E. L. Thomas, W. Tyler, D. D. and J. R. Williams. 1991. Cover crop effects on soil erosion by wind and water. In Hargrove, W.L., ed. 1991. Cover Crops for Clean Water. Ankeny, IA: Soil and Water Conservation Society

49. United States Energy Information Administration. 2016. Average Monthly Bill- Residential. Accessed 2016. http://www.eia.gov/electricity/sales_revenue_price/pdf/table5_a.pdf

Mallows Bay, 2016, Department Photo