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AN ASSESSMENT OF ECOSYSTEM SERVICES: A CASE STUDY FOR BALTIMORE, MARYLAND

by

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Abstract

AN ASSESSMENT OF ECOSYSTEM SERVICES: A CASE STUDY FOR BALTIMORE, MARYLAND

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The purpose of this study is to quantify in economic terms the benefits that ecosystems provide to human societies. We collect per area, per year 2010 US$ estimates of value for the regulating and cultural services provided by different ecosystems (for which land use/ land cover provides a proxy) and transfer those values to Baltimore County and Baltimore City, Maryland. By mapping land use change from 1973 to 2010, we find that ecosystem service value has decreased by about $180 million per year. We also compare the impact of using different metrics and filters to summarize primary valuation data, quantify current stocks of ecosystem services provided by different policy areas, and demonstrate how ecosystem service maps combined with other metrics of ecosystem value can be used to identify potential target areas for conservation.

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Section 1

Introduction

Many aspects of our society thrive on the goods and services provided to us by ecosystems. We depend on our environment to cycle nutrients, water, and gases which support our endeavors. We build and live upon coastlines, slopes, and mountain tops. We harvest food, fiber, and pharmaceuticals from the land. We are inspired by the wonders of the world around us.

In carrying out their essential functions, ecosystems contribute to economic activity. For example, pollination by bees contributes about $4.25 billion to crop production in California per year; an investment in wetland conservation saved New York City at least $4 billion as an alternative to constructing a new water treatment plant, and the value of electricity provided by a hydroelectric dam in China due to water regulation by forests is approximately $700,000 annually (Brauman & Daily 2008). Together, the annual flow of goods and services provided by ecosystems can be thought of as a region's income or "natural capital" (Costanza et al. 1997) which is estimated in ecosystem service value (ESV) studies.

Healthy ecosystems require little maintenance, and it is often more expensive or impossible to replace them with man-made substitutes. We rely on the natural landscape to provide the structural foundation and environmental framework to support our social and economic systems, but often times, benefit values of ecosystems are not incorporated into development decisions which may deplete or degrade them.

The state of Maryland recognizes environmental valuation as a priority for responsible growth and development. An interim report published in 2010 by the Governor's Green Jobs Task Force states the following:

> *To inform the State's decision making on the economic benefits and opportunities of the region's ecological, environmental, and human assets, the State should fully support economic impact studies and valuation analyses to calculate the region's environmental worth, potential revenue for landowners, positive government budgetary impacts, and the direct and indirect jobs that will be created or maintained.*
>
> *- Gill et al. 2010.*

However, environmental economic assessment is a controversial idea in eyes of many conservationists and environmentalists. But until we define ecological values in economic terms, they are effectively assigned zero dollar value by decision makers (Costanza et al. 2006). The economic impact of degrading ecosystems is significant. The Millennium Ecosystem Assessment (2005) states that "60% of ecosystem services… are being degraded or used unsustainably" and "accelerating, abrupt, and potentially irreversible" changes to ecosystems can have "important consequences for human well-being."

The ecosystem services concept is increasingly becoming an important part of both national and state policies, especially in the state of Maryland. The incorporation of an activity's impact on ecosystem services is a more holistic and comprehensive approach to assessing overall environmental impact. Valuation assessments communicate in the monetary language that developers and policy makers rely so heavily upon. Comello *et al.* (2012) conclude that the "concept of ecosystem service monetization is applied as a novel approach to capitalize on the relationship between industry and the natural environment," and that "the framework is able to inform project-level decisions, eventually leading to more sustainable management and development."

Table 1. Categories of ecosystem services reported in the MEA (2005)

Provisioning Services	Food, Fiber, Fuel, Genetic resources, Biochemicals/pharmaceuticals/natural medicines, Ornamental resources, Fresh water
Regulating Services	Air quality regulation, Climate regulation, Water regulation, Erosion regulation, Water purification and waste treatment, Disease regulation, Pest regulation, Pollination, Natural hazard regulation
Cultural Services	Cultural diversity, Spiritual and religious values, Knowledge systems, Educational values, Aesthetic values, Social relations, Sense of place, Cultural heritage values, Recreation and ecotourism
Supporting Services	Soil formation, Photosynthesis, Primary production, Nutrient cycling, Water cycling

Rather than looking at individual parts of the environment under investigation, ecosystem services are an overall measure of the health of the environment directly as it pertains to human well-being. The ecosystem services approach estimates how changes to an environment's structure (biodiversity) and function (nutrient cycling and flow of energy) impact human well-being. The well-being mostly closely related to ecosystem service output includes health, access to clean air and water, adequate livelihood with sufficient food and shelter, personal safety, secure resource access and security from environmental disasters, good social relations/cohesion, freedom of choice and action (Morris and Therivel, 2009). Economists have developed various ways to estimate the monetary value of different types of well-being resulting from ecosystem service flow from different land use types, which allows for value changes resulting from land use change to be estimated in quantifiable monetary terms. Because damages to ecosystem services are often a public issue and need to be resolved through policy and tax dollars, it is especially important for policy and decision makers to have an understanding of how an activity may impact ecosystem services

The concept of ecosystem service valuation can be useful to governments to value ecosystems on par with other programs like healthcare, public safety, education, and infrastructure when developing long-term investment strategies and management plans. We do not know exactly how much this is costing our economy to neglect conservation programs, but it is ultimately the goal of the environmental economist to determine the marginal benefits of investing in conservation to mitigate future costs of environmental degradation.

The goal of my research is to assess different land use/land cover (LULC) types in the Baltimore County/Baltimore City as they contribute to ecosystem services and estimate their economic value. I will use the value transfer method to estimate ecosystem service value (ESV) based on a per area/per year 2010USD for different land use/land cover (LULC) types and map the results using ArcMap. The dollar figures will have been determined by previous studies, many of which are organized through methods outlined in The Millennium Ecosystem Assessment (MA). The MA divides ecosystem services into four categories shown in Table 1: Regulating, Provisioning, Cultural, and Supporting

Services. For the purpose of this report, we utilize the economic contributions of only regulating, provision, and cultural services because they are directly benefit the economy. Attempting to examine the economic value of supporting services can lead to double counting services and ultimately overestimating the economic value of those services. Ecosystem services are valued in the economy as Direct Use Value, Indirect Use Value, Option Value, or Existence Value. We will explain in more detail the differences between primary economic methods of estimating ecosystem services and the impact of selecting different subsets of valuation literature to apply to the study site; the process of basemap creation, land use change mapping, and the techniques and concerns involved with developing ESV maps; and we investigate different ways to incorporate ecosystem service assessments into policy by evaluating ESV losses, quantify current stocks of Natural Capital, and identifying target conservation areas.

Section 2

Literature Review and Background

Section 2.1

History

The term "ecosystem service" was first coined in 1981 by Erlich & Erlich, but the concept of valuation has been driven into the spotlight by three important events. In 1991, the US EPA hosted a conference called the "Ecovaluation Forum" for the purpose of "improving on existing methodologies for natural resource and ecosystem valuation as well as develop[ing] new methods which may be better suited to valuing more subtle system functions and interactions" (Bingham et al. 1995). In the years following the conference, many regional or general valuation studies were produced which were then compiled by Costanza et al., in the paper "The value of the world's ecosystem services and natural capital" published in 1997. This seminal work has been cited over 2700 times and laid a framework for calculation of ecosystem services. The study averaged the total economic value of services provided by the world's ecosystems at almost $48 trillion[1]—that was over 1.8 times the global gross national product at the time. The paper was highly controversial and demanded the attention of ecologists, geographers, and economists alike, spear heading the ecosystem service movement. In 2001, an international group of 1,360 experts were brought together by the UN to dissect the current state of global ecosystem services and define drivers of change. The primary publication of the group was the Millennium Ecosystem Assessment (MEA) released in 2005. Since that time, hundreds of papers have been published on ESV and governments and nonprofit organizations have compiled natural capital inventories in Canada, the UK, the commonwealth of Massachusetts, the state of New Jersey and at various other county and regional levels.

Daily (1997) defines ecosystem services as "the conditions, processes, and components of the natural environment that provide both tangible and intangible benefits for sustaining and fulfilling human life." The MEA (2005) classifies ecosystem services into Provisioning, Regulating, Cultural, and Supporting services.

For the purpose of economic valuation, Bateman et al. 2011 differentiate primary ecological processes (Supporting Services) from 'final ecosystem services' (Provisioning, Regulating, and Cultural Services) which directly generate wellbeing or directly

[1] The figures listed in Costanza et al. (1997) for total ecosystem value and global gross national product were $33 trillion and $18 trillion respectively (both in 1994 $US), and have been adjusted—as have all the dollar amounts in this paper—to 2010 $US.

contribute to the production of goods in order to avoid issues of double counting (Fisher et al. 2008). Because most Provisioning Services are already accounted for in the market (i.e., food crop production, timber prices) I have not included them in this assessment. It is important to note, however, that price is not necessarily equal to value, and therefore the provisioning services can have complex values that go far beyond what we pay in markets. Assessing the non-market values Regulating Services and Cultural Services is the goal of this study.

Section 2.2

What are Ecosystem Services?

Daily (1997) defines ecosystem services as "the conditions, processes, and components of the natural environment that provide both tangible and intangible benefits for sustaining and fulfilling human life." The following table illustrates different organization schemes of ecosystem services published in different synthesis reports.

Table 2. Classification and organization of ecosystem service types

Millennium Ecosystem Assessment (2005)		The Economics of Ecosystems and Biodiversity (2009)		Global estimates of the value of ecosystems and their services in monetary units (2012)	
Provisioning Services	Food, Fiber, Fuel, Genetic resources, Biochemicals/ pharmaceuticals / natural	Provisioning Services	Food, Raw Materials, Fresh water, Medicinal resources	Provisioning services	Food, water, raw materials, genetic resources, medicinal resources,

	medicines, Ornamental resources, Fresh water				ornamental resources
Regulating Services	Air quality regulation, Climate regulation, Water regulation, Erosion regulation, Water purification and waste treatment, Disease regulation, Pest regulation, Pollination, Natural hazard regulation	Regulating Services	Local climate and air quality, Carbon sequestration and storage, Moderation of extreme events, Waste-water treatment, Erosion prevention and maintenance of soil fertility, Pollination, Biological control	Regulating Services	Air quality regulation, climate regulation, moderation of disturbance, water flow regulation, waste treatment, erosion prevention, soil fertility maintenance, pollination, biological control
Cultural Services	Cultural diversity, Spiritual and religious values,	Cultural Services	Recreation and mental and physical health,	Cultural Services	Aesthetics information, recreation, inspiration for

	Knowledge systems, Educational values, Aesthetic values, Social relations, Sense of place, Cultural heritage values, Recreation and ecotourism		Tourism, Aesthetic appreciation and inspiration for culture, art and design, Spiritual experience and sense of place		culture and art, spiritual experience, cognitive development
Supporting Services	Soil formation, Photosynthesis, Primary production, Nutrient cycling, Water cycling	Habitat or Supporting Services	Habitats for species, Maintenance of genetic diversity	Habitat Services	Nursery service, genepool protection

Provisioning services are often not evaluated in ecosystem service assessments because they are already captured in economic markets, or as stated in the Puget Sound study, "[t]he current production of goods can be easily valued by multiplying the quantity produced by the current market price." It is with the remaining types of ecosystem services listed that further investigation focuses due to the complexities associated with defining, capturing, and measuring values. These remaining services are listed as regulating, cultural, and supporting services. Baker et al. in their ESA of the Puget Sound define regulating services succinctly as services "that tend to keep natural disturbances dampened compared to what they would be without a particular ecosystem." The example they provide is from Moore and Wondzell (2005): "When forested basins are heavily harvested so that they are dominated by recently clear-cut or young stands, less water is absorbed by trees and the litter layer on the forest floor and more water flows overland into streams and rivers. This contributes both to higher peak flows and flood events." Regulating services thus provide human systems with a more stable environment on which we can build and exist safely. Cultural services tend to be more difficult to isolate into different categories, as many cultural benefits transgress one particular type of non-use. Habitat and supporting services are those that underlie the other services and functions listed and are generally kept out of ecosystem service assessments to avoid double counting. For this report, we have conducted a meta-analysis of ecosystem service assessments, and thus relied on previous authors to discriminate between supporting services that should not be included and those that are applicable to the overall assessment. Double-counting is a general concern in ecosystem service assessments because while goods (or provisioning services) are excludable (Puget Sound study), services, in general, are not. This means that once a good is extracted and entered into economic systems, it only provides benefits to whomever chooses to purchase it. Services, however, can provide benefits and are thus valuable to many people at once (not excludable) and also do not diminish in quality as the number of beneficiaries increases and are thus said to be non-rival (Puget Sound).

It is crucial to note that ecosystem services assessments measure only the value that a particular ecosystem provides in terms of a particular service to a specific group of people. Although we discuss other types of values of ecosystems in the conclusions, this assessment focuses only on the potential and actual economic value the associated population gains from ecosystems in Baltimore County and Baltimore City, performing certain functions and providing specific structures which are perceived to have value to its residents. We are not, however, including other values such as existence value or ecological value, nor do we attempt to use the ecosystem services to define moral and ethical responsibilities to our planet or fellow organisms.

Section 2.3

Economic Methods

For the purpose of economic valuation, Bateman et al. 2011 differentiate primary ecological processes (Supporting Services) from 'final ecosystem services' (Provisioning, Regulating, and Cultural Services) which directly generate wellbeing or directly contribute to the production of goods in order to avoid issues of double counting (Fisher et al. 2008). Because most Provisioning Services are already accounted for in the market (i.e., food crop production, timber prices) are not included them in this assessment. It is important to note, however, that price is not necessarily equal to value, and therefore the provisioning services can have complex values that go far beyond what we pay in markets. Assessing the non-market values Regulating Services and Cultural Services is the goal of this study.

Methods to value ecosystem services are non-standardized and broad. Generally, values of ecosystem services are grouped in one of two ways: contingent vs. non-contingent or use vs. non-use (or passive use). Contingent refers to the perceived value that an ecosystem provides to an individual or population in light of a number of alternative scenarios. Methods that measure contingent value include wiliness to pay or willingness to accept methods which survey individuals (or review spending habits) in regard to how much people would pay, for instance, to retain a safe water quality for swimming or fishing use. Willingness to accept is an alternative survey technique that measures at what cost people would no longer be willing to pay to retain the health of a current ecosystem in terms of a specified use. Non-contingent values are those such as market value that are derived from actual measurable functions or contents of ecosystems and are more directly translated into economic market schemes. Direct use methods include extractive uses including provisional services wherein ecosystems provide food, fiber, fuels, pharmaceuticals; cultural/recreational uses such as hunting, fishing, birding, camping, and boating. Non-use, or passive use values are those that humans gain simply by ecosystems performing normal functions. These are mostly regulating and supportive services and tend to be the most difficult to estimate but perhaps the most important to understand in light of sustainable development. Passive use values include gas and climate regulation, pollination, habitat/nursery/biodiversity, soil retention and formation, water regulation, etc.

The nature of each type of service lends itself to different economic valuation methods. These include the following:

- *Damage cost avoided* – Example: The cost for a community to recover from flooding which could have been prevented had a wetland not been destroyed. Badola and Hussain (2005) compared three communities in a coastal area in India. One study site was protected by mangrove, one was unprotected by mangroves, and the third possessed an embankment on its seaward side. The study compared the total flood damage for each community after the rainy season.

- *Averting behavior* – Example: The cost that a government would be willing to pay to avoid negative consequences associated with pollution. McConnell and Rosado (2000) assessed the benefits to a community of improved drinking water.
- *Revealed preference methods* – Example: The cost a family spends on a summer vacation to the beach. Mendelsohn and Olmstead (2009) relate the implicit costs of travel (including opportunity costs of missed wages) to specific site characteristics.
- *Stated preference methods* – Example: The use of Willingness to Pay (WTP) surveys that ask individuals the highest dollar value they would pay for specific goods. Sherrhouse et al. (2011) list specific survey questions they asked a New Mexico community to rate the importance of specific ESV and proposed spatial regressions in their results.

Advancements in the economics of ecosystem valuations research include improving Willingness to Pay approaches (Sherrouse et al. 2011, Kozak et al. 2011), and employing the concepts of discounting and shadow values to determine Net Benefits of ecosystems (Bateman et al 2011).

Primary ESV studies generally focus on one ecosystem service at a time and break down the economic contribution by each ecosystem type. Using the methods described above (and more), researchers determine the annual dollar value contribution for each unit area of a particular ecosystem. As a sum total, this is considered the natural capital of that region.

Section 2.4

ESV Table

We rely on the value transfer method to estimate ecosystem service value for our study area. This entails collecting primary valuation data, filtering it for appropriateness of transfer, and summarizing it into a table of ecosystem (for which we use the proxy of LULC) to ecosystem service value. The total ecosystem service value for each LULC type are then set as an input table in corresponding LULC maps in ArcGIS, and total ecosystem services are mapped and tabulated for a specific study area. The following table is our result of a literature review which began by compiling similar ESV tables from other ecosystem service assessments including Costanza et al. (2006), Schmidt et al. (2011), and Batker et al. (2008). All values reported in these studies have been translated into 2010 USD per hectare per year (inflation adjustment calculator provided by U.S. Bureau of Labor Statistics website)—according to Costanza et al. (2006), we do not expect any significant value from the cells that are grayed out.

Table 3. Ecosystem Service Values

All Studies Average (2010 USD/ha * year)	Fresh wetland	Salt Wetland	Coastal Systems	Open water	Beach	Riparian Buffer	Forest	Cropland	Urban Green	Pasture
Aesthetic & recreation	2,694	80	225	3,995	42,114	3,812	527	42	5,628	
Biological control	8		84				98	36		35
Cultural &	2,539	513	162		67	11	48			

spiritual										
Disturbance prevention	161	14,858	816		77,804	165	6	5		
Gas & climate regulation	249	14	273				254	115	670	114
Habitat/ Refugia	3,591	166	626	672		525	763	2,369		
Nutrient regulation			16,232				184	22		
Pollination							376	354		275
Soil retention & formation	3	105					130	11		20
Waste treatment	634	8,371		21			289			128
Water regulation	4,338					293	394		235	4
Water supply	12,228		815	917		5,718	464			
Total	26,444	24,108	19,233	5,605	119,985	10,525	3,531	2,954	6,534	577

Section 2.5

Ecosystem Services in Policy

The World Resources Institute (WRI) has published a useful guideline for incorporating the ecosystem services concept into environmental impact assessment

(Landsberg *et al.*, 2011). This outline includes seven steps to incorporate ecosystem services into three stages of IA (scoping, impact assessment, and mitigation) which is summarized below, and each section is expanded by a review of current literature supporting the ecosystem services concept in impact assessment.

Fortunately, the National Environmental Policy Act (NEPA) is set up in such a way that ecosystem service assessments could easily be included in each step of environmental impact assessments. The challenges of incorporating ecosystem services into EA are developing "(1) a clear understanding of the connections between project ecological affects and how these damage firm/project assets; and (2) the ability to include the project ecological effects in operational decisions," (Comello *et al.* 2012).

Stage of Environmental Impact Assessment: Scoping

Decisions about the scope and scale of analysis should be dictated by a clearly defined policy question (Feldman and Blaustein, 2007). According to a National Research Council (NRC) report (2005), scoping generally involves identifying the geographic extent of both relevant ecosystems and populations. Another consideration in economic valuation of ecosystems is temporal scale. "Most policy impacts last for extended periods, and some last (effectively) forever because they lead to irreversible changes. "This is particularly likely in the context of ecosystems where stock effects are important and losses of key ecosystem services may be irreversible" (NRC report, 2005). Temporal scale is also an issue because different anthropogenic drivers impact the inertia of ecosystem services differently (Morris and Therivel, 2009). Specifically, regulating and supporting services which are arguably the least replaceable yet most overlooked services experience more gradual change after an action than provisional services (Morris and Therivel, 2009). Policy should also consider environmental uncertainty in their decision-making which necessitates flexibility of program design (NRC report, 2005).

Although the priorities of certain laws such as the Clean Water Act (CWA), the Endangered Species Act (ESA), and the Forest Management Act (FMA) may incidentally help to preserve ecosystem services, "these laws were not primarily intended to provide legal standards for conservation of natural capital and the services that flow from it and . . . in practice they usually do not." (Feldman and Blaustein, 2007).

Step 1: Prioritize ecosystem services because of project impact

- In the scoping stage, the first step is providing questionnaires to project members to describe the scope of the potential impacts. Drivers of ecosystem change associated with the project should be identified. Although drivers may be easy to identify, thresholds of impact (pollution, biodiversity loss, fragmentation, channel erosion, etc.) that may push an ecosystem beyond its current function are almost impossible to predict. Therefore, by identifying and thus limiting these drivers of change, land managers can help to prevent unintended negative consequences of lax regulations on environmental impacts.
- The next questionnaire recommended by the WRI in the impact scoping stage is to identify all of the potentially impacted ecosystems, ecosystem services, and beneficiaries. Identifying impacted ecosystems may seem simple, but large scale projects may have impacts that reach far, far beyond the boundaries of land used for development. For instance, the damming of the Susquehanna River could cut off important spawning grounds and impact fish populations near the mouth of the Chesapeake Bay. Also as illustrated in the previous example, beneficiaries of

ecosystem services (fishermen in St. Mary's for instance) could be far removed from the project itself (Conowingo).

- The third questionnaire assesses the project impact on ecosystem services. Often, biodiversity is not monetarily valued independently as an ecosystem services, but the fish population in our example could help to regulate insect larvae populations, and without this predator, pest populations could explode and the development of the dam could impact the service of pest regulation. Finally in the impact scoping stage, stakeholders, including proximally distant beneficiaries should be notified of the projected and invited to participate in the discussion. The National Research Council (NRC) report suggests reviewing the issue of legal standing to help identify potential stakeholders that may be impact (NRC report, 2005).

Step 2: Prioritize ecosystem services because of project dependence

- The second step in scoping identified is the WRI is utilizing a questionnaire to assess the project's dependence on ecosystem services. For instance, in the example of the Conowingo Dam, the capacity to generate electricity is dependent on water and erosion regulation upstream. In an example provided by Brauman and Daily (2004), the water regulation service provided by healthy forested riparian areas upstream contributed $3 billion to electricity generation in a hydroelectric plant in China.

Step 3: Establish the ESIA Terms of Reference for ecosystem services

- The third and final step in scoping is establishing Terms of Reference for communicating about ecosystem services in impact assessment. Policy makers, business people, and especially stakeholders may not be familiar with the ecosystem services approach, and preparing all those involved with background information on the terms can be invaluable once heated discussion begins.

Stage of Environmental Impact Assessment: Impact analysis

Step 4: Assess negative project impact on priority ecosystem services

- Once the priority ecosystems, ecosystem services, and beneficiaries are identified, the first step in impact analysis is to establish a baseline of ecosystem services. A questionnaire can be used to help qualify (or quantify) the impact of these services on the beneficiaries' well-being. Comello *et al.* (2012) suggest utilizing "fundamental biophysics and biochemistry to characterize the component processes of ecosystem services." Establishing a standard method for describing ecosystem function quantitatively is essential for establishing the method in all policy decisions. Another questionnaire can be used to predict how the supply of ecosystem services are expected to change independent of the project, and how these foreseeable changes would potentially impact well-being (in the absence of the project).
- Conversely, the next questionnaire attempts to assess the project's impact on ecosystem services and how that would affect the beneficiaries' well-being. Duan *et al.* (2011) suggest an emergy-based approach to quantify how the changes in fundamental biophysics and biochemistry suggested by Comello (2012) can alter ecosystem service output under different scenarios. Duan *et al.* (2011) also suggest approaching ecosystem services through an emergy accounting method. According to Duan (2011), emergy, defined as the available solar energy used up directly or indirectly to create a service or product, can be used to assess natural inflows and services within a system. They incorporate numerous estimates in Joules of non-

renewable and renewable resources and purchases, and estimates in dollars of ecosystem service yields. The low-quality parameters are combined to form high-quality emergy indices. These indices are combined to estimate net economic benefit index which is a function of considerable economic benefits (I) minus enough feedback (B) to the system to sustain itself. Higher index numbers indicate a greater sustainability of the project. Various emergy-based indices can help to link project impact to ecosystem service provision and can be utilized to predict the impact of alternative project scenarios. By combing the life cycle assessment method and the emergy accounting method, a total picture of ecosystem service change can be compared to the potential benefits associated with project design.

Regardless of the method used, Hiddink *et al.* (2007) point out the importance that whatever governments decide is best to include ecosystem services into environmental impact assessment should be quantitative, validated, repeatable and applicable at the scales of impact and management.

- In this context, the participation of the beneficiaries can help define acceptable levels of change. In this stage, it is important to note that ecosystem service assessments can identify marginal changes in the provision of an ecosystem services, but the NRC report (2005) points out that "[u]nder no circumstances, however, should the value of a single ecosystem service be confused with the value of the entire ecosystem." This is because as changes to environments approach certain thresholds, the function of the ecosystem and therefore the output of ecosystem services can be disproportionately impacted by further small changes (NRC report, 2005). Although thresholds are often very difficult to estimate because they may vary so greatly from ecosystem to ecosystem Hiddink *et al.* (2007) have established a method for assessing the sensitivity of seabed habitat to trawling practices. The sensitivity index was calculated by estimating the time it takes a benthic community

Step 5: Assess project dependence on priority ecosystem services

- In this step, attempts should be made to quantify how changes in ecosystem services will impact the overall performance of the project. Comello *et al.* (2012) suggest in their framework methods to establish a life cycle assessment (LCA) to "quantify project ecosystem emissions." Duan *et al.* (2011) further define the LCA as "resource, energy consumption and environmental emissions of each phase are quantitatively calculated, characterized, normalized and valuated." By characterizing the full impacts of the project from "cradle to grave", potential large scale impacts of each phase can help identify specific project phases which may contribute a disproportionately high amount of negative impacts to both beneficiaries and long-term project success and may need to be altered.
- When considering the ecosystem services on which the project depends, third party beneficiaries which are both recipients of priority ecosystem services and impactors of dependent ecosystem services should be engaged to help illuminate how their activities impact the particular project.

Step 6: Produce summary report

- This final step of the impact analysis stage is to summarize in plain and conclusitory language the projects' impacts and dependence on ecosystem services. This may incorporate a compilation of how each environmental impact may alter the marginal output of ecosystem services defined quantitatively in monetary terms. Comello

(2012) notes the importance of scrutinizing the "functional substitutability" of monetary values for each service and change assessed. Likewise, this summary may include a cost-benefit analysis which incorporates a "representation of ecosystem services value within international financial accounting norms." This step is the final stage which links the ecosystem services on which all human function depends to the economic models on which societal growth and development have come to rely. By incorporating ecosystem services into land use decisions, communities approach sustainable development—"development that meets the needs of the present without compromising the ability of future generations to meet their own needs," (World Commission on Environment and Development, 1987).

Stage of Environmental Impact Assessment: Mitigation

Step 7: Identify options to enhance or at least maintain affected beneficiaries' well-being and project performance derived from ecosystem services at acceptable levels.

- The mitigation stage involves two main perspectives. First, steps should be taken to mitigate the projects' negative impacts on the well-being of ecosystem service beneficiaries, and also to help regulate the project's dependence on changing ecosystem service supply.
- The next perspective is to incorporate public awareness, policy, and incentives for beneficiaries and third-party beneficiaries to participate in activities that will lessen the negative impacts of the project on their well-being and on the performance of the project.

Summary

In summary, the ecosystem services concept can be applied to environmental impact assessment to provide a more holistic perspective on how ecosystems and human well-being might be impacted by an activity over time. The Ecosystem Service Assessment conducted here may be used to supplement current and future EIAs for development in the Baltimore area, and can help provide a framework for other jurisdictions looking to include the ecosystem services concept in EIA policy.

Section 3

Research Goals

Section 3.1

Introduction

As the concept of ecosystem services unfolded during the literature review process, it became clear that as with any new science or management strategy, these nascent stages often produces more questions than answers. The first we address is the concept of using land use/land cover (LULC) as a proxy for ecosystem services—and the importance of selecting and utilizing the best possible GIS data available. Thus, in Section 3.2 we create LULC maps that satisfy both the needs of the assessment—comparing historic and current ecosystem service provision—but also avoid over and underestimations of ESV. We use these LULC maps to assess LULC change in Baltimore from 1973 to 2010 in Section 3.3. Another common concern of using the value transfer method is the appropriateness of transferability from primary study sites to the target site. The common technique of compiling primary ESV data for a study region such as Baltimore is to average ecosystem service estimates published in any study whose site of data collection is in western Europe, Canada, or the United States (excluding highly specialized services such as the value of alligator meat to the Mississippi River delta) which we refer to as both “all studies,” and also the standard metric. In Section 3.4, we quantify the difference between using a variety of summary statistics for the primary valuation estimates both in terms of ESV per area, and also in terms of ecosystem service assessment for our study area. Next, we use the standard metric, to quantify the impact different land management strategies have had on ESV provision for Baltimore from 1973 to 2010 in Section 3.5. In the following Section, 3.4, we take stock of current Natural Capital for the study area, both cumulatively as well as for different protected areas. Finally, we incorporate maps published by the Maryland Department of Planning that identify Ecological Value and Development Risk into our Ecosystem Service Assessment to identify a potential target area for conservation in Section 3.7.

Section 3.2

Create Land Use/Land Cover Map

Introduction

Often mapping processes require LULC sets that are different than those currently available by government or mapping organizations. For this exercise, we review the common LULC typology employed by various ecosystem service assessments, and determine which classification scheme is most suited to conduct an ecosystem service assessment for Baltimore, Maryland using the value transfer method to quantify changes in LULC from 1973 to 2010. The selection of appropriate data concerns both relevant GIS map data and appropriate ecosystem service valuation data. We are also concerned with LULC data sets that employ the land use classification of “Urban,” where the land cover may be in fact a more natural land cover. The concern is that ecosystem services may be under estimated when LULC is used as a proxy for ecosystem service.

The LULC scheme used h ere depends equally on the GIS data layers available for the region of interest, but also the classification of available primary valuation literature. Because we do not intend to evaluate primary valuation studies individually, we look to other ecosystem service assessments for possible classification schemes and techniques of creating LULC basemaps. Where the primary valuation literature allows, we attempt to match our LULC maps to the most specific classifications possible, i.e. freshwater wetlands vs. saltwater wetlands; evergreen forest, deciduous forest, riparian areas; etc. This is most limited by our 1973 data where LULC was classified into fewer groups due to the limitations of remote sensing imagery at that time. For our temporal comparisons, we therefore remained consistent and reduced our 2010 classifications to only those listed in 1973

Creation of 1973 LULC Map

Methods

The Maryland Department of Planning (MDP) has published three land use/land cover (LULC) maps spanning from 1973 to 2010. LULC maps use LC data derived from remotely sensed imagery with classifications like forest and water combined with LU data extracted from zoning maps with classifications like industrial and institutional. LU cannot be determined from remotely sensed imagery and was only included when the zone type covered at least five acres. While a combination of LULC is useful in many planning and development applications, there are as many applications where LC only is necessary, and at this time there are no LC maps available for Baltimore County and Baltimore City which go back as far as 1973.

For this exercise, we identified pixels with a LU classification from the existing 1973 LULC and reclassified them into appropriate LC types using 1972 Landsat 1 MSS satellite imagery using Idrisi Taiga.

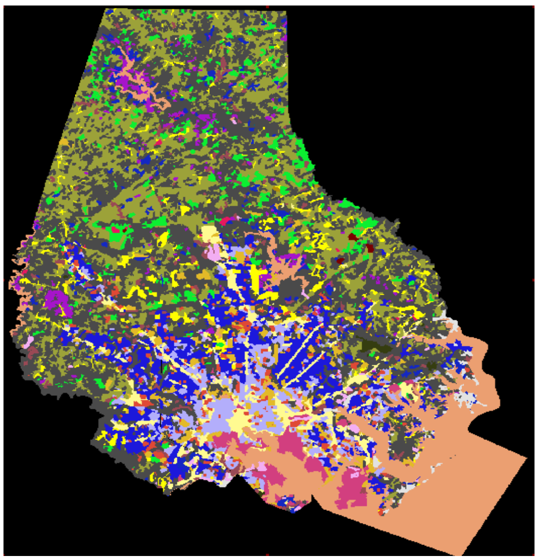


Figure 1. 1973 LULC map with 23 classifications (MDP 1973)

The satellite imagery used was from Landsat 1 MSS (path 16, row 33) collected on 11 October 1972 and included the following four bands of information: B4 - visible green (0.5 – 0.6 μm), B5 - visible red (0.6 – 0.7 μm), B6 - near IR (0.7 – 0.8 μm) and B7 - far IR (0.8 – 1.1 μm) (USGS 2011).

The original MSS pixel size was 79 x 57 m, but the USGS resampled the imagery to 57 x 57 m pixels (USGS 2011). The file was downloaded from University of Maryland's Global Land Cover Facility FTP server and had 10-19% cloud cover.

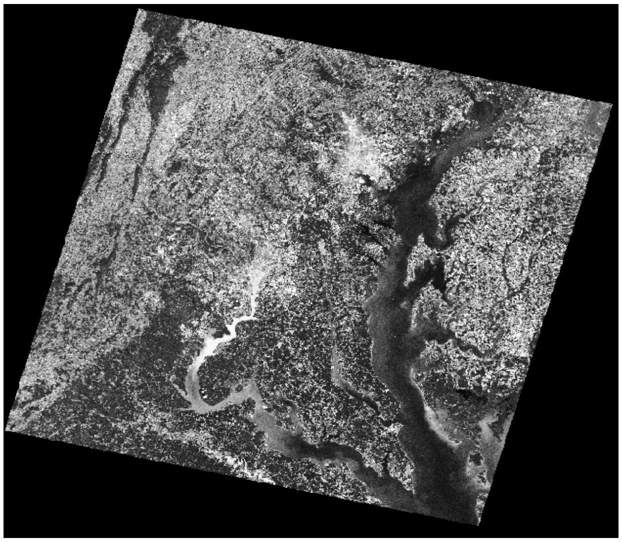


Figure 2. 1972 Landsat 1 MSS Band 4 Imagery (NASA Landsat Program 2001)

Before beginning the classification process, we used the raster clip tool in ESRI's ArcMap to clip Baltimore County and Baltimore City from the Landsat scene with the LULC map to define the boundaries. Then we geometrically corrected the LULC map to match the Landsat image by resampling in Idrisi. Using a mask of the LU categories from the MDP map, we identified a subset 143,992 of the original 1,094,472 pixels that required reclassification.

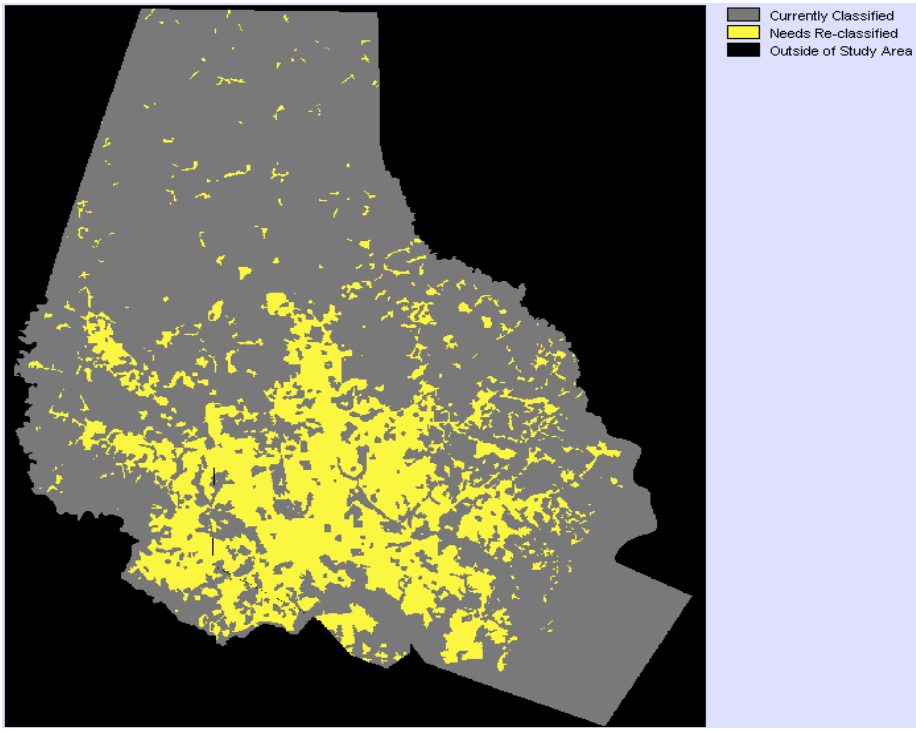
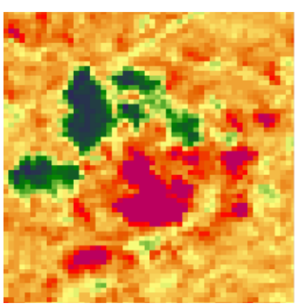


Figure 3. Subset of Maryland Department of Planning data for reclassification

Radiometric correction included haze removal by dark object subtraction, followed by a linear stretch with saturation on each band as necessary. Next, we identified cloud cover by density slicing B7 into 20 equal interval slices and classified slices 9-20 as other and incorporated those pixels into the mask.



Figures 4 & 5. A close-up of clouds shown in B7 of the Landsat data (left) and the result of the cloud density slice (right).

We then created a number of different color composites and vegetation indices using different band combinations. By overlaying a vector file of the LULC map, we were able to identify LC types in the composites by proximal association. We determined that the 654 and 547 composites as well as the PCA1 would be useful for reference when distinguishing LC types.

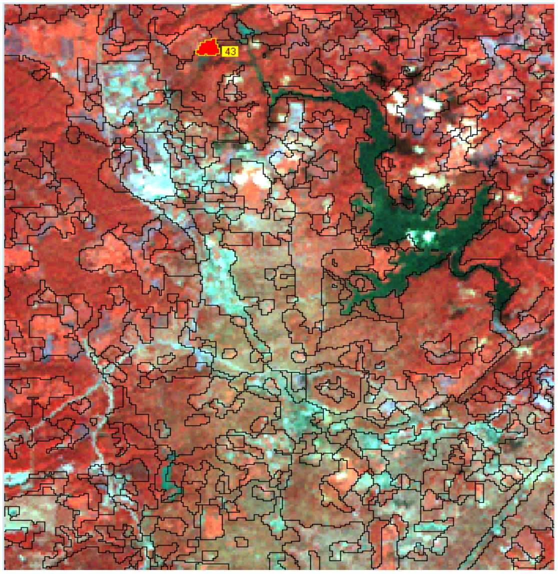
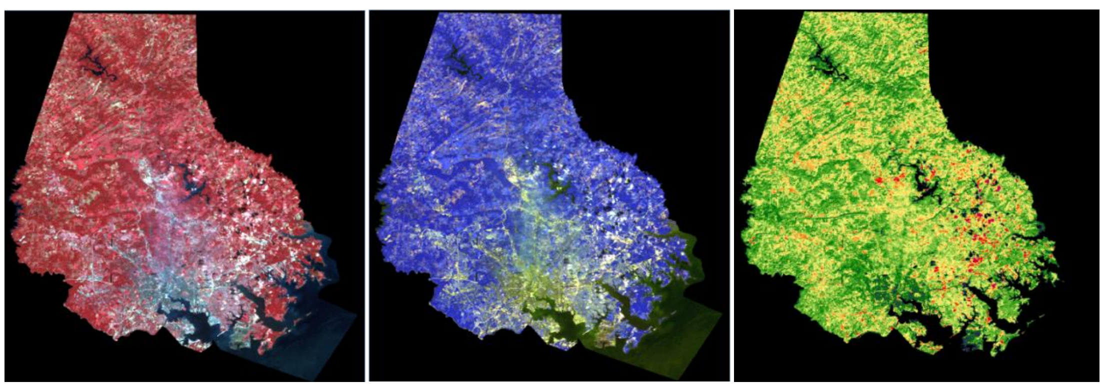


Figure 6. A vector overlay of the original LULC map onto the 654 color composite.



Figures 7, 8 & 9. Color Composites 654 (left) and 547 (center) and PCA1 (right).

Using the mask described above, we ran a series of unsupervised classifications on the four preprocessed Landsat bands in KMeans with a maximum number of output clusters set at 16 and all the other settings at default. We assigned the output pixels to the appropriate LC type. After 80% of the pixels in the subset had been classified, we reduced the number of output clusters to 10; after 90%, we reduced it to 6. After running KMeans 7 times, the remaining pixels identified an overlap of pixels at the county/city border and shadows from cloud cover and so were classified as other. Challenges to classification of pixels were due to the low spectral and spatial resolution of the Landsat imagery; however, by combining a variety of techniques, we were able to create a LC map with acceptable accuracy.

Results

Once all of the pixels in the subset had been classified, we ran a 3 x 3 modal filter to reduce pixelation. We then performed an overlay (first covers second except where zero) onto the original MDP map which we first reclassified into the new 12-class typology. The results indicate that although most of the pixels in the subset were indeed developed, as many as 20% of the pixels identified as urban were in actuality a different land cover type, with 15.61% of the pixels now classified as forest.

Table 4. New classifications of pixels in subset.

	Pixels	Percentage of subset
Other	2329	1.62%
Agriculture	3194	2.22%
Grassland/ Rangeland	579	0.40%
Forest	22473	15.61%
Open Water	1099	0.76%
Wetlands	46	0.03%
Beaches	0	0.00%
Barren Land	967	0.67%
Urban Greenspace	529	0.37%
Low Density Urban	10469	7.27%
Medium Density Urban	58950	40.94%
High Density Urban	43323	30.09%
	143992	100.00%

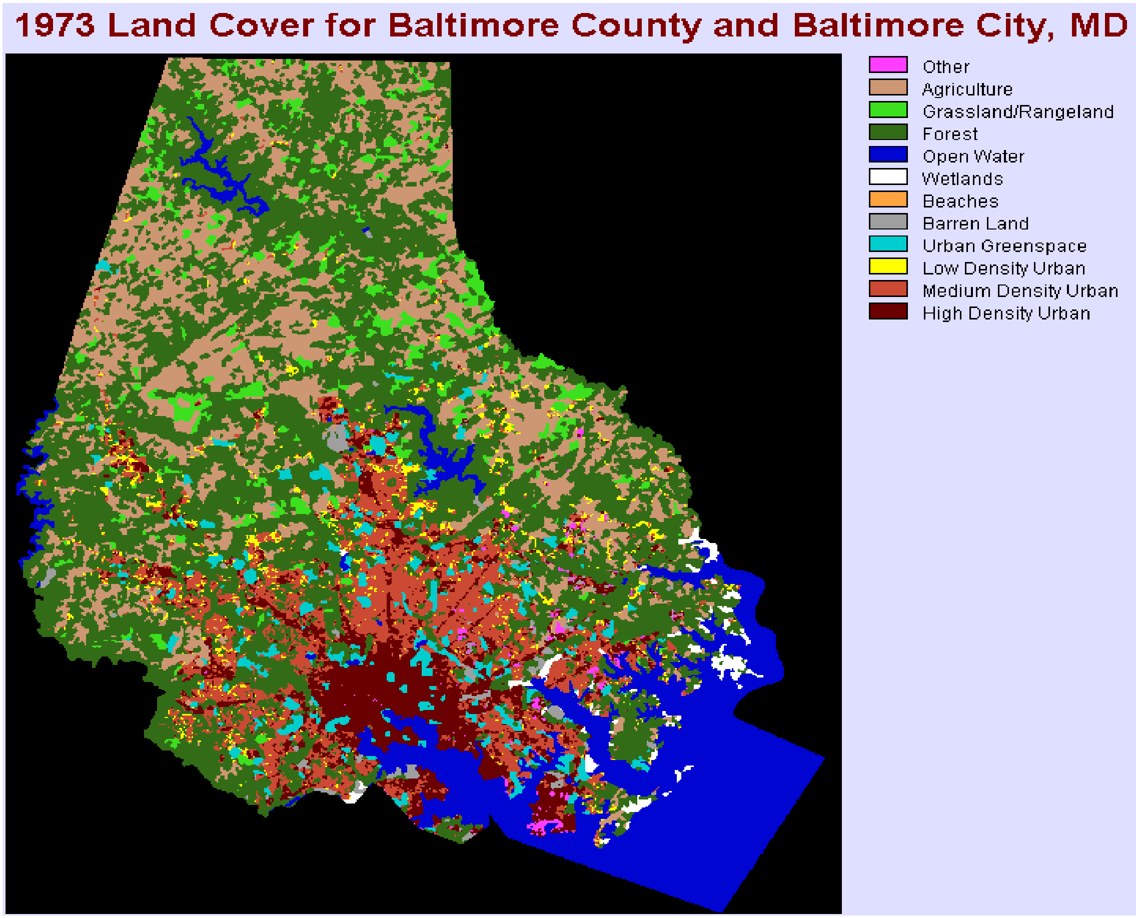


Figure 10. 1973 Land Cover map with combined MDP land cover pixels and new classification of land use categories including three urban classifications.

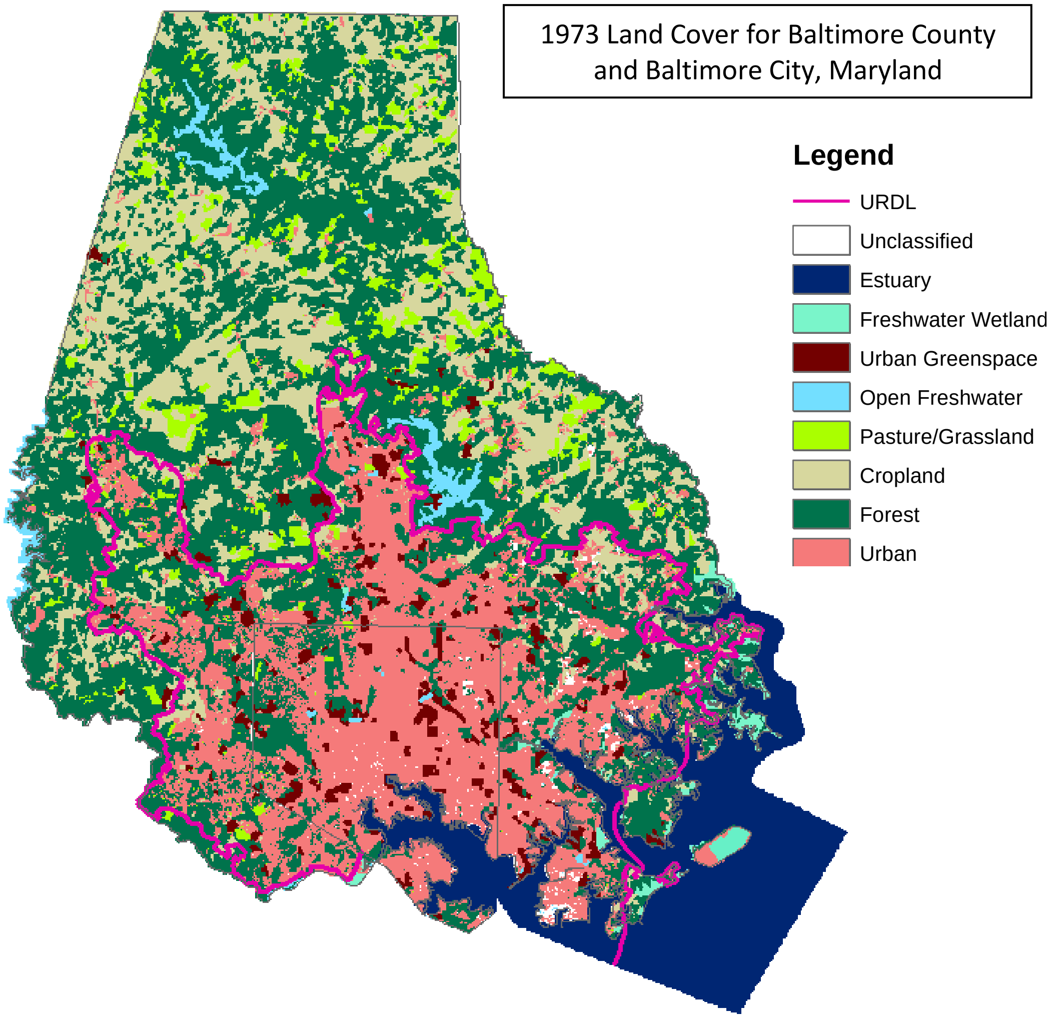


Figure 11. Updated 1973 Land Cover Map with combined urban classifications.

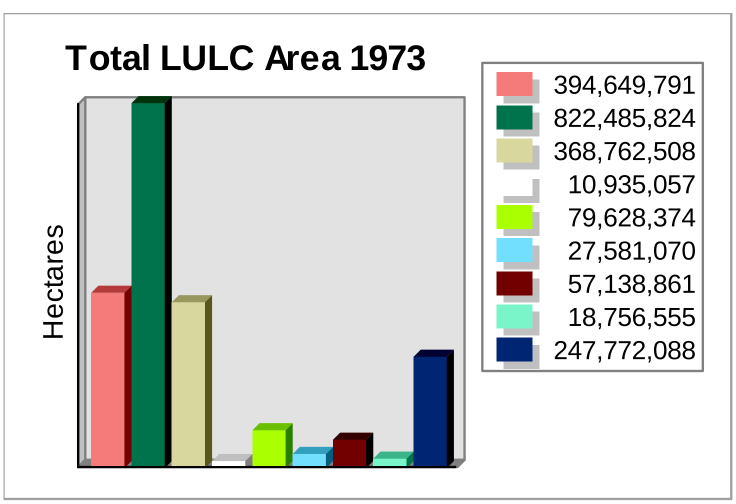
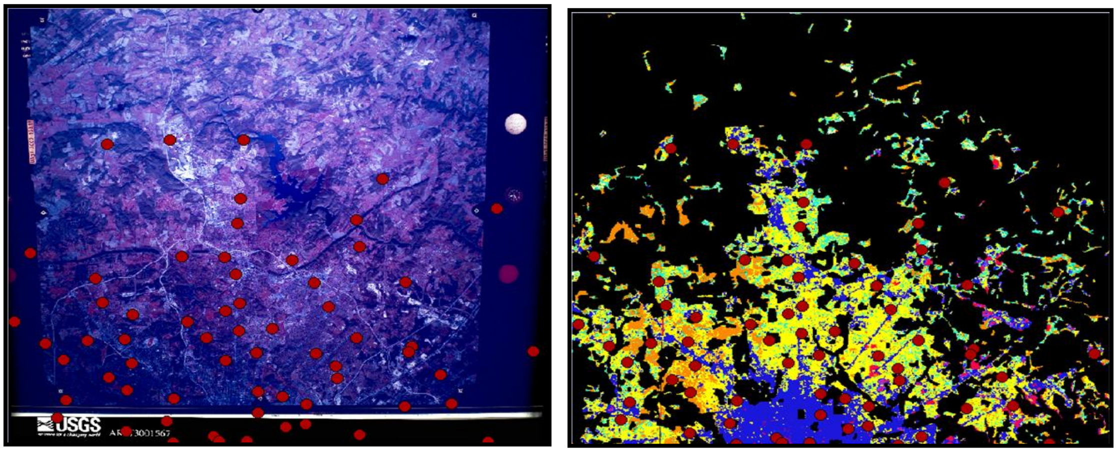


Figure 12. Total LULC Area in 1973.

For ground truth data, it was difficult to use the original Landsat images as a reference because of the coarseness of the imagery (57 m resolution) and the inability to create a true-color composite image. We were also unable to use Google Maps as a reference because the earliest imagery available for the area was recorded in 1983. So we located on the USGS Earth Explorer website a three-band color infrared photograph that overlapped most with my data subset (USGS 1975). It was taken on 1 December 1973 from an aircraft and had a scale of 1:28,000. Unfortunately it had not been georeferenced. We geometrically corrected the image by resampling in Idrisi using the Landsat 654 composite as a reference. We chose the bilinear interpolation method and attained a root mean square (*rms*) value of 0.43 by narrowing down my original 47 ground control points to the 12 with the lowest *rms*.

To identify sample points, we used the sample tool to select 500 stratified random sample points within the subset. We then used the raster to vector function to transform the vector point file into a raster file, and performed an overlay to multiply the points by a mask of the newly classified subset. We performed the window operation and specified the aerial photo for the window, reducing the number of sample points to 44 that fall within the data frame. We also performed the window operation on my newly classified subset, created a raster group of the aerial photo and the subset, and group linked them before overlaying the sample point file onto both. We recorded the reference and thematic map classes into Microsoft Excel and performed the accuracy assessment manually.



Figures 13 & 14. Sample points overlayed onto the reference aerial photo (left) and the thematic map (right).

The overall measure of classification accuracy was 63.64% and the Cohen's Kappa Coefficient was 50.54%. The lowest accuracy was in the urban classes, which may have been due to the subjectivity in urban density determination in both the Landsat imagery during the classification process and in the aerial photograph during the ground truth collection. It is important to note that although the overall accuracy was low, if the urban categories were condensed into one classification type, the user's accuracy for that category would jump to 89.47%. We also performed the accuracy assessment on the data without the modal filter which yielded identical results. For the purpose of ecosystem service assessment, the urban classes were combined into a single class.

Table 5. Accuracy Assessment of 1973 Land Cover map.

		Ground Truth Data Classes							Number of Classified Points	User's Accuracy
		1	2	3	4	10	11	12		
Thematic Map Classes	1	0	0	0	0	1	0	0	1	0.00%
	2	0	0	0	0	0	0	0	0	N/A
	3	0	0	1	0	0	0	0	1	100.00%
	4	0	0	0	4	0	0	0	4	100.00%
	10	0	0	0	1	5	2	0	8	62.50%
	11	0	0	0	1	4	13	2	20	65.00%
	12	0	1	0	1	1	2	5	10	50.00%
Number of ground truth points		0	1	1	7	11	17	7	44	
Producer's Accuracy		N/A	0.00%	100.00%	57.14%	45.45%	76.47%	71.43%		

*Note: only classes where there were numbers in both columns and rows were included.

Creation of 2010 LULC map

Introduction

For the 2010 map, we wanted to utilize existing LULC data as much as possible, but also try to correct for the generalization of areas with an Urban classification. Ultimately, we were limited by the number of classes in the 1973 map for conducting LULC change analysis despite access to GIS data with greater precision.

Methods

The 2010 LULC map was created by combining Maryland Department of Planning's 2010 LULC polygon file, the National Wetlands Inventory Database polygon file, and the National Hydrography Dataset vector file. The LULC file was used to identify Urban/Barren, Agriculture, Forest, and Pasture/Prairie. In the hierarchy of layering datasets, polygons identified in the LULC layer as Urban/Barren or Agriculture remained with their original assignment. All other polygons (or portions thereof)—including forest and pasture/prairie—assumed the landcover type of polygons created from the wetlands or hydrography layers that overlapped, with the hydrography dataset used to identify Coastal Zone, Open Freshwater, and Estuary assuming the highest position on the hierarchy. Any polygon identified as a water feature in the hydrography data set was labeled as such in the final land cover map.

The land cover types in the final map are as follows:

Table 6. Land cover typology used as a proxy for ecosystem services.

Urban/Barren
Urban Greenspace
Cropland
Pasture/Grasslands
Forest
Freshwater Wetland
Coastal Systems (Includes estuary)
Open Freshwater

First, the polygons from the Maryland Department of Planning 2010 dataset were reassigned into one of those classes as follows:

Table 7. Reclassification rules used for 2010 land use/ land cover map.

High Density Urban → Urban/Barren
Medium Density Urban → Urban/Barren
Low Density Urban→ Urban/Barren
Agricultural Buildings → Urban/Barren
Row Crops → Cropland
Feedlots → Agriculture
Deciduous Forest → Forest
Evergreen Forest → Forest
Mixed Forest → Forest
Brush → Forest
Wetlands → Wetlands
Beach → Beach

Next, the National Wetlands Inventory Database Polygon file was used to identify and reclassify wetlands and other water features through a series of prioritized selections. First, we selected urban/barren and cropland polygons from the new LULC layer, and used the CLIP tool in ArcGIS to cut any polygons (or parts thereof) in the wetlands layer that overlapped those in the LULC layer. This is assuming the because the quality of the National Wetlands Inventory Database is unknown (data collected continuously, most recent data not dated, developed on a national level, rather than state level), we assume that the data from the Maryland Department of Planning is more accurate when identifying developed features. Likewise, the rule in this process in general is to err on the side of underestimating ecosystem services, rather than overestimating.

Then, we selected only those polygons listed as saltwater wetland or freshwater wetland and use the OVERLAY tool to replace features (or parts thereof) from the forest and pasture/grasslands categories in the LULC layer with those polygons in the National Wetlands Inventory database identified as wetlands. There are no saltwater wetlands in the Baltimore area, so all of the wetland features were listed as freshwater wetland. The rationale being that because NWID specializes in the identification of wetlands, it is more likely to correctly identify natural areas than the Maryland Department of Planning. Finally, the open freshwater and estuary features identified in the National Hydrography Dataset were overlayed onto the new LULC layer.

Results

The result is a LULC map mostly based on the original LULC map from the Maryland Department of Planning, but with more accurate identifications of wetlands (in areas originally identified as forest or grasslands/prairies) based on data from the National Wetlands Inventory Database.

We then addressed a major concern associated with using Land Use/ Land Cover as a proxy for ecosystem services regarding the classification of urban LULC types under the Maryland Department of Planning classification scheme. We identified as urban the following classes: Low Density Residential, Medium Density Residential, High Density Residential, Transportation, Institutional, Large Lot Subdivision, Agricultural Feeding Operations, and Agricultural building breeding and training facilities, storage facilities, built-up areas associated with a farmstead, small farm ponds, and commercial fishing areas. The definition of Large Lot Subdivisions states that areas classified with this LULC type are residential subdivisions between 5-20 acres but have a dominant land cover of open fields, pasture, deciduous, evergreen, or mixed forest. Classifying these as urban will result in undervalue of ecosystems, and so we reclassified these areas to attain a more accurate assessment of ecosystem services.

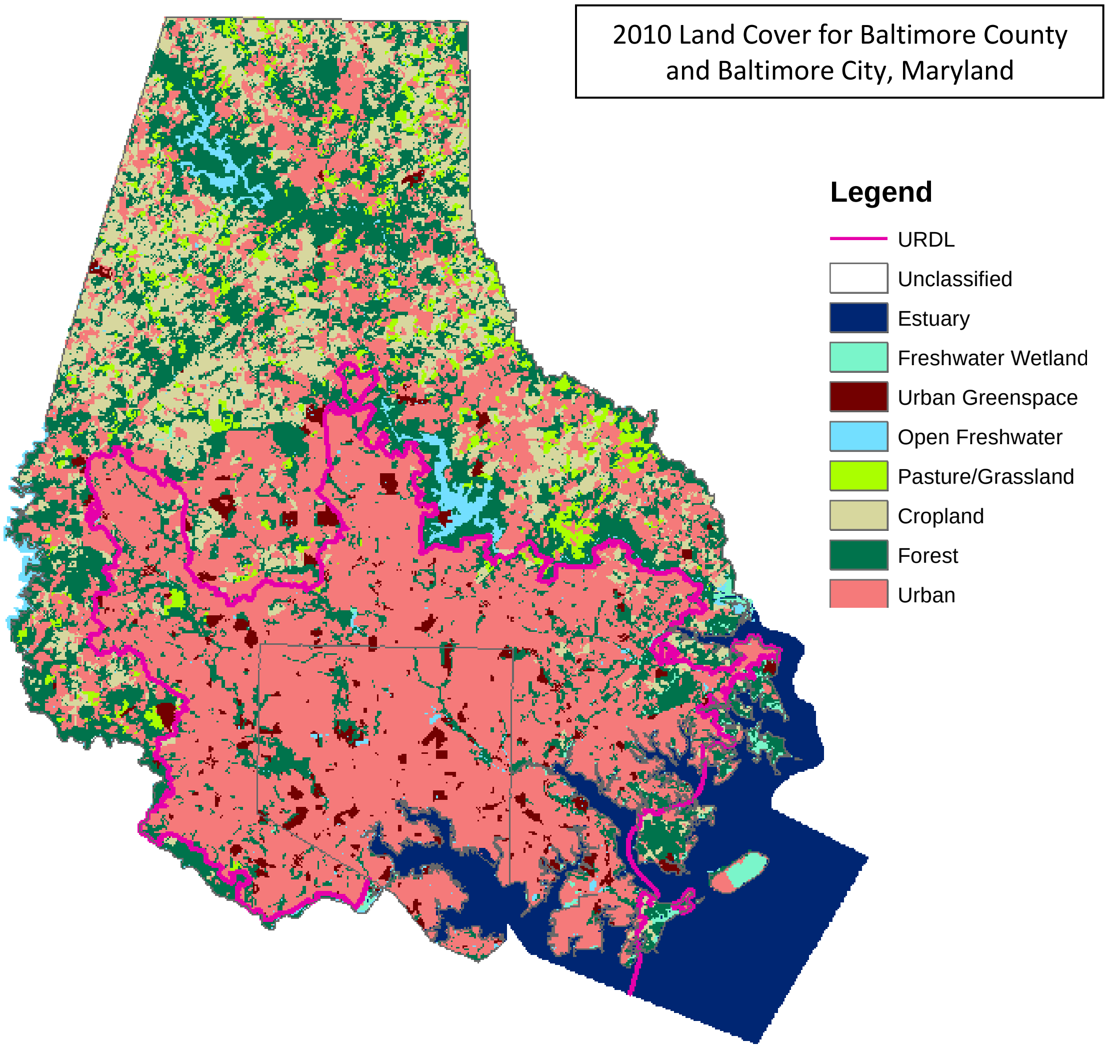


Figure 15. 2010 Land Use/ Land Cover Map.

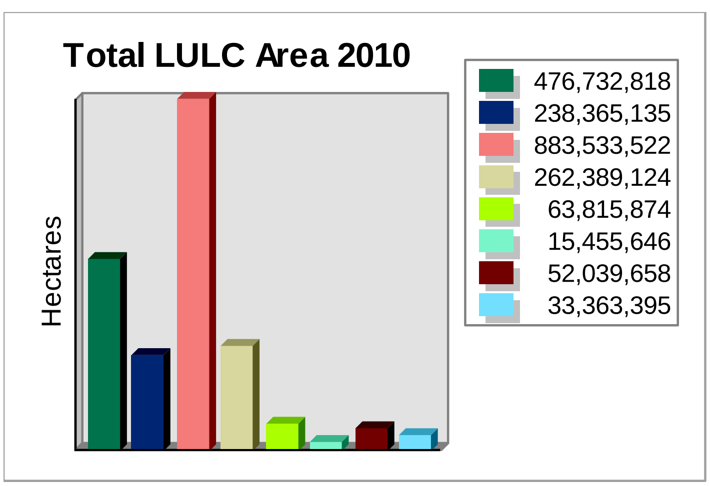


Figure 16. Total LULC Area in 2010.

We then compare the how the different inputs of GIS data impact the outputs of ecosystem service value of overall and in terms of geographic distribution, LULC change, and policy/ conservation initiatives. The results of ecosystem service value will be discussed in a later chapter.

Accuracy assessment for 2010 data was not calculated but instead is a combination of all the data layer input accuracies. Each classification will have its own accuracy level based on the source.

Discussion

In order to streamline the ecosystem assessment processing in ArcGIS, the riparian classification was excluded and reclassified into forest. There was no correlating classification for 1973, and once the ecosystem service value layers were created, it was difficult and time-consuming to re-create them in order to add one extra data classification type. Based on a simple ESV calculation, the addition of the riparian layer had an insignificant impact on the resulting ESV assessment.

Several sources indicate problems with comparing the values of one land cover type to another land cover type. This is because with the current incomplete valuation data, the result is often only a reflection of the quality of the economic valuation data available, and not the actually the difference in value between, for instance, an acre of forest and an acre of wetland. In order to compare, then, the change in ecosystem services provided by Maryland’s natural resources over time, it was an important consideration to assess the quality of the economic data and the potential impacts on the resulting valuation assessment. This is why we conducted an assessment of just how LULC changed over time. We by identifying the amount of land that changed from one undeveloped land type to another undeveloped land type, we determined the significance of this overall change to our economic valuation estimates. Because most of the areas that experienced a land change from undeveloped to developed, and because our economic values for undeveloped lands are surely underestimates, and developed lands are assumed to be $0, we were able to estimate an overall economic loss of ecosystem service value from 1973 to 2010.

Section 3.3

Display Land Use/Land Cover Change and Resulting ESV Losses

Introduction

For this exercise, we spatially identify changes in LULC types from 1973 to 2010 for both visualization but also to identify some unexpected results including significant losses in estuary and gains in open freshwater.

We also compare the newly created merged maps to the LULC basemaps published by the Maryland Department of Planning and quantify the differences results both in terms of LULC change and in terms of ecosystem service loss once the value transfer method was applied.

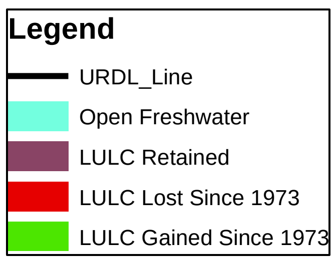
Methods

The following procedures were conducted using both the newly created LULC map described in the previous section—this is referred to as the “Merged” LULC map; we also conducted this procedure on the Baltimore County and Baltimore City LULC maps as published by the Maryland Department of planning on which we conducted no re-classification.

For each year of data (1973 and 2010), an individual LULC type was selected by attribute and a layer file was created for each LULC type. Next, each pair of land cover data layers was set as an input feature in the Intersect tool—the output feature class is a new data layer of the land area that had the same classification in 1973 and 2010, or the "retained" layer. When the three layers are displayed simultaneously with the retained layer on top, the 1973 layer displays areas that were lost since 1973 and the 2010 layer displays areas that were gained since 1973 of that particular LULC type. By subtracting the retained area from the 1973 area, we calculated the total area lost of that LULC type, likewise for the 2010 area we calculated the total amount gained.

Results

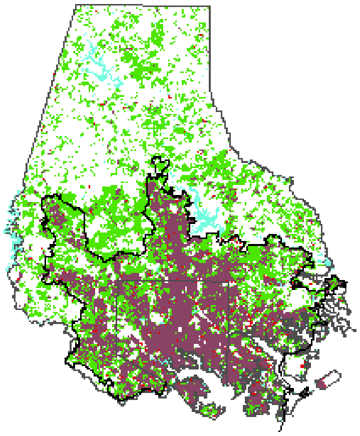
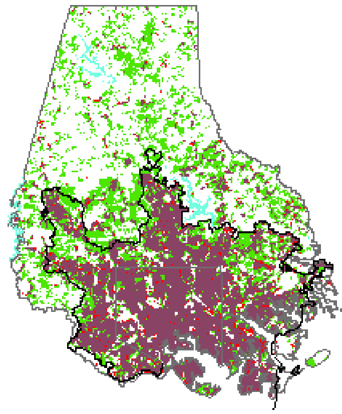
Results of LULC Change
All maps have the following legend:



Units for all areas listed are in hectares.
Units for all ESV are in 2010 USD.
Open Freshwater and the URDL Line are included solely for visual reference.

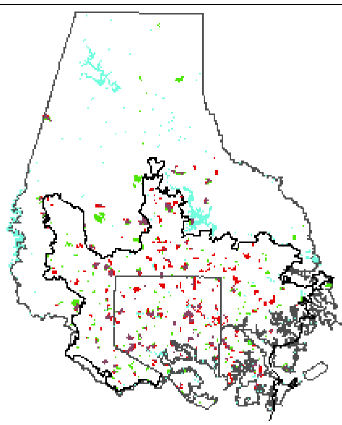
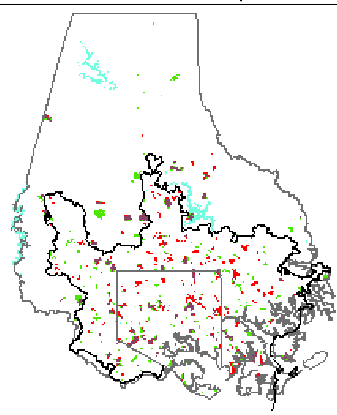
Merged Map	MD Dept. of Planning	Change

Urban

Merged Map	MD Dept. of Planning
	

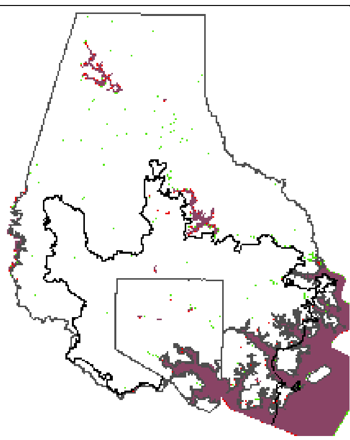
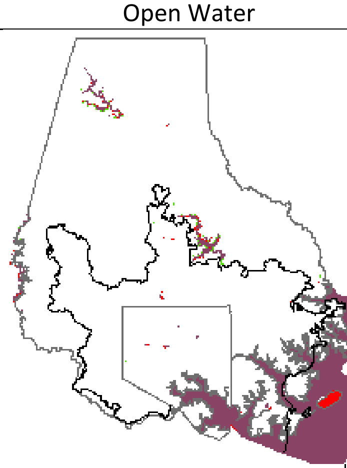
	Merged	MDP
1973 Area % of Total	20%	27%
2010 Area % of Total	44%	44%
Area Retained	37,233	50,384
Area Lost	2,337	4,560
Area Gained	51,161	38,345
ESV Lost (Millions)	$0	$0
ESV Lost % of Total Lost	0%	0%

Urban Greenspace

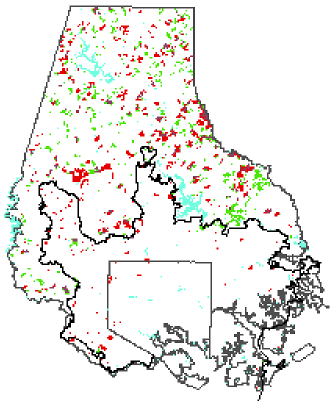
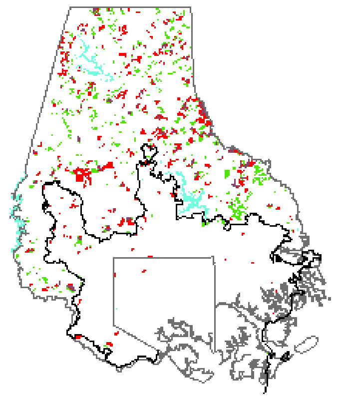
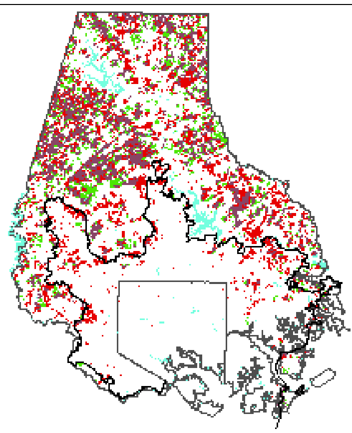
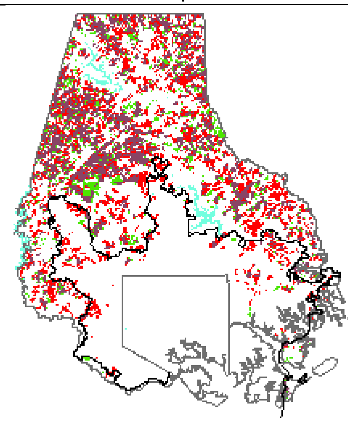
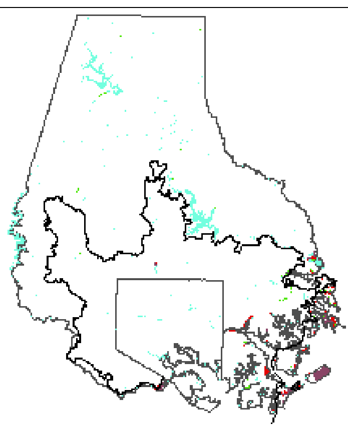
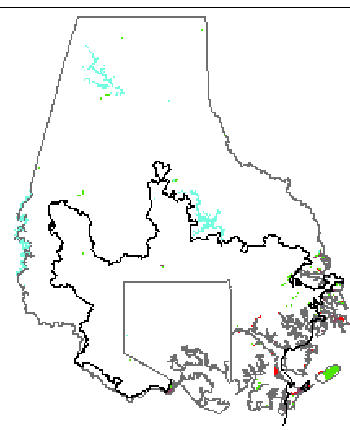
Merged Map	MD Dept. of Planning
	

	Merged	MDP
1973 Area % of Total	3%	3%
2010 Area % of Total	3%	3%
Area Retained	2,581	2,728
Area Lost	3,125	2,720
Area Gained	2,624	2,561
ESV Lost (Millions)	-$3.27	-$1.04
ESV Lost % of Total Lost	1%	1%

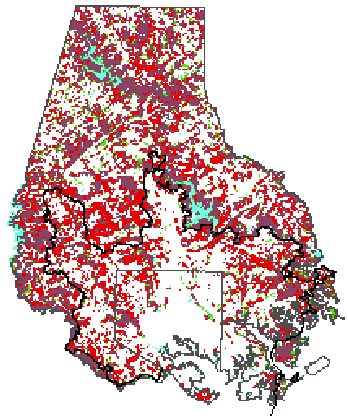
Open Water

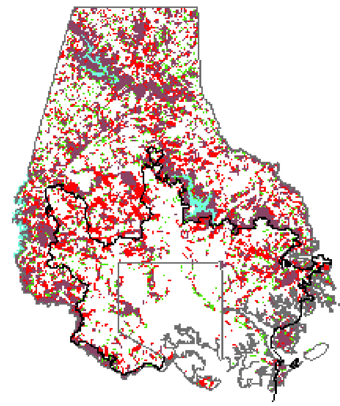
Merged Map	MD Dept. of Planning
	

	Merged	MDP
1973 Area % of Total	14%	13%
2010 Area % of Total	13%	13%
Area Retained	25,329	25,183
Area Lost	2,252	1,185
Area Gained	1,864	790
ESV Lost (Millions)	-$15.47	-$2.21
ESV Lost % of Total Lost	4%	1%

<table>
<tr><th>Merged Map</th><th>MD Dept. of Planning</th><th colspan="3">Change</th></tr>
<tr><td colspan="5">Pasture</td></tr>
<tr><td rowspan="9"></td><td rowspan="9"></td><td></td><td>Merged</td><td>MDP</td></tr>
<tr><td>1973 Area % of Total</td><td>4%</td><td>4%</td></tr>
<tr><td>2010 Area % of Total</td><td>3%</td><td>3%</td></tr>
<tr><td>Area Retained</td><td>1,699</td><td>1,881</td></tr>
<tr><td>Area Lost</td><td>6,225</td><td>6,007</td></tr>
<tr><td>Area Gained</td><td>4,685</td><td>4,790</td></tr>
<tr><td>ESV Lost (Millions)</td><td>-$0.89</td><td>-$0.70</td></tr>
<tr><td>ESV Lost % of Total Lost</td><td>0%</td><td>0%</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td colspan="5">Cropland</td></tr>
<tr><td rowspan="9"></td><td rowspan="9"></td><td></td><td>Merged</td><td>MDP</td></tr>
<tr><td>1973 Area % of Total</td><td>18%</td><td>21%</td></tr>
<tr><td>2010 Area % of Total</td><td>13%</td><td>13%</td></tr>
<tr><td>Area Retained</td><td>17,376</td><td>20,435</td></tr>
<tr><td>Area Lost</td><td>19,487</td><td>22,359</td></tr>
<tr><td>Area Gained</td><td>8,874</td><td>6,433</td></tr>
<tr><td>ESV Lost (Millions)</td><td>-$31.35</td><td>-$47.05</td></tr>
<tr><td>ESV Lost % of Total Lost</td><td>9%</td><td>23%</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td colspan="5">Wetland</td></tr>
<tr><td rowspan="9"></td><td rowspan="9"></td><td></td><td>Merged</td><td>MDP</td></tr>
<tr><td>1973 Area % of Total</td><td>1%</td><td>1%</td></tr>
<tr><td>2010 Area % of Total</td><td>1%</td><td>1%</td></tr>
<tr><td>Area Retained</td><td>940</td><td>613</td></tr>
<tr><td>Area Lost</td><td>899</td><td>472</td></tr>
<tr><td>Area Gained</td><td>603</td><td>987</td></tr>
<tr><td>ESV Lost (Millions)</td><td>-$7.83</td><td>$13.63</td></tr>
<tr><td>ESV Lost % of Total Lost</td><td>2%</td><td>-7%</td></tr>
<tr><td></td><td></td><td></td></tr>
</table>

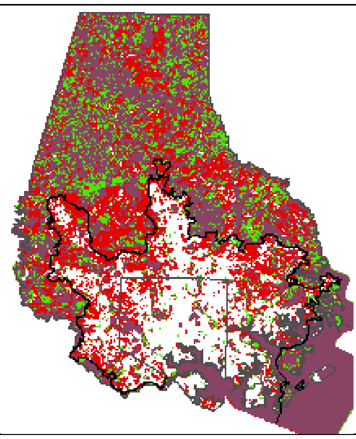
Forest

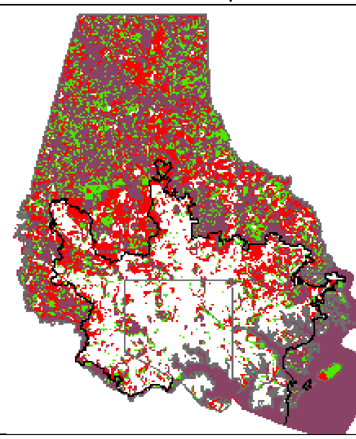




	Merged	MDP
1973 Area % of Total	41%	32%
2010 Area % of Total	24%	23%
Area Retained	40,640	37,885
Area Lost	41,596	26,241
Area Gained	7,064	9,636
ESV Lost (Millions)	-$121.94	-$58.64
ESV Lost % of Total Lost	33%	29%

All Non-Developed Land



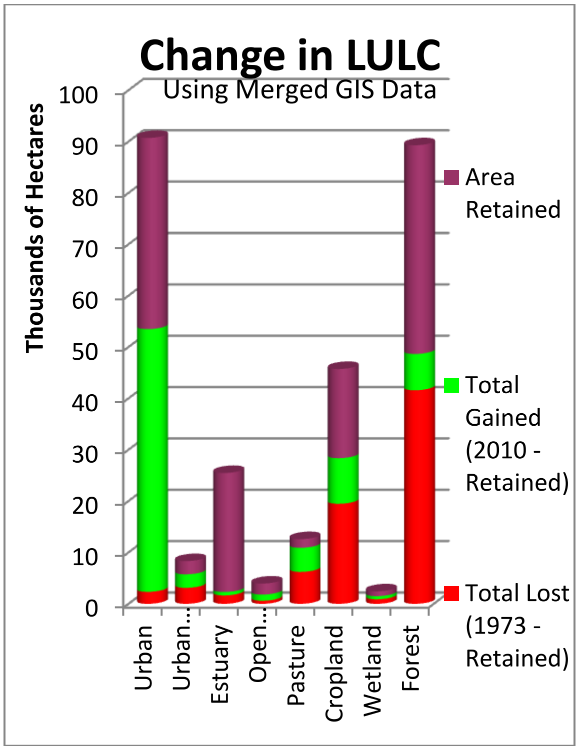


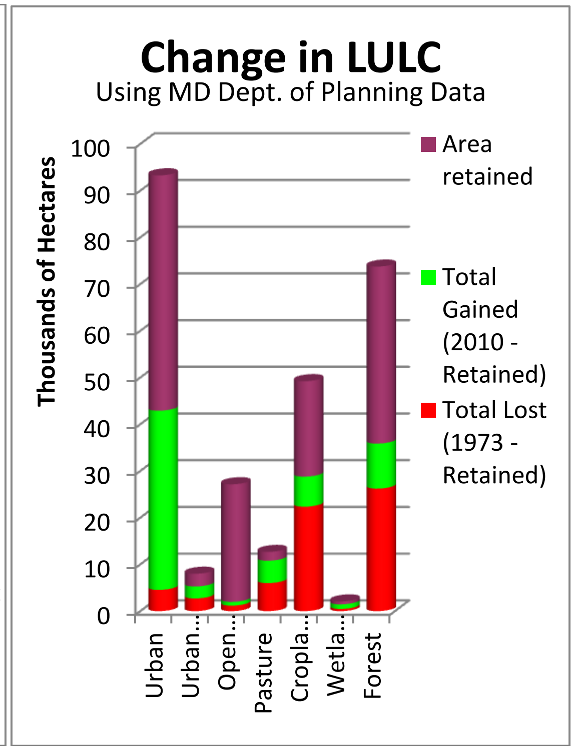
	Merged	MDP	
1973 Area % of Total	80%	73%	
2010 Area % of Total	56%	56%	
Net Change	-29%	-23%	-17%
ESV Lost (Millions)	-$181.75	-$96.01	73%

Figure 17. Results of LULC Change Analysis.

Discussion

In general, we find that the percentages of 1973 and 2010 area (as well as of ESV lost) are basically the same regardless of which data set we use. As long as we use consistent sources for both sets of data, the comparisons are similar—the differences are in total area and thus total ESV. Despite refining our Urban classifications, we find that both the merged map and the Maryland Department of Planning map conclude the same total percentage of non-urban area for 2010, but the merged map identifies 7% more land identified as non-urban in 1973. The largest losses in ESV for both maps are in forest and cropland, but MDP shows an 7% increase in wetland while the merged map shows a 2% decrease.





Figures 18 & 19. Change in LULC that was retained, gained, or lost since 1973 using Merged GIS Data (left) and MD Dept. of Planning GIS Data (right).

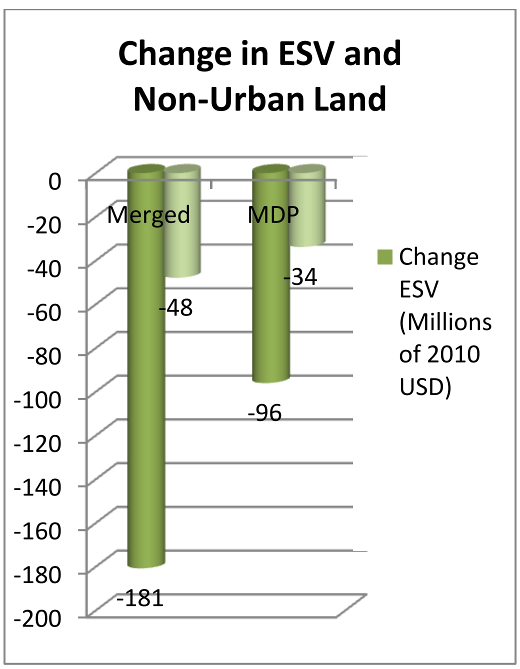
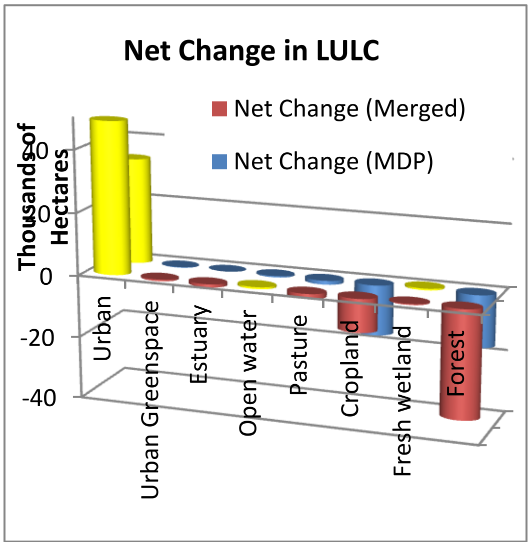
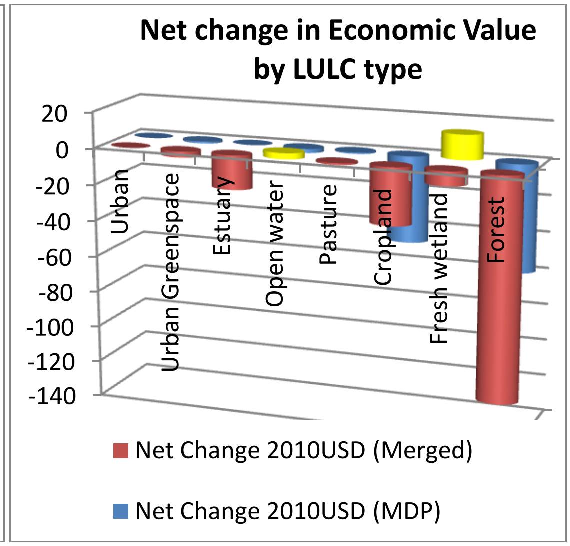


Figure 20. Change in ESV and Non-Urban Land.





Figures 21 & 22. Net Change in LULC (left) and Net change in Economic Value by LULC Type.

Discussion

When conducting an ecosystem service assessment, it is crucial to discuss the impact that different mapping methods map have on the overall results. Different maps are more sensitive to different LULC types than others, and can ultimately lead to great variation when looking at absolute dollar values of ecosystem services. There is, however, much greater agreement when values and land cover are normalized by percentage—this may mean that where we cannot be sure how exact our estimates are for a particular ecosystem providing a single or suite of services, we can more accurately state that the ecosystem likely accounts for a certain percentage of total ecosystem services for an area.

Section 3.4

Compare Metrics

Introduction

We compare the results ecosystem service assessments using different metrics both overall using tables and also geospatially using maps. Previous studies quantify the differences in utilizing different map types (such as vector vs. raster) or different economic methods for gathering data (such as contingent vs. non-contingent), but as the number of primary valuation estimates increase, so does the use of geospatial and socioeconomic filters on selecting estimates for value transfer. Likewise, there is little agreement on which metrics best represent a summary of ecosystem service estimates. Here we quantify the impact of using different filters and different metrics in terms of per area estimates. Using the same basemaps, we calculate change in different LULC types, and calculate the change in ESV using five methods in which the value transfer set is the 1) median of all studies, 2) mean of all studies (referred to as the "standard metric" because it is the most commonly used metric to summarize ESV data), 3) mean of all studies where the primary study site is within the USA, 4) mean of all studies where the primary study site is within a similar Ecoregion (as defined by the US Forest Service), 5) mean of all studies published after 1997. Though displayed in the table below, there are no areas classified as beach or saltwater wetland in our study region and so those were left out of the analysis.

Methods

The first step was to create ESV tables that represent each of the new metric/ filter summaries. We used the Descriptive Statistics tool in Microsoft Excel to determine the median value for each cell, and then summed the results to find the ESV for each LULC type based on the median of all studies. We used Microsoft Excel's filter tool to organize each study by date published and selected only those published after 1997 to create the Post-1997 average ESV table. The year of 1997 was selected not only because it was a landmark year for ecosystem service literature with the publication of both "The value of the world's ecosystem services and natural capital," (Costanza et al. 1997), and also Daly's "Nature's Services: Societal Dependence on Natural Ecosystems." We relied on the information included in the reference ecosystem service assessments to note the study site country for each valuation study and filtered the master list to include only those from the United States. For the a more precise geographic filter within the USA, we first had to collect more complete information about each study than what was originally published the reference ecosystem service assessments. We relied on the Environmental Valuation Reference Inventory (EVRI)—a searchable database of primary valuation literature—to research the study site of each valuation reference. We used the U.S. Forest Service Ecoregion provinces classification scheme to assign each state an average value for the Ecoregions lying therein, and identified states having an Ecoregion average of 220 – 230 as those most closely relating to that of the state of Maryland (average Ecoregion value of 225).

This left us with the 52 records from the following states: Delaware, Georgia, South Carolina, North Carolina, Louisiana, Maryland, Virginia, Minnesota, New Jersey, and Rhode Island. From these, we removed the four records from Minnesota due to geographic anomaly (the average of 227 was biased due to the extreme low value of 210 (Warm Continental) and extreme high of 250 (Prairie)—neither of which are representative of the mostly hot continental and subtropical divisions found in Maryland. There are other states not listed that may also be considered part of the same Ecoregion, however, there are no primary valuation studies situated there and therefore were not included in the list.

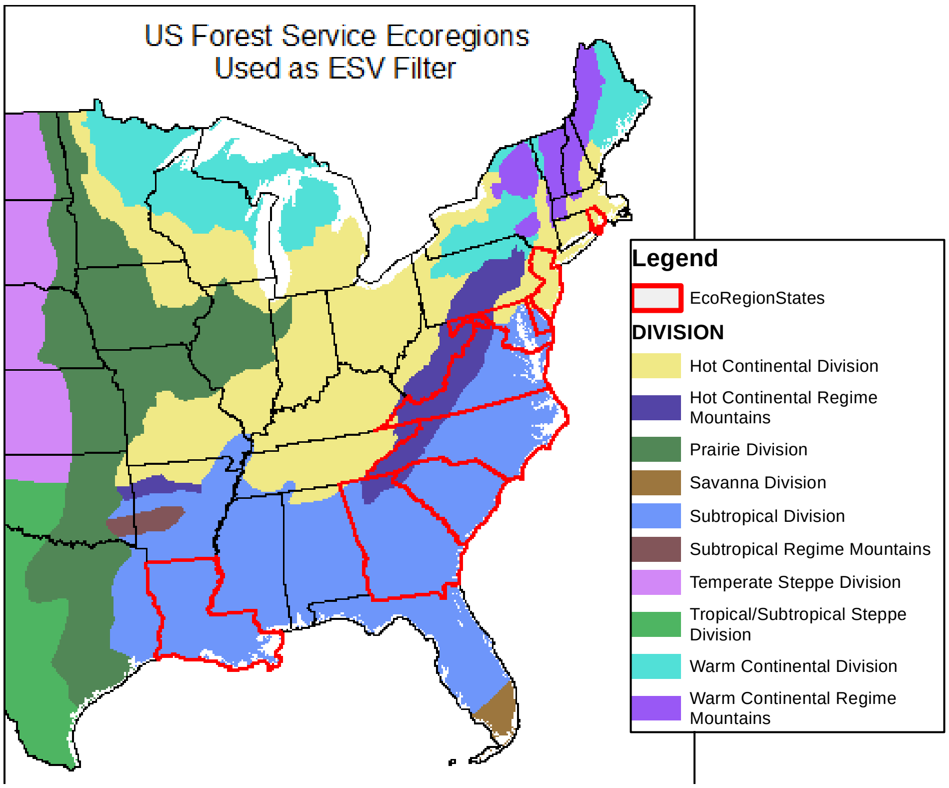


Figure 23. US Forest Service Ecoregions Used as ESV Filter

Using ArcGIS, the base raster maps were created the same way as for summarizing impacts of policy, except instead for each of the 12 LULC types, we created rasters that represented the losses of ESV using the five methods listed above. The result was a 32-bit single banded floating raster data set. Using map algebra, we computed the average of each of the five metric maps and recorded the metrics of the resulting map, as well as noted the geography. Next, to compare the differences between each metric and the standard metric (average of all studies) we used map algebra to create maps of observed (or new metric) – expected (standard metric) / expected (standard metric) and summarized the statistics of these difference maps, as well as noted regions that were especially different from the standard metric map.

Table 8. Comparing ESV for each LULC type using different metrics and filters of primary valuation studies.

2010 USD/ ha * year					
	Mean All	USA Only	Ecoregions	Post 1997	Median
Fresh wetland	$26,444	$39,417	$7,372	$14,928	$7,726
Salt Wetland	$24,108	$44,926	$56,789	$53,027	$6,063
Coastal Systems	$19,233	$1,610	$159	$19,516	$18,595
Open water	$5,605	$6,445	$2,701	$9,815	$1,375
Beach	$119,985	$119,985	$119,985	$113,916	$77,871
Riparian Buffer	$10,525	$11,521	$31,707	$18,461	$1,068
Forest	$3,531	$3,733	$1,193	$3,695	$1,958
Cropland	$2,954	$93	$73	$3,592	$2,612
Urban Green	$6,534	$905	$0	$6,672	$777
Pasture	$577	$474	$178	$303	$211

Results

The following tables display the change in ESV per hectare of LULC from one type (left) to another type (top). Blue indicates the greatest gains, red indicates the greatest losses.

Table 9. Loss in ESV (in 2010 USD/ ha*year) as a result of losing one hectare of LULC (vertical axis) to another (horizontal axis) using the mean from all studies.

All Studies	Fresh wetland	Coastal Systems	Open water	Riparian Buffer	Forest	Cropland	Urban Green	Pasture	Urban
Fresh wetland	0	-7,211	-20,839	-15,918	-22,913	-23,489	-19,910	-25,867	-26,444
Coastal Systems	7,211	0	-13,628	-8,707	-15,702	-16,279	-12,699	-18,656	-19,233
Open water	20,839	13,628	0	4,920	-2,074	-2,651	929	-5,028	-5,605
Riparian Buffer	15,918	8,707	-4,920	0	-6,994	-7,571	-3,992	-9,948	-10,525
Forest	22,913	15,702	2,074	6,994	0	-577	3,003	-2,954	-3,531
Cropland	23,489	16,279	2,651	7,571	577	0	3,579	-2,377	-2,954
Urban Green	19,910	12,699	-929	3,992	-3,003	-3,579	0	-5,957	-6,534
Pasture	25,867	18,656	5,028	9,948	2,954	2,377	5,957	0	-577
Urban	26,444	19,233	5,605	10,525	3,531	2,954	6,534	577	0

Table 10. Loss in ESV (in 2010 USD/ ha*year) as a result of losing one hectare of LULC (vertical axis) to another (horizontal access) using the mean from USA studies.

USA Only	Fresh wetland	Coastal Systems	Open water	Riparian Buffer	Forest	Cropland	Urban Green	Pasture	Urban
Fresh wetland	0	-37,807	-32,972	-27,896	-35,684	-39,324	-38,511	-38,943	-39,417
Coastal Systems	37,807	0	4,835	9,911	2,123	-1,517	-704	-1,135	-1,610
Open water	32,972	-4,835	0	5,076	-2,712	-6,352	-5,539	-5,971	-6,445
Riparian Buffer	27,896	-9,911	-5,076	0	-7,788	-11,428	-10,615	-11,046	-11,521
Forest	35,684	-2,123	2,712	7,788	0	-3,640	-2,827	-3,258	-3,733
Cropland	39,324	1,517	6,352	11,428	3,640	0	813	382	-93
Urban Green	38,511	704	5,539	10,615	2,827	-813	0	-431	-905
Pasture	38,943	1,135	5,971	11,046	3,258	-382	431	0	-474
Urban	39,417	1,610	6,445	11,521	3,733	93	905	474	0

Table 11. Loss in ESV (in 2010 USD/ ha*year) as a result of losing one hectare of LULC (vertical axis) to another (horizontal axis) using the mean from Ecoregion studies.

Ecoregion	Fresh wetland	Coastal Systems	Open water	Riparian Buffer	Forest	Cropland	Urban Green	Pasture	Urban
Fresh wetland	0	-7,213	-4,671	24,336	-6,179	-7,298	-7,372	-7,193	-7,372
Coastal Systems	7,213	0	2,542	31,548	1,034	-86	-159	20	-159
Open water	4,671	-2,542	0	29,006	-1,508	-2,628	-2,701	-2,522	-2,701
Riparian Buffer	-24,336	-31,548	-29,006	0	-30,515	-31,634	-31,707	-31,529	-31,707
Forest	6,179	-1,034	1,508	30,515	0	-1,120	-1,193	-1,014	-1,193
Cropland	7,298	86	2,628	31,634	1,120	0	-73	105	-73
Urban Green	7,372	159	2,701	31,707	1,193	73	0	178	0
Pasture	7,193	-20	2,522	31,529	1,014	-105	-178	0	-178
Urban	7,372	159	2,701	31,707	1,193	73	0	178	0

Table 12. Loss in ESV (in 2010 USD/ ha*year) as a result of losing one hectare of LULC (vertical axis) to another (horizontal axis) using the mean from Post-1997 studies.

Post 1997	Fresh wetland	Coastal Systems	Open water	Riparian Buffer	Forest	Cropland	Urban Green	Pasture	Urban
Fresh wetland	0	4,588	-5,113	3,533	-11,233	-11,336	-8,256	-14,625	-14,928
Coastal Systems	-4,588	0	-9,701	-1,055	-15,821	-15,924	-12,844	-19,213	-19,516
Open water	5,113	9,701	0	8,646	-6,120	-6,223	-3,143	-9,512	-9,815
Riparian Buffer	-3,533	1,055	-8,646	0	-14,766	-14,869	-11,789	-18,158	-18,461
Forest	11,233	15,821	6,120	14,766	0	-103	2,977	-3,392	-3,695
Cropland	11,336	15,924	6,223	14,869	103	0	3,080	-3,289	-3,592
Urban Green	8,256	12,844	3,143	11,789	-2,977	-3,080	0	-6,369	-6,672
Pasture	14,625	19,213	9,512	18,158	3,392	3,289	6,369	0	-303
Urban	14,928	19,516	9,815	18,461	3,695	3,592	6,672	303	0

Table 13. Loss in ESV (in 2010 USD/ ha*year) as a result of losing one hectare of LULC (vertical axis) to another (horizontal axis) using the median from all studies.

Median	Fresh wetland	Coastal Systems	Open water	Riparian Buffer	Forest	Cropland	Urban Green	Pasture	Urban
Fresh wetland	0	10,869	-6,351	-6,658	-5,767	-5,113	-6,949	-7,515	-7,726
Coastal Systems	-10,869	0	-17,220	-17,527	-16,637	-15,983	-17,818	-18,384	-18,595
Open water	6,351	17,220	0	-307	583	1,238	-598	-1,164	-1,375
Riparian Buffer	6,658	17,527	307	0	891	1,545	-291	-857	-1,068
Forest	5,767	16,637	-583	-891	0	654	-1,182	-1,747	-1,958
Cropland	5,113	15,983	-1,238	-1,545	-654	0	-1,836	-2,402	-2,612
Urban Green	6,949	17,818	598	291	1,182	1,836	0	-566	-777
Pasture	7,515	18,384	1,164	857	1,747	2,402	566	0	-211
Urban	7,726	18,595	1,375	1,068	1,958	2,612	777	211	0

Discussion

The tables note a remarkable difference in the outcomes of using different inputs as ESV estimates. Overall, none of the metrics agree with any particular transition resulting in the greatest increase or loss in ESV. The mean of all studies and of USA studies agree that loss of wetlands to any other LULC type will result in the greatest ESV loss, likewise the gain is the greatest as well, while Ecoregion studies put the most weight in riparian areas. The post 1997 studies have more balanced results, in that coastal systems, riparian areas, and freshwater wetlands all are highly valuable LULC to lose or gain over time.

The following map displays the losses of ESV from 1973 to 2010 based on the standard metric of ESV assessment—average of all studies.

The following maps display the spatial differences between each metric and the standard metric used to assess ecosystem service loss. Because we used the same LULC map, any regions that did not change LULC are represented in white. The grayed areas are regions where the magnitude of the losses (or gains) in ESV from 1973 to 2010 is less than that of the standard metric. That is to say, the overall change in ESV for the regions in gray is less dramatic than those reported by the standard metric. The red colors indicate regions where the difference in ESV between 1973 and 2010 are more pronounced by use of the noted metric than as reported by the standard metric. For example, an area symbolized by dark red indicates that the loss in ESV as reported by the noted metric is two times greater (or more) than the loss as reported by the standard metric. Likewise, an area symbolized by bright blue has gained at least twice as much ESV from 1973 to 2010 than if we used the standard metric to quantify ESV. Purple indicates gains in ESV, darker brown indicates the greatest losses. The legend indicates ESV change per 36 x 36 m pixel.

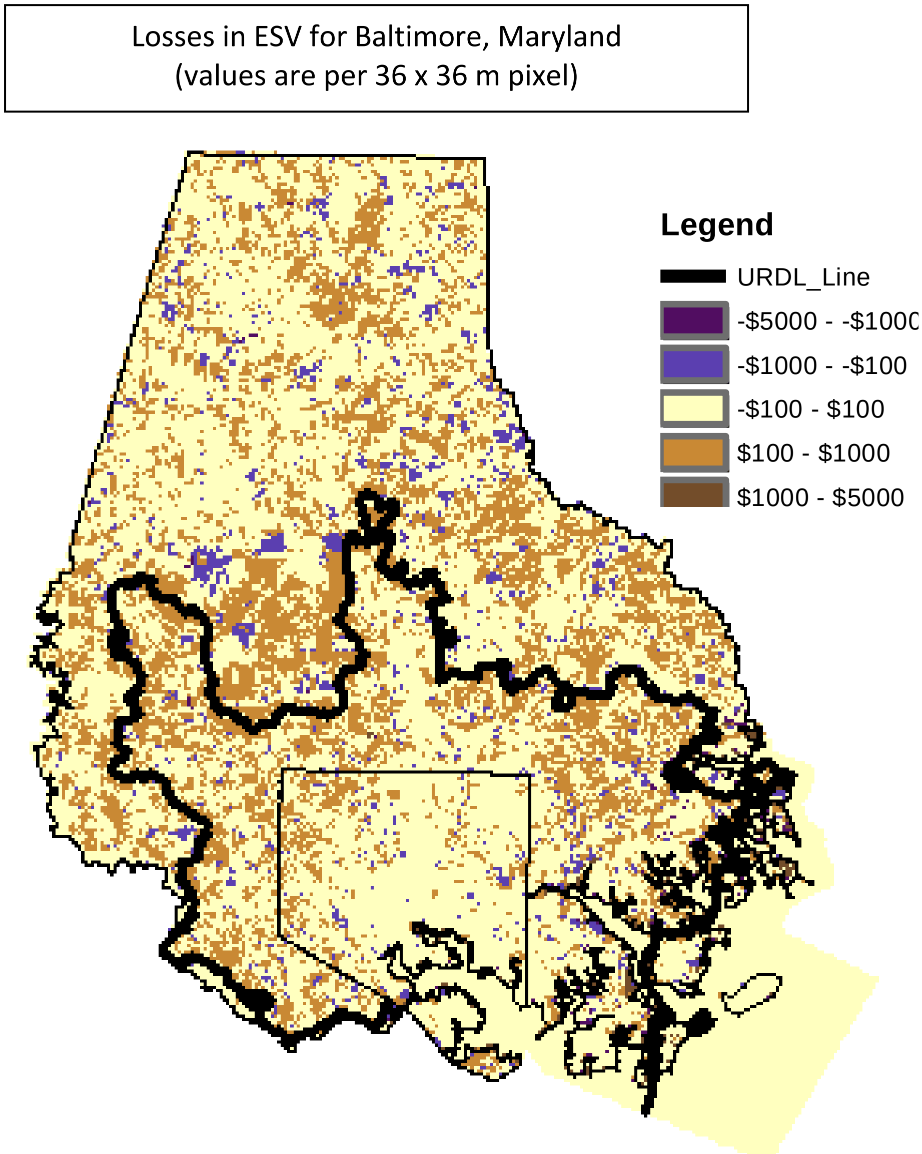


Figure 24. Losses In ESV for Baltimore County and Baltimore City, Maryland based on the average of all primary valuation studies.

The following maps display the losses or gains in ecosystem service value for four alternative filters or metrics of primary valuation data as they compare with the results for ESV of all studies. The legend below is consistent for all of maps.

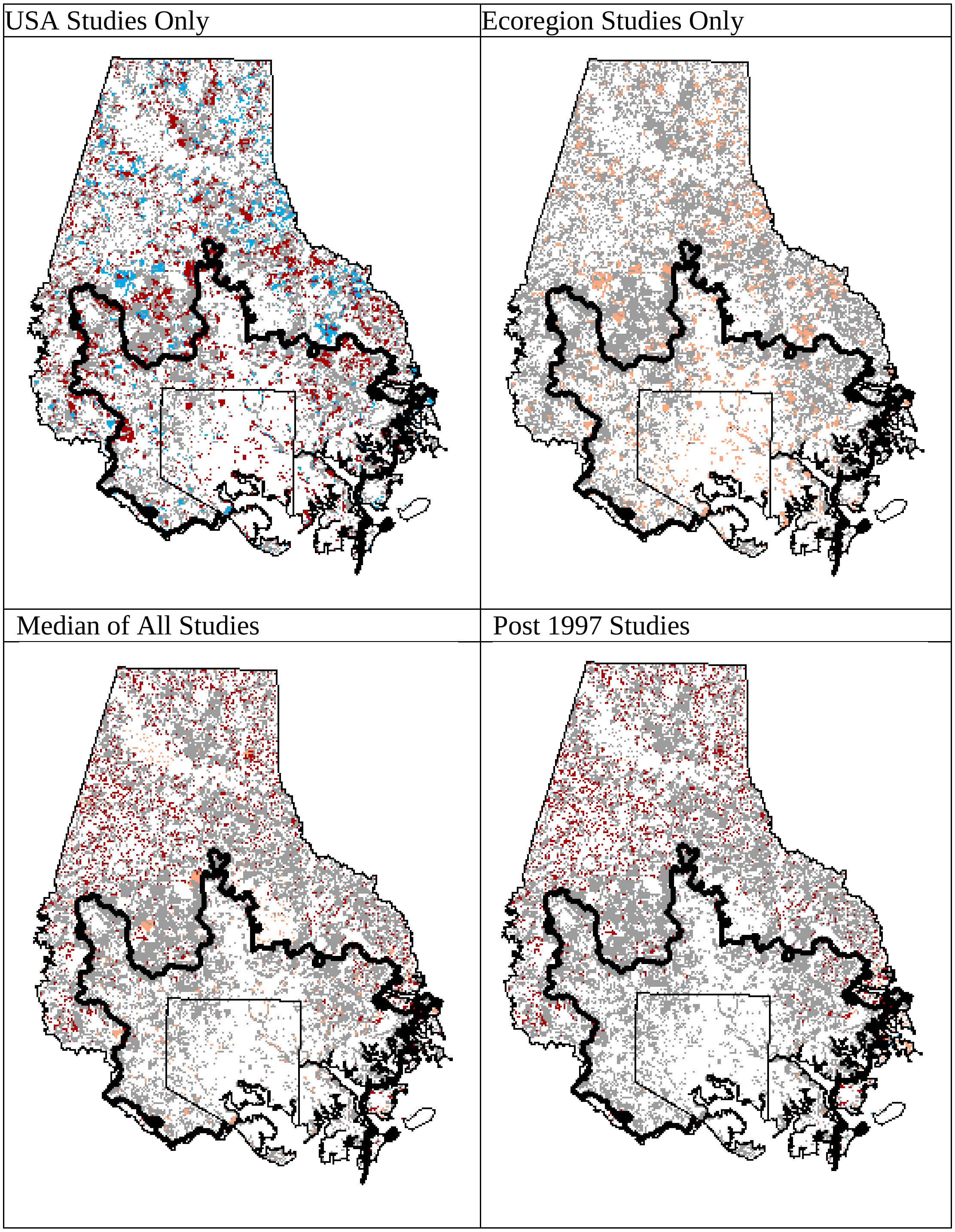


Figure 25. Losses in ESV for different metrics as they compare to the results of the standard metric.

Discussion

Overall, it can be noted that the application of the Ecoregion and Post 1997 filters or use of median as a summary statistics all result in a less exaggerated loss of ecosystem services, especially in rural areas where cropland was lost. Though the Ecoregion map shows less extreme variation, it is important to note that it is more widespread—extending well into the urban section of the URDL as well as into Baltimore City, as compared to the median or post-1997 maps. We see that the USA map has large areas mainly in the rural parts of the county where estimates of ecosystem service lost are far greater than those using the standard metric. It would be useful to assess each particular region under consideration for either development or conservation, as the particular management goals (i.e. managing for the protection of a particular ecosystem service) may vary, or there could potentially be agreement or disagreement among metrics for measuring ESV.

Section 3.5

Summarize Impacts of Policy

Introduction

In this section, we quantify the impact that different land management policies have had on ecosystem service provision in the Baltimore region between 1973 and 2010. The polices we review are the Urban Rural Demarcation Line (URDL), Maryland's Critical Area program, and the Maryland Agricultural Land Preservation Foundation because they were enacted before or near the time of our initial LULC data (1973) and are still in place today. Brief descriptions of each program are listed below.

URDL: Established 1967 Urban Rural Demarcation Line (URDL) has divided the county into "urban" and "rural" to contain the growth of intense urban uses in order to preserve agricultural and natural resources outside this urban core.

Critical Area: Established 1984, the Chesapeake Bay Critical Area Act was established to regulate development, manage land use and conserve natural resources on land in those areas designated as Critical Area (within 1000 feet of a water body).

MALPF: Established 1977, The Maryland Agricultural Land Preservation Foundation (MALPF) protects agricultural lands through the use of perpetual easements.

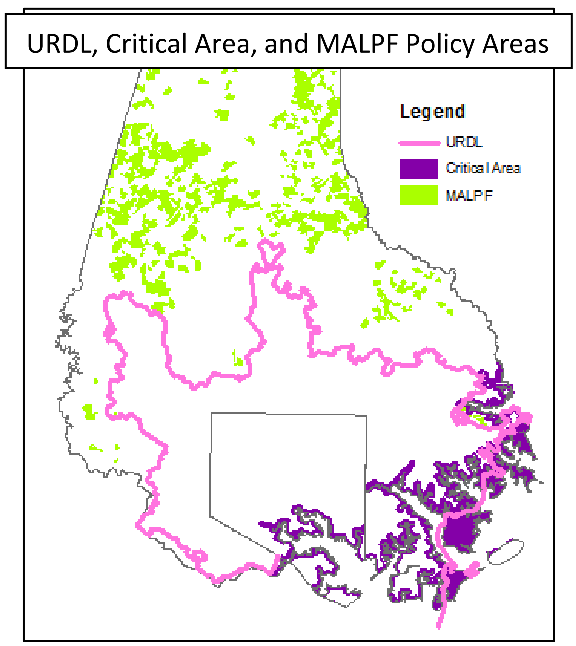


Figure 26. Policy Areas Covered in this Exercise.

Methods

We started with the basemaps used for temporal comparison and used the Convert from (vector) to (raster) tool in ArcMap to rasterize each dataset with a 36 x 36 m pixel size. We then Converted the LULC values for each ecosystem service from USD per hectare to USD per pixel to create a value table in Excel and imported the table into the Map document. Next, we performed a Spatial Join between the ESV table and each LULC map based on LULC type. We then used the Lookup tool in Spatial Analyst with the input raster set to the LULC raster joined to the ESV table (average all studies), and the lookup field set to one ecosystem service field. The results are two sets (one per year of data) of 13 singled banded raster layers (one for each of the 12 ecosystem services evaluated, and one for total ESV based on the average values for all studies). Next, we used Map Algebra in Spatial Analyst to subtract the 2010 raster layer from the 1973 layer for each of the 13 paired raster layers. The results are 13 summary raster layers that represent losses of ESV between 1973 and 2010 per pixel (high values here represent high losses, negative values represent gains in ESV). To summarize losses by different policy initiatives, we then added the MALPF, URDL, and Critical Area polygon data sets clipped by the study area to the map document. We then used the Zonal Statistics tool in Spatial Analyst where the input feature zone data was specified as a policy vector layer and the input value raster was set to one of the 13 single banded raster layers representing ESV losses. The statistics type was set to “Mean.” The resulting raster layer displays the average (per pixel) loss of ecosystem service value for the total area of the policy region. We performed the Zonal Statistics process five times using the input feature zone data set to Critical Area, MALPF, URDL rural designation, URDL urban designation, and the entire Baltimore region.

The following map displays the policy regions addressed in this section. When we refer to URDL rural, we are referring to the region north of the URDL line; when we refer to URDL urban, we are referring to the region south of the URDL line, but not including Baltimore City. When we refer to Baltimore Region, we refer to the entire study area displayed below including Baltimore City—unlike the other assessments, we do not include the total estuary in this exercise.

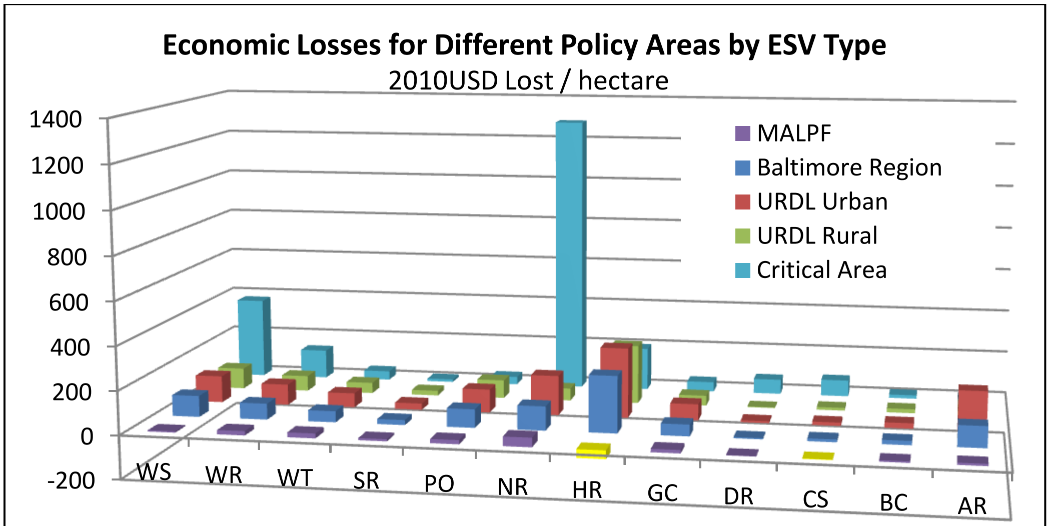
Results

Overall, we found that the Baltimore Region lost between 1973 and 2010 an ecosystem service flow of about $180 million per year, or on average about $889 per year per hectare. The greatest loss per hectare of policy site was for critical area, followed by URDL urban, URDL Rural, and MALPF areas. We also found several interesting correlations between the policy area ESV losses by ESV types as shown in the graphs below. This is clearly highly associated with the types of LULC associated with each policy area—for instance, critical area is associated with wetlands and estuary which have nutrient regulation values and therefore, losses in critical area result in great losses to nutrient regulation ESV. Similarly, the URDL Rural area lost a great deal of forest and grassland, which ultimately result in great losses for habitat and cultural services.

Table 14. Impacts of Policy on ESV loss from 1973 to 2010.

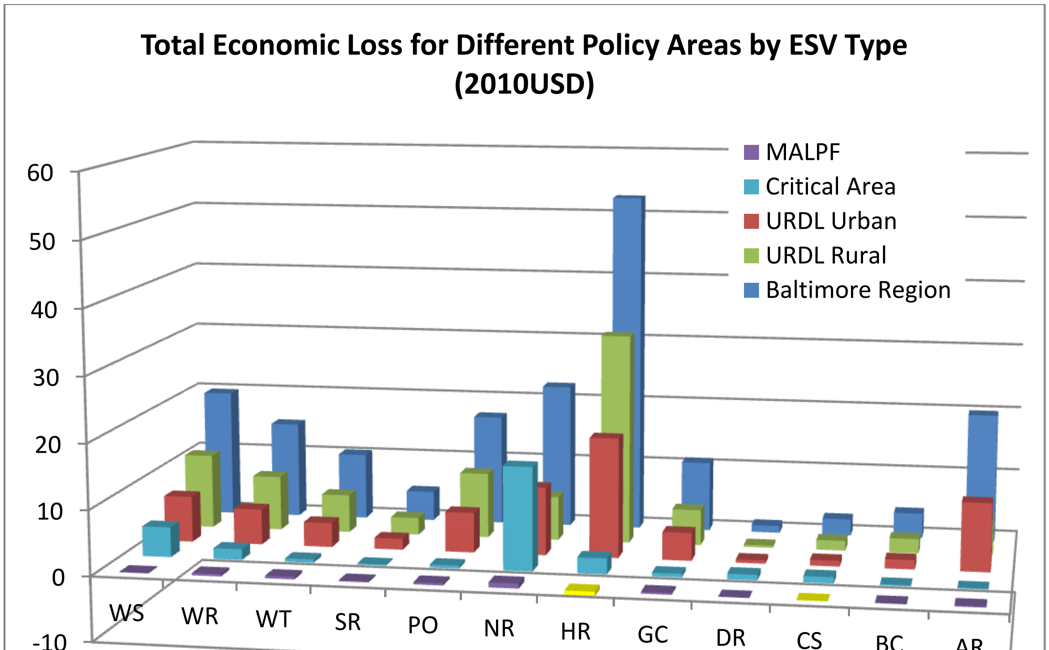
	Baltimore Region	URDL Urban	URDL Rural	MALPF	Critical Area
Economic Loss per Hectare	$889	$1,235	$781	$110	$2,301
Total Economic Loss	$180,213,375	$70,886,037	$93,142,711	$1,953,419	$28,359,457

We would also like to note that the bars symbolized in yellow are actually gains in ESV from 1973 to 2010. These include habitat and refugium and cultural and spiritual ESV for MALPF properties.



Key to Ecosystem Service Types
WS - Water Supply; WR - Water Regulation; WT - Waste Treatment; SR - Soil Retention and Formation; PO – Pollination; NR - Nutrient Regulation; HR -Habitat and Refugium; GC - Gas and Climate Regulation; DR - Disturbance Regulation; CS - Cultural and Spiritual; BC - Biological Control; AR - Aesthetic and Recreational

Figure 27. Economic Losses (per area) for Different Policy Areas by ESV Type.



Key to Ecosystem Service Types
WS - Water Supply; WR - Water Regulation; WT - Waste Treatment; SR - Soil Retention and Formation; PO – Pollination; NR - Nutrient Regulation; HR -Habitat and Refugium; GC - Gas and Climate Regulation; DR - Disturbance Regulation; CS - Cultural and Spiritual; BC - Biological Control; AR - Aesthetic and Recreational

Figure 28. Total Economic Loss for Different Policy Areas by ESV Type.

Discussion

When we analyzed LULC change maps, we noted that some of the losses for estuary were likely due to low resolution in 1973 imagery which did not pick up piers and other shoreline features that were displayed in 2010 resolution. With the increased resolution, we therefore "lost" a great deal of estuary area, and due to the high ESV of that LULC type, we saw great losses for Critical Area. The following graph shows average loss per hectare of policy sites but excludes Critical Area for better visualization.

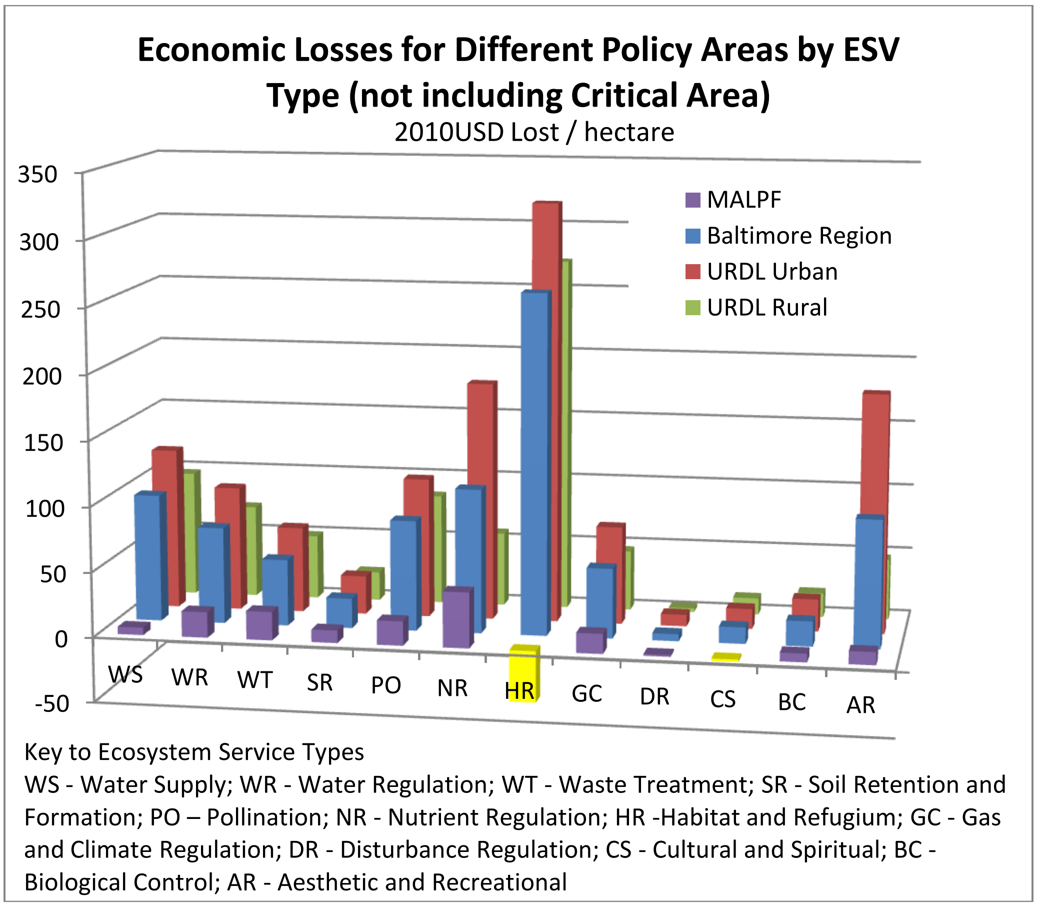


Figure 29. Economic Losses (per area) for Different Policy Areas by ESV Type (no Critical Area Shown).

There certainly are difficulties in assessing the effectiveness of different land management policies on protecting ecosystem services. Based on a simple interpretation of this graph, it appears that while URDL concentrated new development (as indicated by a greater average loss of ESV per hectare for each service compared to Baltimore in general), it was not especially effective in preventing ESV loss in that area considered rural. There was indeed a tremendous amount of development within this zone, which likely would have been greater had the URDL not been in place. It can be said that if we use ecosystem services as a measure of natural and agricultural resources, this URDL did not appear to achieve its goal of preserving said resources. The MALPF, however, clearly did an excellent job conserving ESV and on average lost much less ESV per hectare than Baltimore in general.

Section 3.6

Identify Current Natural Capital

Introduction

For this exercise, we inventory current stocks of Natural Capital in terms of ESV within certain policy areas described below. The results help to identify programs of special importance in terms of specific ecosystem services for which lands may be managed.

It is important to understand the concept of economic capital in general to answer this question, and therefore we begin by looking at natural capital in the context of what Puget Sound study refer to as "the four capitals that are required to attain economic progress and a high quality of life." These are:

1. *Natural Capital: earth's stock of organic and inorganic materials and energies inventory of living biological systems (ecosystems)*
2. *Human Capital: acquired knowledge*
3. *Social Capital: inventory of organizations, institutions, laws, informal social networks, and relationships*
4. *Built Capital: productive infrastructure of technologies, machines, tools, and transport*

Note here that capitals are not measured by any particular quantifiable or normalized metric, but rather are inventoried. The authors cite Vemuri and Costanza's (2006) conclusion that there is "a high level of correlation at the national level between human, built, and natural capital; especially the presence of adequate natural capital and subjective well-being between." However, while built capital depreciates over time, natural capital not only requires no maintenance (assume a healthy, intact ecosystem) and does not depreciate, but even appreciates over time as new, complex interactions develop within the system and information is gained and stored (Puget Sound). Daly and Farley (2004) state that Natural capital and built capital are most often productively used as complements rather than substitutes. This perspective should be maintained throughout the process of assessing ecosystem services and applying the concept to policy—it is natural to think of natural capital and built capital as competitors, but when they are both valued highly by human systems, land managers can creatively find ways to optimize the benefits of both.

The authors of the Puget Sound study elegantly connect ecosystems, ecosystem services, and natural capital in their following statement:

> *Ecosystems consist of structural components (trees, wetland plants, soil, hill slopes, etc.) and dynamic processes (water flows, nutrient cycling, animal life cycles, etc.) that create functions (water catchment, soil accumulation, habitat creation, reduced fetch, buffers to hurricane storm surges, etc.) that generate ecological goods (fish, timber, water, oxygen) and services (storm and flood protection, water filtration, recreation, aesthetic value, etc.).*

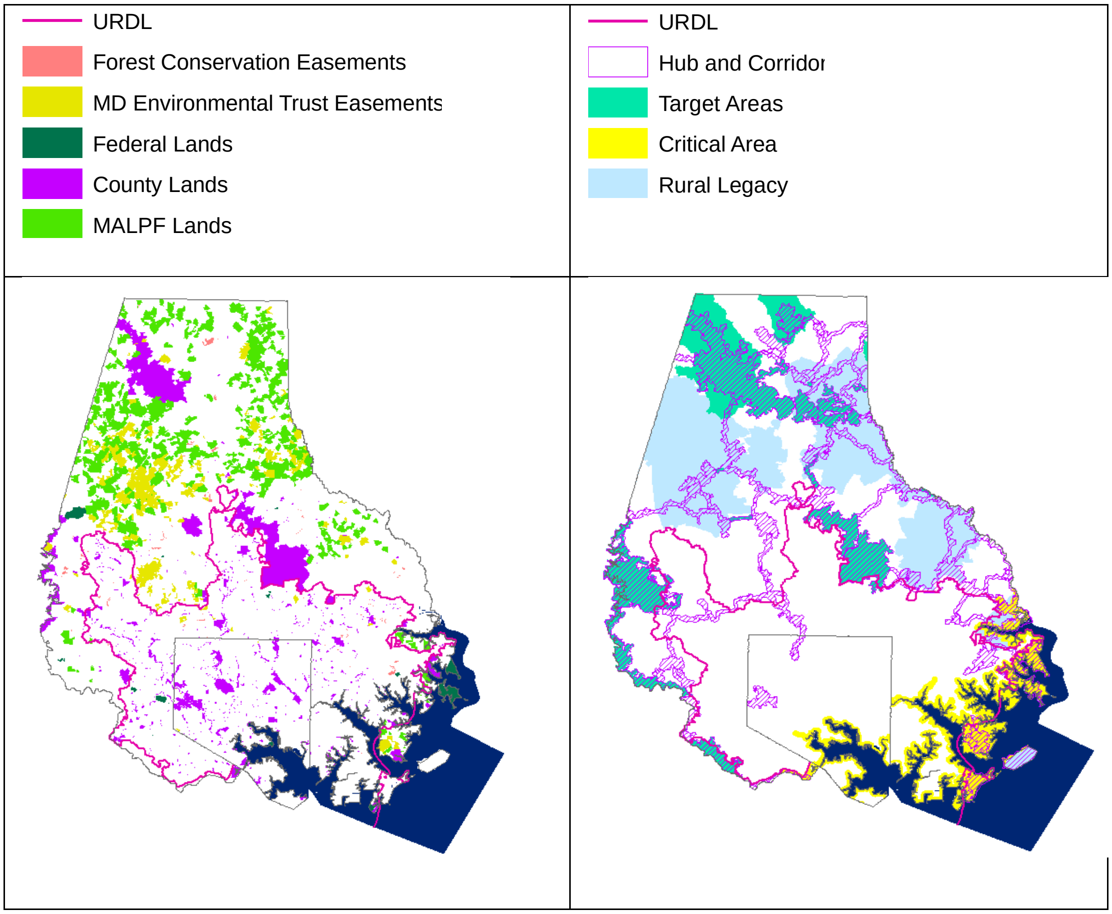


Figure 30. Policy and Program Sites under Investigation.

Methodology

We started this exercise by downloading GIS data for a number of different policy and conservation areas from the state of Maryland's MERLIN GIS database and clipped them to our study region. We then created a map of the total ESV of the area for 2010 using the 2010 LULC map with the following data layers and associated ESVs.

Table 15. ESV Table used for Value Transfer.

	AR	BC	CS	DR	GC	HR	NR	PO	SR	WT	WR	WS	Total
Cropland	5.39	4.59	0.00	0.68	14.65	301.92	2.86	45.05	1.39	0.00	0.00	0.00	376.54
Estuary	28.63	10.72	20.66	103.97	34.85	79.73	2,068.72	0.00	0.00	0.00	0.00	103.92	2,451.20
Forest	67.15	12.44	6.08	0.72	32.41	97.27	23.39	47.93	16.56	36.80	50.22	59.08	450.04
Freshwater Wetland	343.29	0.96	323.55	20.57	31.76	457.63	0.00	0.00	0.38	80.78	552.90	1,558.42	3,370.23
Open Water	509.14	0.00	0.00	0.00	0.00	85.61	0.00	0.00	0.00	2.68	0.00	116.92	714.35
Pasture/ Grassland	0.00	4.52	0.00	0.00	14.52	0.00	0.00	35.08	2.57	16.32	0.56	0.00	73.56
Riparian Buffer	485.88	0.00	1.45	21.04	0.00	66.96	0.00	0.00	0.00	0.00	37.31	728.79	1,341.45
Urban Greenspace	717.32	0.00	0.00	0.00	85.43	0.00	0.00	0.00	0.00	0.00	29.96	0.00	832.71
Urban/ Barren	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

WS - Water Supply; WR - Water Regulation; WT - Waste Treatment; SR - Soil Retention and Formation; PO – Pollination; NR - Nutrient Regulation; HR -Habitat and Refugium; GC - Gas and Climate Regulation; DR - Disturbance Regulation; CS - Cultural and Spiritual; BC - Biological Control; AR - Aesthetic and Recreational

Then, we used the Lookup tool in Spatial Analyst to create a map layer displaying the ESV value for each individual ecosystem service (and the totals) based on the average of all studies. Using Zonal Statistics in Spatial Analyst, we created a series of maps that displayed the distribution of ESV for each policy types. The zone was set to the shapefile of the policy site, and the input value raster set to each new ecosystem service layer that was created in the previous step using the Lookup tool. To create the All Policy area maps, each policy site was set as an input layer to the Union tool. The output map avoids the double counting that results from overlapping policy sites. The results are a series of maps that both summarize the 2010 total ESV of each policy area but also visualize the geography of those services.

Results

The following displays a summary of each policy area as compared to the total study area which includes Baltimore County, Baltimore City and Estuary.

Table 16. Current Total ESV for Different Policy Areas in Baltimore, Maryland.

	Area (ha)	% of Total Policy Area	Total ESV (millions of 2010 USD per year)	% of Total ESV	Average ESV (2010 USD) per area (ha)
Rural Legacy	441,611	21.79%	$1,353	16.87%	$3,064
MET	66,989	3.30%	$194	2.42%	$2,897
MALPF	177,408	8.75%	$512	6.39%	$2,888
Hubs & Corr.	374,951	18.50%	$1,472	18.35%	$3,927
Forest CE	4,224	0.21%	$14	0.17%	$3,256
Federal Lands	9,790	0.48%	$80	0.99%	$8,138
Critical Areas	123,299	6.08%	$524	6.54%	$4,253
County Owned	126,390	6.24%	$521	6.50%	$4,123
Target Area	229,205	11.31%	$703	8.76%	$3,067
All Policy Areas	899,606	44.38%	$4,021	50.12%	$4,469
Total Area	2,026,932	100.00%	$8,023	100.00%	$3,958

Table 17. Current Total ESV for Different Policy Areas in Baltimore, Maryland as a percentage of total ESV for the entire study site.

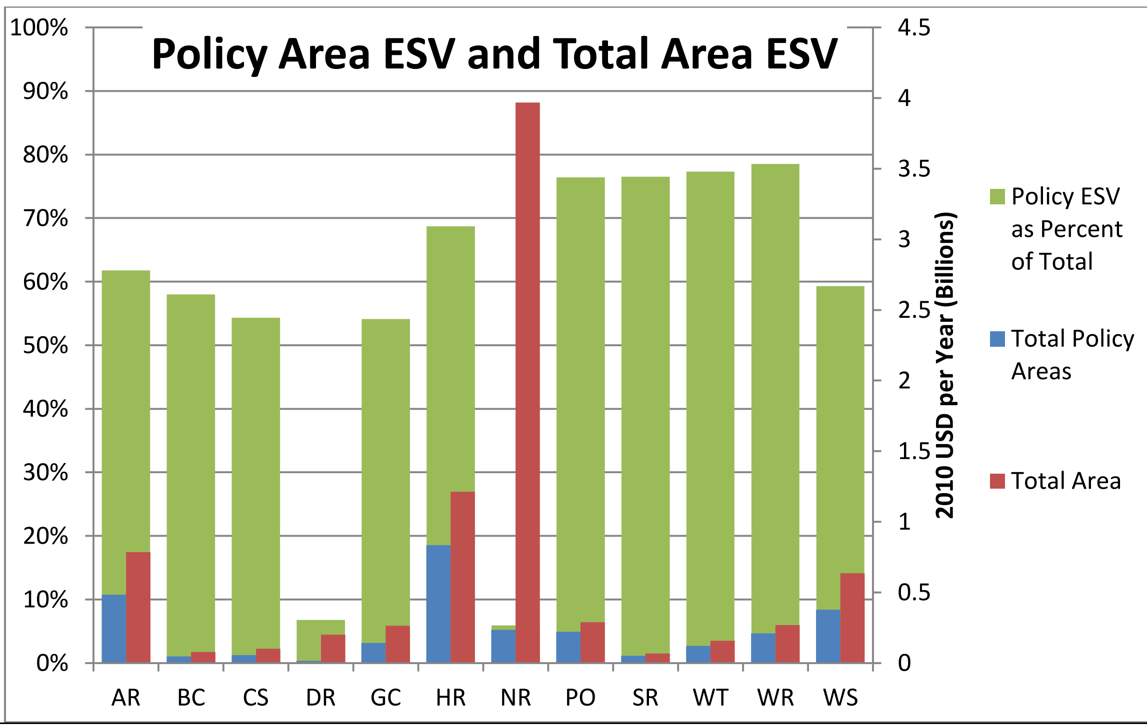
Natural Capital as % of Total	AR	BC	CS	DR	GC	HR	NR	PO	SR	WT	WR	WS	Total
Rural Legacy	18%	28%	34%	3%	25%	42%	2%	42%	34%	36%	40%	32%	17%
MET	3%	5%	2%	0%	4%	7%	0%	7%	6%	6%	4%	2%	2%
MALPF	5%	12%	4%	0%	10%	22%	0%	20%	13%	12%	9%	5%	6%
Hubs & Corr	35%	32%	39%	4%	27%	24%	4%	35%	48%	50%	53%	42%	18%
Forest CE	0%	0%	0%	0%	0%	0%	0%	0%	1%	1%	1%	0%	0%
Federal Lands	1%	1%	5%	0%	1%	1%	0%	1%	1%	2%	4%	4%	1%
Critical Areas	12%	5%	27%	3%	6%	6%	2%	5%	7%	10%	21%	22%	7%
County Owned	25%	10%	7%	1%	11%	7%	1%	10%	15%	15%	15%	11%	6%
Target Area	22%	18%	7%	0%	15%	15%	1%	21%	27%	26%	20%	14%	9%

WS - Water Supply; WR - Water Regulation; WT - Waste Treatment; SR - Soil Retention and Formation; PO – Pollination; NR - Nutrient Regulation; HR -Habitat and Refugium; GC - Gas and Climate Regulation; DR - Disturbance Regulation; CS - Cultural and Spiritual; BC - Biological Control; AR - Aesthetic and Recreational

Table 18. Current Average ESV per Area as % of Average ESV for Total Policy Area.

ESV/area as %	AR	BC	CS	DR	GC	HR	NR	PO	SR	WT	WR	WS	Total
Rural Legacy	60%	98%	127%	77%	94%	125%	59%	111%	90%	94%	103%	109%	99%
MET	64%	116%	37%	34%	109%	140%	36%	131%	109%	98%	75%	51%	93%
MALPF	42%	106%	40%	36%	98%	165%	29%	135%	87%	78%	60%	47%	93%
Hub & Corr.	136%	133%	172%	140%	119%	85%	143%	109%	151%	155%	162%	172%	127%
Forest CE	104%	139%	121%	45%	130%	83%	48%	118%	159%	156%	147%	123%	105%
Federal Land	184%	95%	889%	509%	125%	124%	350%	69%	98%	186%	448%	646%	263%
Critical Area	139%	61%	356%	271%	87%	69%	223%	48%	62%	94%	195%	269%	137%
County Land	290%	120%	95%	59%	148%	70%	70%	96%	142%	139%	134%	133%	133%
Target Area	138%	124%	50%	27%	107%	88%	42%	110%	138%	130%	101%	90%	99%

WS - Water Supply; WR - Water Regulation; WT - Waste Treatment; SR - Soil Retention and Formation; PO – Pollination; NR - Nutrient Regulation; HR -Habitat and Refugium; GC - Gas and Climate Regulation; DR - Disturbance Regulation; CS - Cultural and Spiritual; BC - Biological Control; AR - Aesthetic and Recreational



WS - Water Supply; WR - Water Regulation; WT - Waste Treatment; SR - Soil Retention and Formation; PO – Pollination; NR - Nutrient Regulation; HR -Habitat and Refugium; GC - Gas and Climate Regulation; DR - Disturbance Regulation; CS - Cultural and Spiritual; BC - Biological Control; AR - Aesthetic and Recreational

Figure 31. Policy Area ESV and Total Area ESV.

Discussion

We find that in general, the policy areas identified by the state or county government as targeted policy areas provide a great deal of the area's ecosystem services. It is important to note, however, that while a great deal of the nutrient regulation is not showing as part of the policy sites, this is due to the fact that most of that service is provided by the estuary which is closely monitored by government and conservation agencies alike, though not under the particular programs shown here. Overall, the lands owned by the federal government are highly valuable in terms of ecosystem service, but only represent 0.48% of the total land area. Over 35% of the regions ecosystem services are provided by Rural Legacy areas and Hubs and corridors, but it is important to note that these policy areas only account for about half of the total ecosystem service provision for the entire region.

When we take out the service of nutrient regulation, our summary table changes but not as drastically as expected—total policy areas account for 62% of the regions total ecosystem service value. Though this exercise was not exhaustive of all conservation and land protection programs in the state, it is important to note the possibility that nearly 40% of ecosystem service value may not currently be protected under any program and could be lost due to land use change.

Table 19. Comparing % area and % ESV of Different Policy Areas.

	Area (ha)	% of Total Area	Total ESV (millions of 2010 USD per year)	% of Total ESV	Average ESV (2010 USD) per area (ha)
Rural Legacy	441,611	21.79%	$1,286	31.70%	$2,911
MET	66,989	3.30%	$188	4.63%	$2,803
MALPF	177,408	8.75%	$499	12.30%	$2,813
Hubs & Corridors	374,951	18.50%	$1,332	32.86%	$3,554
Forest CE	4,224	0.21%	$13	0.33%	$3,130
Federal Lands	9,790	0.48%	$71	1.74%	$7,225
Critical Areas	123,299	6.08%	$453	11.16%	$3,672
County Owned	126,390	6.24%	$498	12.28%	$3,940
Target Area	229,205	11.31%	$678	16.71%	$2,957
Total Policy Areas	899,606	44.38%	$2,554	62.97%	$2,839
Total Area	2,026,932	100.00%	$4,055	100.00%	$2,001

Section 3.7

Identify Target Conservation Areas

Introduction

The ultimate goal of any ecosystem service assessment is to inventory natural capital of an area to help guide decision making related to conservation and development policies. So far, we have quantified the success of different policies in conserving ecosystem services—here we identify target areas for future conservation plans.

Methodology

This map starts with the 2010 LULC Raster map and the All Policy Lands map created in the previous sections. From the LULC map, we isolate all areas that are non-urban, and erase all areas that are currently identified as policy lands. The results are non-developed areas that are not currently managed or monitored for natural resource conservation—we call this raster layer Non-policy Undeveloped and display it based on

ESV. We then added to the map document two map layers published by the Maryland Department of Planning: Ecological Value and Development Risk. Each layer is a raster map of pixels ranked from 0-100 for each category. We clipped those two layers by the geometry of the Non-policy Undeveloped data layer and then used symbology to display by color ramp four rankings of each layer which were then adjusted for transparency for visualization.

Results

Combination of ESV, Ecological Value and Development Risk Raster Maps for Non-Policy, Currently Undeveloped Sites in Baltimore, Maryland

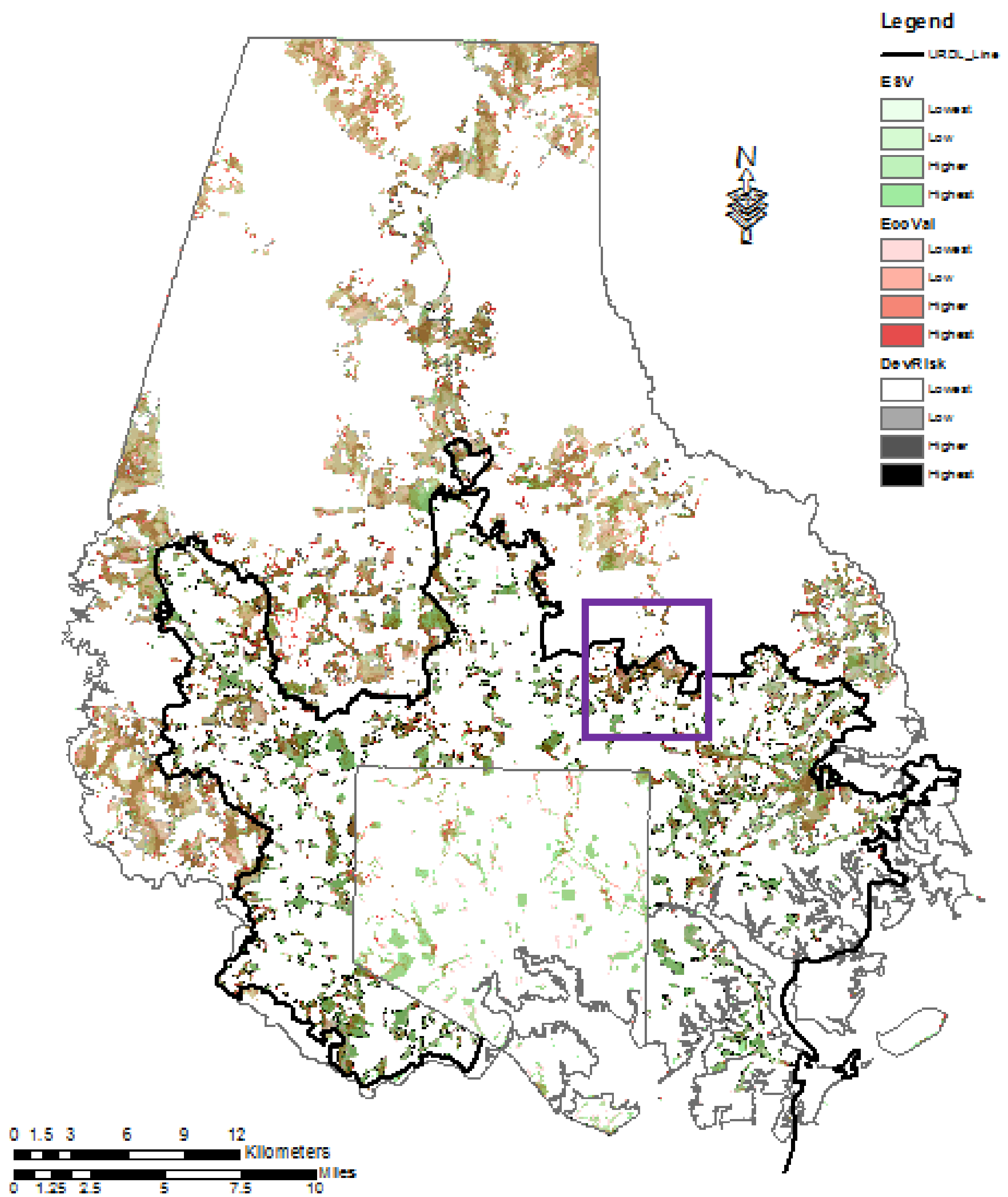


Figure 32. Combination of ESV, Ecological Value and Development Risk Raster Maps for Non-Policy, Currently Undeveloped Sites in Baltimore, Maryland.

Figure 32 displays in brown/gold the areas that overlap in ESV and Ecological Value--the darker the color, the greater development risk. We were surprised to find almost no overlapping areas that ranked highest in all three categories—but identified one site that covered a large, continuous area, and overall ranked high in each of the three categories. We created a new data layer called Target Sites and drew polygons around the area identified as a potential target area for conservation. This table below summarizes several characteristics of the site.

Table 20. Target Conservation Site Characteristics.

Target Site		
Total area (ha)	3921	
Avg ESV Per ha	$203.38	(High)
Total ESV (2010 USD/yr)	$797,374	
Overall Development Risk	82	(High)
Overall EcoValue	29	(High-Highest)

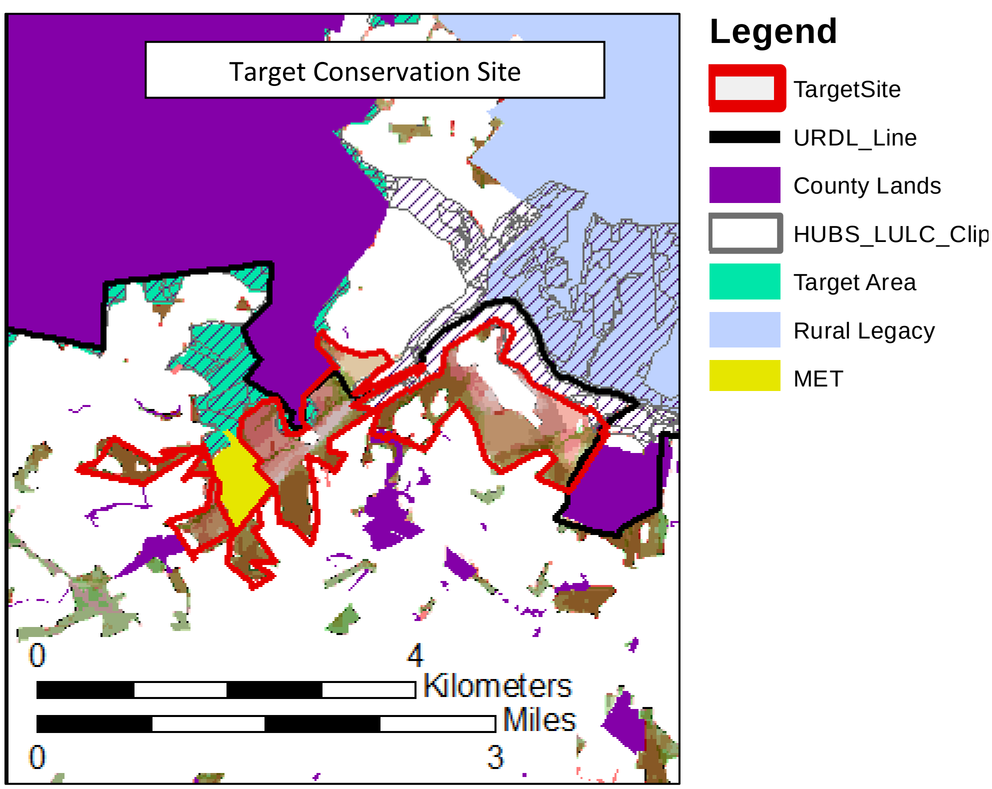


Figure 33. Target Conservation Site and Nearby Policy Sites.

Discussion

Consistently, it is important to recall that ESV alone is not the only metric that should be used to value land. This technique incorporates land management strategies from several different perspectives, and attempts to optimize the efficacy of each method. Further work should be done to incorporate ESV into current land management and conservation plans—this is only one example of how ESV can help narrow down potential conservation sites and utilize resources effectively to generate the greatest returns both economically and ecologically.

Section 4

Discussion

The challenge in ecosystem service assessments is one of communication. In order for people to become more aware of the services that ecosystem services provide, they must be translated into tangible terms that people understand. While phrases and sayings like “bare necessities,” “a glass of water in the desert,” and “spaceship earth” provide excellent illustrations to convey describe our complete dependence on the natural environment around us, they border hyperbole for most. It is difficult to understand the full consequence of our reliance on our the structure, processes, and functions of our environment not only because we are in a society where we are disconnected from ecosystems directly, but also because we do not fully understand exactly what makes ecosystems work.

What does infiltrate every aspect of our daily lives is money, and one way ecological economics place ecosystems into context is by translating their function into the more common language of economics—much in the way mathematicians use word problems to demonstrate complex theorems. The pith in ecological economics is that our daily decisions impact the quality and quantity of ecosystem services on which everyone depend for not only basic survival needs but also to maintain the high quality of life that we have come to expect. In Baltimore, Maryland, this means amenities like clean drinking water, a stable and comfortable climate, and a system of beautiful public parks. It is an essential responsibility of governments to manage these on behalf of their citizens, and it is a central interest of conservation organizations to protect the ecosystems that make these possible. Once we grasp the role of governments in protecting ecosystem services, for instance through the environmental impact assessment process, we can frame our ecosystem service assessment to provide the information necessary for those land managers to fulfill their requirements of certain policies.

Through a calculated assessment of ecosystems, we inventory the services provided into the list of ecosystem services that we utilized throughout this assessment. We thusly used land use/ land cover as a proxy for ecosystem services and through GIS we can easily estimate what we may refer to as the total ecosystem services provided by that area. There are many economic rules that explain why ecosystem service value should not be measured in total but is better utilized to estimate marginal changes or rather values that have been normalized to percentages. But, due to extreme variation both in estimating, collecting, summarizing, and applying ecosystem service values it is essential that researchers evaluating ecosystem services effectively communicate the lack of agreement or confidence in the output of assessments. Perhaps the most appropriate way to address this is not a lengthy discussion of sources of error and limitations in techniques—it may be that an adjustment to those techniques themselves more adequately capture and adjust for problems with using a particular metric or method to summarize the array of ecosystem service valuation data currently available. This may mean adopting a standard technique to filter ESV studies for value transfer, normalizing output results to a percentage of ecosystem services value or other economic measures, or utilizing a ranking system similar to Maryland's ecological value or development risk metrics.

As with any science in its nascent stages, direction may seem nebulous. It is crucial to maintain open dialogue within research on concerns, limitations, and insights on the appropriate interpretation and utilization of ecosystem service assessments as a tool for guiding land management decisions. Ultimately, the process of ecosystem service valuation will open up an important line of communication between those interested in an economic bottom line, and those whose goals are long-term ecosystem service conservation.

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