Valuing Maine's Natural Capital

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Background

Ecosystem Services

Functioning ecosystems contribute to human welfare and represent a significant, yet often uncounted, portion of the total economic value of the landscapes we live in.[1] The benefits thus provided—either directly or indirectly--are known as "ecosystem services."[2] They include products such as food, fuel and fiber; regulating services such as climate stabilization and flood control; and nonmaterial assets such as aesthetic views or recreational opportunities.

For instance, a forested watershed might provide valuable benefits to a downstream community,[3] such as regulation of flood peaks (which protects property from destruction), regulation of water for municipal supply (which helps ensure a reliable and regular flow of water), filtration of nutrients and pathogens in the water (which maintains high quality of drinking water supplies), and scenic amenities for recreation and enjoyment (which can be reflected in nearby property values). Urban development of that watershed would result in private market benefits. But it would entail a number of social costs not internalized in that private development decision: either new structural flood controls would have to be built, or downstream property would be destroyed; a filtration plant might need to be built to deal with the increasingly turbid water supply; and consumer surplus would be lost along with the amenity value of the local forest. The ecosystem services framework provides an approach for weighing whether those market benefits might outweigh those social costs.

Ecosystem goods and services occur at different spatial scales. For instance, climate regulation and carbon sequestration are global, while flood protection, water supply, and pollination are local or regional. They also vary with in terms of how directly connected they are with human welfare; services like carbon sequestration are highly indirect, while food, raw materials, and recreational opportunities are far more direct.[4] The 2003 Millennium Ecosystem Assessment[5] places ecosystem services into four categories: provisioning (e.g. food, fresh water, fuel, genetic resources), regulating (e.g. climate, disease and flood regulation), cultural (e.g. recreation, aesthetics, and education), and supporting (services necessary for production of other ecosystem services, e.g. soil formation, waste treatment, and nutrient cycling).

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[1] Wilson, M., A. Troy, et al. (2004). The Economic Geography of Ecosystem Goods and Services:Revealing the monetary value of landscapes through transfer methods and Geographic Information Systems. Cultural Landscapes and Land Use. M. Dietrich and V. D. Straaten, Kluwer Academic**:** 69–94.

[2] Costanza, R., R. d'Arge, et al. (1997). "The Value of the World's Ecosystem Services and Natural Capital." Nature **387**: 253-260, de Groot, R. S., M. A. Wilson, et al. (2002). "A typology for the classification, description and valuation of ecosystem functions, goods and services." Ecological Economics **41**(3): 393-408.

[3] See, for instance Kaiser, B. and J. Roumasset (2002). "Valuing indirect ecosystem services: the case of tropical watersheds." Environment and Development Economics **7**: 701-714.

[4] Wilson, M. A. and S. R. Carpenter (1999). "Economic Valuation of Freshwater Ecosystem Services in the United States 1971-1997." Ecological Applications **9**(3): 772-783, Farber, S., R. Costanza, et al. (2006). "Linking ecology and economics for ecosystem management." BIOSCIENCE **56**(2): 121-133.

[5] Millennium Ecosystem Assessment (2003). Ecosystems and Human Well-Being: A Framework for Assessment. Washington DC., Island Press. Available online at http://www.millenniumassessment.org/en/Framework.aspx.

The process of identifying and quantifying ecosystem services is increasingly recognized as a valuable tool in assessing the allocation of environmental resources. Many approaches exist for integrating the consideration of these services into policy decisions. A popular way of doing so is the monetary valuation of ecosystem services. The economic literature has employed a number of different valuation techniques to estimate these values. Some examples of these include:

- Contingent valuation: uses surveys to elicit "stated preferences," often in the form of "willingness to pay" for a hypothetical or real good, service, or condition
- Travel cost: statistically disaggregates the amount spent on recreational visits to a site to derive a "revealed preference" and estimate the value of that site or some quality associated with it.
- Hedonic pricing: disaggregates that price to reveal preferences among bidders in the housing market.
- Conjoint analysis: presents survey respondents with scenarios composed of different combinations of characteristics; the revealed tradeoffs can then be used to estimate marginal rates of substitution between those characteristics.
- Avoided cost: estimates the potential financial damages avoided by preserving an ecosystem and maintaining its services. For instance, if flood-reducing wetlands were filled, how much damage would result to downstream housing?
- Replacement cost: this is similar to avoided cost, but the assumption is that society would not accept the potential damages resulting from an unregulated system and so would pay for some engineered substitute, like levees, in the case of flood.

There are many obvious advantages to being able to value ecosystem services in dollar terms. For one, social costs or benefits can be directly weighed against competing market opportunities in a cost-benefit framework. In other words, cost-benefit analysis, which normally fails to include any significant costs to the environment, can now incorporate some environmental considerations. This approach recognizes that there is an opportunity cost associated with natural capital, and that its loss comes at a price to society. We may never know that price with full accuracy, but assigning some value to natural capital is clearly more accurate than assigning none, as is currently the norm.

On the other hand, valuation comes with a number of significant limitations. If valuations are greatly underestimated, then use of a cost-benefit analysis will lead to false conclusions. In this case, it would have been better to simply attempt to balance tradeoffs using some other non-monetary values framework.

This danger of undervaluing nature in an economic framework is underscored by the fact that market values vastly easier to derive than non-market ecosystem service values—hence, much more work must be done to "prove" that nature is worth something in this framework. Consequently, the fewer the available resources to derive that "proof," the derived values of nature will likely be smaller. This high cost comes from the fact that large amounts of data are needed and the time and expense involved in valuation can be considerable. And even when data are available and funding is not an issue, some ecosystem services—those can be valued with avoided or replacement cost methods in particular-- are simply much easier to value than others.

Among the most difficult services to value are those that involve non-use values, including existence or option values—the former referring to the value that people have simply knowing a place exists, even if they do not directly benefit from it or ever plan to "use" it, and the latter referring to the value of keeping a place unimpacted so that it could potentially result in future benefits. This is a particularly important issue for more remote wild areas that do not have direct connectivity with beneficiary populations or that do not receive much visitation. Society recognizes that these remote places are valuable and important, yet if we only relied on non-market use values, they would be highly undervalued. This difficulty in monetizing intangibles suggests that alternate forms of input are needed for characterizing some types of ecosystems where benefits are less easily quantified.

Another commonly cited critique relates to applying marginal valuation analysis to areas that are too large for marginal analysis—that is, in cases where the area being valued is so large that prices of natural capital cannot be assumed to be exogenous, or uninfluenced by the supply of remaining ecosystems. Put another way, in evaluating ecosystem service values across large areas (like a continent) where the aggregate value represents the willingness for consumers to be compensated for the loss of all the natural capital in the study area, this would imply a significant shift in the supply and hence the shadow price of all types of natural capital. This was a critique leveled against the landmark 1997 *Nature* paper by Costanza et al., where the authors tried to value the natural capital of the whole earth.[6] However, economists have argued that analysis can be considered "marginal" and price functions can be assumed to be constant for more contained areas.[7] We consider Maine to be sufficiently contained for this purpose.

Hence, valuation is fraught with some limitations and pitfalls. Yet, if used carefully and caveated transparently, it can provide an extremely useful tool to natural resource managers that can complement existing management decision frameworks.

Maine is an excellent location to assess ecosystem services. It contains vast areas of woodland, inland waterway, and wetland, as well as extensive coastline. The Gulf of Maine is among the most biologically productive offshore areas in the United States, supporting immensely important fisheries. Maine is also tremendously important for its recreational and aesthetic resources. Its lakes, beaches, woods, and bays draw countless visitors and have led to a thriving second home market. While Maine contains no large cities, it is urbanizing in the south and the coastal region is populated almost throughout, meaning that large numbers of coastal residents depend on ecosystem services, like flood protection.

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[6] Pearce, D. (1998). "Auditing the Earth." Environment **40**(2): 6.
[7] Palmquist, R. (1992). "Valuing localized externalitities." Journal of Urban Economics **31**(1): 59-68.

The Spatial Value Transfer Methodology

Undertaking original valuation studies at the policy site can be extremely costly and take years. Because of this, a common practice is to use valuation estimates generated in other research sites which are contextually similar to the policy site. This approach of appropriating information from a study site for use in a policy site is known as “value transfer,” or “benefits transfer.” This method involves the adaptation of existing valuation information to new policy contexts where valuation data is absent or limited, using valuation estimates from the established literature.[8]

For ecosystem service valuations (ESVs), this involves searching the literature for valuation studies on ecosystem services associated with ecosystem types (e.g. forests, wetlands, etc.) present at the policy site. Value estimates are then transferred from the original study site to the policy site based on the contextual similarity—both biophysical and socio-economic. It is important that the studies from which valuation multipliers are obtained for transfer are from contexts that are as similar to the policy site as possible.[9] This means that not only must there be similarities in the ecosystem type being valued (e.g. wetland), but ideally, there is also similarity in contextual factors such as climate (e.g. temperate vs. tropical), local supply/scarcity of the ecosystem type in question, and characteristics of the beneficiaries (e.g. city versus small town).

Value transfer is a popular method for a number of reasons. Most importantly, it is low cost, making ecosystem service assessment available to managers who might otherwise be unable to afford primary data collection. It is also popular because it can be done in a spatially disaggregated, in which case estimates of ecosystem service flow value (typically measured in dollars per hectare per year) can be summarized by geographic units, such as by watershed or parcel. Such information can be valuable in planning applications.

Like with valuation in general, though, value transfer has many limitations that must be considered whenever it is applied. First, unlike with more sophisticated dynamic spatial models, it only considers total amount of an ecosystem type without considering its spatial arrangement. This is important because ecosystem processes depend not just on the amount of an ecosystem type, but on its spatial pattern.[10] For instance, two landscapes may have the same area of forest, but in one that forest might be in one big patch, allowing for more interior species, while in another, it might be highly fragmented into many small patches. Value transfer also does not account for the relationship between the service-providing area and the beneficiaries who consume that service. This method

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[8] Loomis, J. B. (1992). "The Evolution of a More Rigorous Approach to Benefit Transfer - Benefit Function Transfer." Water Resources Research **28**(3): 701-705, Desvousges, W. H., F. R. Johnson, et al. (1998). Environmental policy analysis with limited information: principles and application of the transfer method., Edward Elgar.

[9] Desvousges, W. H., F. R. Johnson, et al. (1998). Environmental policy analysis with limited information: principles and application of the transfer method., Edward Elgar.

[10] Alberti, M. (2005). "The effects of urban patterns on ecosystem function." International Regional Science Review 28(2): 168-192.

cannot easily differentiate between the potential that a particular ecosystem type has to deliver benefits, and the actual benefits it delivers to humans. There are some ways around this, to a limited extent, by defining land cover types in a way that accounts for proximity to beneficiaries, but the relatively limited number of studies that break up ecosystem service values across this spectrum of contextual difference makes this challenging.

Related to this, the paucity of empirical economic valuation studies in the literature is a significant constraint to use of value transfer. In cases where we know of no valuation estimate, we have no choice but to treat the value as zero, even though this greatly underestimates the value of natural systems. So, in many cases we undervalue resources because of a lack of valuation estimates. But in other cases, we might overvalue them because the only valuation studies available are from "higher value" contexts. Likewise, the small number of usable studies means we need to create "lumped" categories which contain a great deal of internal heterogeneity. For instance, a "forest" land cover category necessarily includes both early successional and old growth forests, yet clearly the two yield very different ecosystem service profiles. Rarely would the valuation literature or GIS data be available to make this distinction. Therefore, finding a study that perfectly matches one's need in a particular value transfer context is understandably difficult. Related to this limitation is the fact that so many of these attributes are poorly documented within these studies, if they are documented at all. Most published studies on non-market valuation were not intended for meta-analysis or value transfer, so mining them for the needed attributes is often difficult and requires consultation of ancillary material.

In addition to the relatively limited number of usable studies is the fact that what studies exist are somewhat skewed towards certain services—particularly recreation, aesthetic/amenity, and other cultural services. This has much to do with the fact that economists conduct most of the valuations and economists tend to be more comfortable with studying socio-economic phenomena than biophysical phenomena. Further, the methods for addressing these cultural services are far better established in their literature. That means that value transfer generally underestimates the value of more biophysical services, such as nutrient regulation, soil regulation, disturbance avoidance, water supply regulation, etc. To a certain extent this lack of studies in these areas is due to the fact that they are often valued through accounting methods such as replacement or avoided cost, but these methods are out of favor with many economists, who consider them too simplistic. Further, journals often will not publish these studies because they are considered to have little academic novelty.

Finally, there is the problem of how to properly categorize ecosystem services in a mutually exclusive way that eliminates double counting. The challenge stems from the fact that many services can be defined in different ways that potentially result in overlap between service categories. For instance, should the category "habitat refugium" be its own ecosystem service category or should it instead be counted under end use-services, such as recreational hunting/fishing/birdwatching? Should "water quality" for lakes be included as an ecosystem service category or should it be counted under recreation, since water quality influences recreation? What if it water quality is its own category, but some recreational studies include composite valuations that include elements of water quality values under "recreation?" These questions are complicated by the fact that so much of the literature is vague on the question of exactly which service is being studied and very often the valuations being presented are for a composite set of services that cannot easily be disentangled. In these cases it is critical to be consistent from study to study so that no double counting occurs. These questions are extremely important because what valuation estimates we average together will depend on how we lump or split ecosystem service categories. We must strike a balance between averaging together valuations that are actually complements (e.g. averaging a bird watching recreational study and a canoeing recreational study), and separating out values that are really duplicative.

Despite all these shortcomings, however, value transfer remains a highly useful tool that is necessary in cases where large research funding is not available for primary data development. Hence, its benefits greatly outweigh its liabilities and it will continue to be a commonly applied method until other, alternative approaches become more feasible.

Project Methods

We conducted a spatially disaggregated ecosystem service valuation for the state of Maine using our proprietary Natural Assets Information System™ (NAIS) database along with the spatial value transfer-based methodology outlined by SIG Principal Dr. Austin Troy and SIG Senior Scientist Matthew Wilson in their 2006 article "Mapping ecosystem services values: Practical challenges and opportunities in bridging GIS and value transfer."[11] NAIS consists of a large number of summaries of valuation studies tagged with extensive information about valuation (e.g. value per unit area or household, year of valuation, valuation method used, economic models used, etc.), ecosystem service, land /aquatic types valued, and the location(s) in which the study was performed. These tags allow us to easily write queries to filter and summarize studies. Figure 1 shows much of this information for a single valuation record associated with a particular article.

This project used the following workflow, based on Troy and Wilson's article: 1) study area definition 2) typology development; 3) literature search and updating of Natural Assets database; 4) mapping; 5) total value calculation; and 6) geographic summaries. Steps 2 and 3 are presented together because of their iterative nature.

[11] Troy, A. and M. A. Wilson (2006). "Mapping ecosystem services: Practical challenges and opportunities in linking GIS and value transfer." <u>Ecological Economics</u> **60**(2): 435-449.

Figure 1: NAIS interface showing a single valuation estimate

Step 1: Study area definition

In this step we worked with Manomet to determine the exact boundaries of the study area. It was decided that this would include all of Maine's terrestrial and freshwater resources, in addition to estuarine inlets, as defined by the National Hydrography Dataset.

Steps 2-3: Typology development and literature search

We first developed preliminary typologies for land cover and ecosystem services for the value transfer linkage. This typology was initially based on Maine's MELCD 5 meter land cover layer[12] but alternations to the typology were made to better fit the existing characterizations in the valuation literature. Typical land cover classifications do not adequately consider socio-economic context (e.g. urban forest vs. non-urban forest), which is critical in value transfer. Therefore, some MELCD classes were lumped, while others were split using ancillary data. Furthermore, many classes given in MELCD were not valued in the literature. Some of the splitting in categories was done to better represent the relationship between the ecosystem and beneficiaries. Because the ecosystem service framework is based on consumer utility, there must be consumers who benefit from the ecosystem or that system's valuation is limited to mere existence value (which we did not include). Some services are global (e.g. carbon sequestration), in which case beneficiary proximity does not matter, but other services are local, and benefits depend on connectivity. Hence, we chose to subdivide several land cover classes into subclasses based on the surrounding population density: namely non-urban, urban and suburban, to account for the fact that, for instance,

[12] Southern Ontario Land Resource Information System. 2008. Ontario Ministry of Natural Resources

wetlands or forests near human communities yield far greater ecosystem services because of the larger number of beneficiaries. Some categories were split off based on biophysical characteristics, such as stream-proximate (riparian) forests vs. all other forests, because studies existed on these distinct sub-categories and because they delivered different values. In cases where a unit of land might be two different classes (e.g. both urban forest and riparian forest), the higher valued class was applied. The Forest: light partial cut/regenerating and Forest: heavy partial cut categories were from the MELCD. Since we do not have direct valuation estimates for forests in these conditions, we simply assumed a reduction in ecosystem service flows proportional to the reduction in canopy for these classes that was reported in the MELCD metadata.[13]

MELCD did not break down water pixel by the type of water body. This had to be done by overlaying that layer with vector layers of lakes, large rivers and estuaries. However, a large number of water pixels were left unclassified following this method, either because of boundary errors between the vector and raster layers, or because certain water bodies were not coded or included in the vector layers. In either case, we called these unclassified pixels "open water: unclassified." Areas with this classification conservatively took the value of open water: river, which is the lowest valued of the water categories.

The final typology is given in Table 1, along with general definitions and the numeric code for each category. Underlined terms in the table are defined at the bottom of the table. More detailed class definitions and descriptions of the data and methods used to create them are given in Appendix 1.

Table 1. Land cover classes

Code	**Class Name**	**Class Description**
11	Agriculture and blueberry	Areas suitable for row crops outside of designated urban areas
12	Grassland/pasture/hayfield	Likely areas for pasture or hayfields, or identified native grasslands outside of urban areas, including recent clearcuts
21	Forest: non-urban	Areas of tree cover located outside of designated urban, suburban, or riparian forests
22	Forest: urban	Areas of tree cover located in designated urban areas
23	Forest: suburban	Areas of forest cover located in designated suburban areas
24	Forest: adjacent to stream	Areas of forest cover located within 30 meters of the banks of 2nd order or greater streams, excluding urban /suburban areas
27	Forest: light partial cut or regenerating	35% reduction in canopy and ecosystem services from Forest: non urban
28	Forest: heavy partial cut	75% reduction in canopy and ecosystem services from Forest: non urban
31	Urban herbaceous greenspace	Herbaceous open space in designated urban areas
41	Open water: river	Rivers designated as areas in NHD
42	Open water: urban/suburban river	Rivers designated as areas in NHD in designated urban or suburban areas
43	Open water: inland lake	Perennial inland lakes and reservoirs
44	Open water: urban lake	Perennial inland lakes and reservoirs in designated urban or suburban areas

[13] http://www.maine.gov/dep/gis/training/melcd/overview.shtml. It reports a reduction in forested area for light partial cut of 20-50% and 50-100% for heavy partial cut. In both cases we took the average of these ranges: 35% and 75%. "Regenerating forest" was its own category, but because no information existed on its canopy area, we lumped it with the light partial cut category.

45	Open water: estuarine	Areas of marine open water defined as estuaries by the National Hydrography dataset; this includes embayments, inlets, and channels with direct ocean connectivity
46	Open water: unclassified	Water pixels that could not definitively be classified as lakes, rivers, or estuarine, using automated methods
51	Wetlands: non-urban, non-coastal	Wetlands, bogs, marshes, swamps, and fens, excluding those in urban/suburban areas and those considered coastal
52	Wetlands: urban/suburban	Wetlands, bogs, marshes, swamps, and fens in urban/suburban areas, including those considered coastal
53	Wetlands: coastal	Wetlands, bogs, marshes, and fens designated as coastal/salt by the National Wetlands Inventory, but not located in urban/suburban areas
61	Beach	Coastal sand dunes both near and not near settlements
95	Alpine	Treeless and tundra cover above elevational or latitudinal limit of boreal forest
99	Unvalued	All remaining types of terrestrial surfaces for which no value is known, plus open ocean and inland waters that were not classifiable
Definitions		
Urban: designated as areas in or within 2km of a Census dissemination area with a population density greater than 386 people/sq km (1000 people/sq. mile) located within a municipality of 50,000+ people. This is based on the US Census definition of an urban area, which includes areas with population density greater than 1000 people/sq mile (386/sq km) located within jurisdictions of 50,000+		
Suburban: designated as areas in or within 5km of a Census dissemination area with a population density greater than 100 people/sq km located within a municipality of 50,000+ people or in a municipality that shares a border with a 50,000+ municipality. The 100 person/sq km criterion was based on an article by Pozzi and Small.[14]		

We also developed a customized typology of ecosystem services for this project. While based loosely on that from the Millennium Ecosystem Assessment, our typology was driven also by the constraints of the valuation literature. The insufficient number of studies and the lack of information in many of those studies required us to lump some ecosystem service categories together. Our list includes the following services: 1)aesthetic and amenity, 2) disturbance regulation, 3) gas/atmospheric regulation, 4) habitat refugium, 5) nutrient regulation, 6) other cultural, 7) pollination and seeding, 8) recreation, 9) soil regulation and 10) water supply and regulation. Direct market values for commodities, such as forest products, commercial fish catches, or agricultural crops were not included here. We do, however, include studies that value inputs to some market good—for instance habitat refugium necessary to support game species or fisheries. In some cases, the line between market and non-market goods can be thin and ambiguously addressed in the literature. For instance, two recreation studies in our database measured benefits that reflect a hybrid of both market and non-market goods[15]. Separating out the market from non-market expenditures in these studies was not possible given the scope of this project, but we felt it was still worthwhile to use these studies.

Once typologies were set, the Natural Assets Information System database was queried to summarize values by service and land cover types, subsetting only the applicable valuation records. The criteria for

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[14] Pozzi, F. and C. Small (2001). Exploratory analysis of suburban land cover and population density in the USA. Proceedings of the IEEE/IEPRS joint Workshop on Remote Sensing and Data Fusion over Urban Areas. Rome, Italy.
[15] Olewiler, N. (2004). The Value of Natural Capital in Settled Areas of Canada, Ducks Unlimited Canada and the Nature Conservancy of Canada.

what to include was discussed with the client. For instance, we determined that we would include studies from temperate areas of central and eastern North America, northern Europe, and New Zealand, as these represent roughly comparable environmental and socio-economic contexts. We included studies where valuations were reported by the authors in the units we use: dollar value per area per year. However, many studies we used did not report in these terms, using instead dollars per household, per trip, per individual, or aggregate value for an entire study area. Where enough information existed, we converted these into a reasonable dollar per area per year figure. Where estimates were reported as a one time stock value, we used a conservative 3% discount rate to convert to yearly flows.

We avoided using studies where the non-market benefit was based on existence or option value—that is where there is no direct use value, but rather an abstract non-use value based on either knowing that some ecosystem exists, or that someone has the possibility of one day interacting with it. We chose not to include these estimates because they are highly controversial among academics and have been noted as subject to significant biases.[16] In particular, it has been found that respondents to non-use value surveys can be conflicted in assigning dollar values to concepts they hold in a non-quantitative ethical framework, rendering them unable or unwilling to monetize meaningful existence values.[17] This difficulty in monetizing intangibles suggests that alternate forms of input are needed for expressing the societal value of more remote areas.

One particularly difficult challenge we faced in our analysis was how to deal with the valuation of atmospheric carbon sequestration, which we classify under “atmospheric regulation” in this study. There are literally hundreds of studies that have attempted to put a social cost value on each ton of atmospheric carbon, with widely diverging results. Rather than include all these studies in the database, we used an existing meta-analysis of 211estimates of the social cost of a ton of carbon written by Tol[18]. We used the mean of all the peer reviewed studies from Tol’s meta-analysis, based on a Fisher-Tippet Probability Distribution Function, which accounts for strong right-tailed distributions. This value was $71/ ton (the number is $127/ton when non-peer reviewed studies are also included). To go from a social cost per ton of carbon to a per hectare ecosystem service value for carbon sequestration for forests, we then use a well-established study by Birdsey[19], which

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[16] Boudreaux, D., R. Meiners, et al. (1999). "Talk is cheap: The existence value fallacy." Environmental Law 29: 765-810.

[17] See for instance Stevens, T. H., J. Echeverria, et al. (1991). "Measuring the Existence Value of Wildlife - What Do Cvm Estimates Really Show." Land Economics **67**(4): 390-400.

[18] This comes from two similar studies published in different venues by the same author: 1) Tol, R. S. J. (2008). "The Social Cost of Carbon: Trends, Outliers and Catastrophes." Economics: the Open-Access, Open-Assessment E Journal **2**(25): 1-24. And: Tol, R. S. J. (2011). "The Social Cost of Carbon." Annual Review of Resource Economics, Vol 3 **3**: 419-443.

[19] Birdsey, R. (1992). Carbon storage and accumulation in United States forest ecosystems. General Technical Report-WO-59. U. F. Service. Washington, DC, USDA Forest Service. **General Technical Report-WO-59**.Another source of information that is consistent with this figure is Jenkins, J., P. Murdoch, et al. (2008). Measuring and monitoring forest

estimates yearly sequestration rates of a hectare of North American forest at 1.4 tons per year, or 0.56 tons per acre per year. This average sequestration rate plus the social cost per ton then allows for the estimation of a value per acre for this ecosystem service. We assumed that all forest types in our typology sequester equally. While forest carbon sequestration rate clearly does vary based on factors like forest type, size class, and successional stage, we simply did not have the geographic data to make these distinctions. Overall, we believe this approach represents a very conservative estimate of the value of carbon sequestration.

The vast majority of the studies used in this project are from peer-reviewed journals, but a small number of “gray literature” studies were included where we felt the studies were of sufficient quality and would fill important gaps. We also use almost entirely primary studies in the database. One notable exception is the secondary study by Olewiler.[20] Olewiler’s estimates came from a different study and the text of that study could not be obtained, so we cite Olewiler although the information contained is secondary. However, we felt it was important to include these estimates because they were from relatively comparable contexts in Ontario and Prince Edward Island.

Valuation estimates in NAIS are recorded in a large number of different currencies and currency years. For each valuation estimate we input a conversion to US dollars from that year. We then inflated the converted dollar value to 2011 US dollars using the consumer price index.

Steps 2 and 3 are presented together because there is an iterative nature to the development of the literature database and the land cover typology. Hence, the two steps happen in tandem. If valuation studies are found for a particular ecosystem type not already in the typology, and the GIS data needed to map that type were available, then that class was added to the typology.

Step 4: Land Cover Mapping

Once the typology was finalized, we created a raster map based on that typology and reported the areas by category. A detailed description of the steps used to create each class is given along with class descriptions in Appendix 1.

Step 5: Value Calculation

We first cross tabulated per acre ecosystem service value flow estimates by land cover type and ecosystem service. For each value in this matrix, we use a conservative “average of averages” approach where we average the high and low estimates, producing a single point estimate for that study, then averaging the

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carbon stocks and fluxes. In: The Delaware River Basin Collaborative Environmental Monitoring and Research Initiative, Gen. Tech. Rep. NRS-25. P. Murdoch, ed. Newtown Square, PA, US Department of Agriculture**:** 32-40.

[20] Olewiler, N. (2004). The Value of Natural Capital in Settled Areas of Canada, Ducks Unlimited Canada and the Nature Conservancy of Canada. Also: Wilson, S. (2008). Ontario's Wealth, Canada's Future: Appreciating the Value of the Greenbelt's Eco-Services. Vancouver, BC, David Suzuki Foundation.

study values by land cover and ecosystem service category. In other words, for ecosystem service-cover type combinations with multiple studies, we take an average of all these averaged values as the final value for that cover type. While this method accounts for the effects of very high or very low value estimates, it can average very high or low values up to twice, producing a more conservative value estimate. For the forest: light partial cut and forest: heavy partial cut rows, the values were derived by multiplying the forest: non-urban values by the average tree cover percentage in these categories (65% and 25% respectively).

Total ecosystem service flow value was estimated in aggregate and broken down by land cover type and ecosystem service. To get ecosystem service value flows by land cover, we use the following equation.

$$V(ES_i) = \sum_{k=1}^{n} A(LU_i) \times V(ES_{ki})$$

Where $A(LU_i)$= area of land cover type (i) and $V(ES_{ki})$= annual value per unit area for ecosystem service type (k) generated by land cover type (i). Total ecosystem service value can be derived by adding up the values for all land cover types.

A table was produced that cross-tabulated ecosystem service value by both land cover and ecosystem service type. A similar table was created that gave the number of valuation estimates used for each ecosystem service-land cover type combination. In some cases, a given valuation estimate was entered repeatedly if it applied to multiple land cover types. For instance, a particular carbon sequestration value (atmospheric regulation) would apply equally for both urban forest and non-urban forest, so that value would be entered once for each land cover it applied to.

Step 6. Geographic Summaries

First, we created a continuous raster map of ecosystem service value for the state summarized at the 180 meter pixel scale (approx. 8 acres each). Ecosystem service values were determined for each grid cell by first assigning a value per hectare to each constituent 5 meter grid cell from the original land cover typology map, then summing those values for all 5 meter pixels within a 180 meter pixel. We then summarized land cover type and valuation estimates by both county and HUC-10 watershed boundaries using the Arc GIS Tabulate Areas function. The output of this is a table where columns give cover type, rows give geographic units and cells give areas. Using a looping model built in Arc Model Builder, these areas were then multiplied by the per area value multiplier for each cover class, and then summed to yield a total estimated ecosystem service value flow and average per acre service flow. We then produced maps of both total and per acre values for watersheds and counties. Finally, similar maps were made at the parcel level for the Sebago Lake district.

Project Results

Figure 2 gives a map of the land cover typology. Table 2 gives the number of valuation estimates cross-tabulated by ecosystem service and land cover types. There were a total of 87 individual studies and 202 valuation records used. As mentioned above, the number of valuation estimates is distinct from the number of studies referenced, because many studies contain multiple valuation estimates. In this table, the count of valuations is mutually exclusive within rows (i.e. the same valuation record cannot be used twice for two different ecosystem services applying to the same land cover type, which would be double counting), but not across rows (i.e. a particular valuation estimate can apply to two or more land cover types in cases where the valuation estimate applies to a general type, like "forest," but classes are more specific, like "riparian forest"). As can be seen, there are a number of gaps in this matrix. Some are because certain ecosystem services may not be provided by a given land cover type. But in other cases this is due to a lack of research. In particular, there is a paucity of valuation studies on regulating services like disturbance, soil and water regulation, as well as supporting services like pollination, relative to cultural services like recreation and aesthetic/amenity value. This is because so much of the research comes from the economic literature, which largely uses economic methods to determine stated or revealed human preferences, and so is biased towards services that humans directly experience.

Table 3 gives the mean ecosystem service value per acre per year cross tabulated by ecosystem service type and land cover type, in 2011 US dollars. Where only one study exists for a cell, only that value is given. The final column gives the total estimated value, summed across all ecosystem services, for each land cover type. Additionally, we generated a complete detailed listing of all individual valuation estimates, broken down by source study and ecosystem service, using a function in the Natural Assets Database. This is given in Appendix 2. Note that valuations for Forest: light partial cut and Forest: heavy partial cut categories are not given in this list because they are simply a discounted version of Forest: non-urban. Appendix 3 has the complete bibliographic list of references. Table 4 gives the area of each land cover class, the average value per acre per year for that class, and the total service value per year of that class for the entire area of that class. The total estimated ecosystem service flow is $14.67 billion per year.

Figure 3 shows average ecosystem service value per acre per year on a continuous raster surface with 60 meter pixels. Figure 4 gives total aggregate ecosystem service value per year by county while figure 5 gives average value per hectare per year by county. Figure 6 and 7 give the same as figure 4 and 5 respectively except they are summarized by HUC-10 watershed. Figures 8 and 9 give the total ecosystem and average per hectare ecosystem service value by parcel for the Sebago Lake area.

Figure 2. Map of land cover typology for Maine

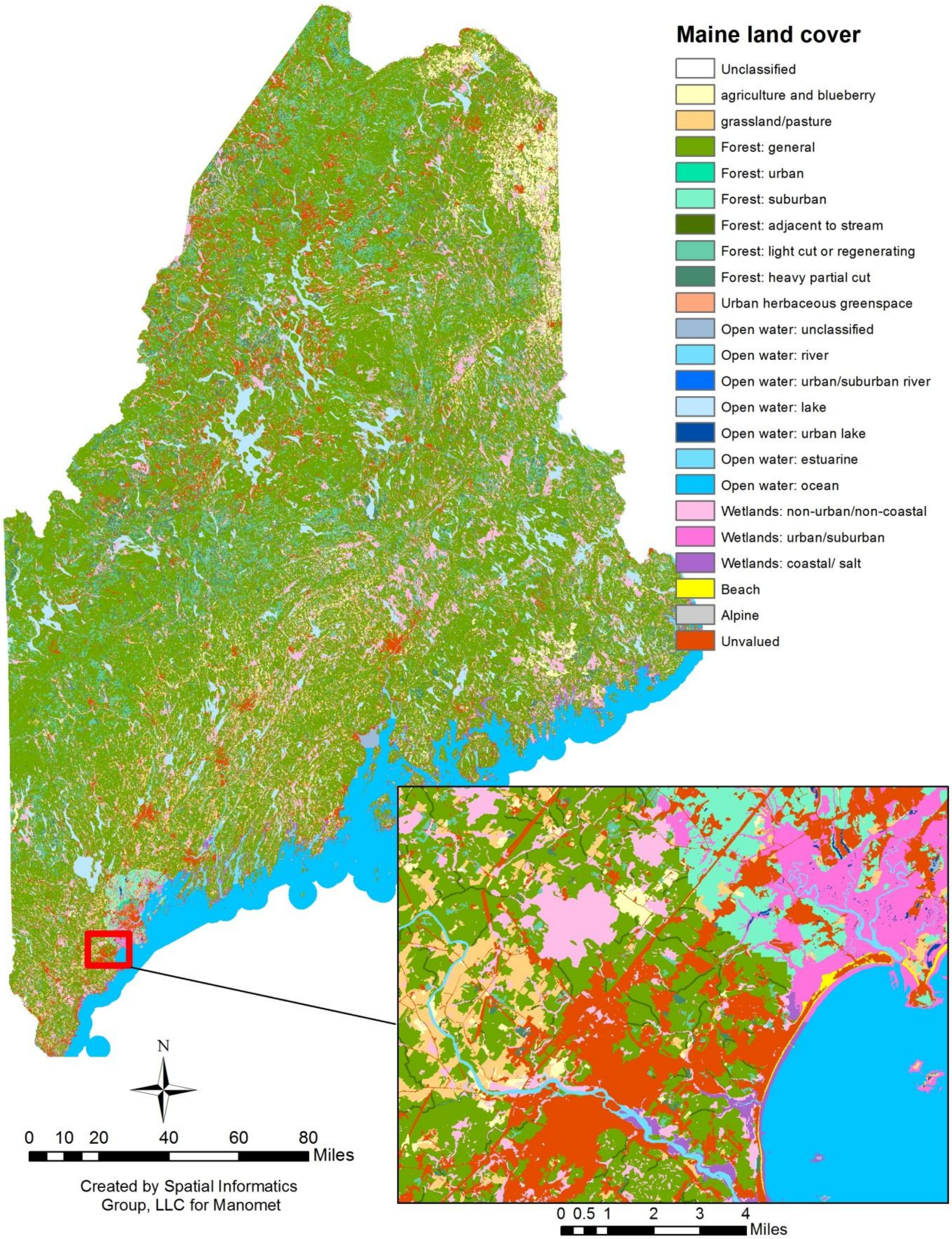


Table 2. Count of valuation estimates by land cover class and ecosystem service

Land Cover Category Name	Code	Aesthetic and Amenity	Dist-urbance Reg.	Gas/ Atmos. Reg.	Habitat Refugium	Nutrient Reg.	Other Cultu-ral	Pollina-tion and Seeding	Rec-reation	Soil Reg.	Water Supply	Total
Agriculture	11			1			5	2	1			9
Alpine	95				1							1
Beach near structure	61	4	2						6			11
Forest: adjacent to stream	24		1	1	4	1			1	1	2	11
Forest: heavy/partial cut	28	same as forest: non-urban										
Forest: light/partial cut	27	same as forest: non-urban										
Forest: non-urban	21			1	2	1	4		12			20
Forest: suburban	23	1		1		1	1		3		1	8
Forest: urban	22			1		1	1	1	7		1	11
Grassland/ pasture	12		1	3	1	1	3		2	2		13
Open water: estuaries/ tidal bays	45	1	2		3	2			5			13
Open water: fresh, unclassified	46	same as open water: river										
Open water: inland lake	43	4				1	1		13			19
Open water: river	41						1		5			6
Open water: urban/ suburban river	42	1				1			5		1	7
Open water: urban/suburban lake	44	5				1	1		4		1	12
Urban herbaceous greenspace	31	2					1					3
Wetland: urban/ suburban (fresh or salt)	52	7	4	1		4	1		2		1	20
Wetlands: non-urban, non-coastal	51	3		1	3	7	1		5			20
Wetlands: salt/coastal	53		1		1							2

Table 3. Average value estimate per acre per year (USD 2011) by land cover class and ecosystem service

Land Cover Type	Code	Aesthetic and Amenity	Dist-urbance Reg.	Gas/ Atmos. Reg.	Habitat Refugium	Nutrient Reg.	Other Cultu-ral	Pollina-tion and Seeding	Rec-reation	Soil Reg.	Water Supply	Total
Agriculture	11			$11			$34	$10	$49			$103
Alpine	95				$7							$7
Beach near structure	61	$57,519	$10,899						$25,382			$93,800
Forest: adjacent to stream	24		$53	$71	$163	$183			$198	$277	$469	$1,414
Forest: non-urban	21			$71	$52	$183	$106		$66			$478
Forest: suburban	23	$1,574		$71		$183	$89		$691		$586	$3,193
Forest: urban	22			$71		$183	$89	$3,246	$5,298		$586	$9,472
Grassland/ pasture	12		$2	$7	$34	$9	$48		$23	$2		$123
Open water: estuaries/ tidal bays	45	$99	$1,734		$30	$18			$160			$2,042
Open water: inland lake	43	$180				$218	$9		$1,211			$1,617
Open water: river	41						$9		$1,173			$1,182
Open water: urban lake	44	$161				$218	$9		$14,775		$568	$15,730
Open water: urban/ suburban river	42	$86				$12,026			$16,034		$568	$28,715
Urban herbaceous greenspace	31	$15,468					$89					$15,557
Wetland: urban/ suburban (fresh or salt)	52	$3,704	$4,167	$5		$1,151	$3,190		$3,531		$17,374	$33,122
Wetlands: non-urban, non-coastal	51	$436		$5	$27	$908	$20		$450			$1,846
Wetlands: salt/coastal	53	$436	$371	$5	$117		$20		$450			$1,399

Table 4. Area, average value per acre per year and total value per year by land cover category

Land Cover Category Name	Code	Pixel Count	Areas (ac)	$/ac/yr (2011)	Total Value Estimate
Agriculture and blueberry	11	84,788,674	523,793	$103	$54,192,541
Alpine	95	1,060,582	6,552	$7	$46,152
Beach	61	111,001	686	$93,800	$64,346,800
Forest: adjacent to stream	24	48,899,354	302,082	$1,414	$427,191,795
Forest: heavy partial cut	28	116,939,337	722,408	$120	$86,397,185
Forest: light partial cut or regenerating	27	287,432,205	1,775,651	$311	$552,138,467
Forest: non-urban	21	1,928,745,901	11,915,087	$478	$5,699,992,133
Forest: suburban	23	10,764,182	66,497	$3,193	$212,342,508
Forest: urban	22	1,109,286	6,853	$9,472	$64,913,291
Grassland/pasture/hayfield	12	85,890,190	530,598	$123	$65,265,117
Open water: estuarine	45	22,150,738	136,839	$2,042	$279,372,916
Open water: inland lake	43	157,937,964	975,683	$1,617	$1,578,105,808
Open water: river	41	16,505,365	101,964	$1,182	$120,552,206
Open water: unclassified*	46	8,332,578	51,476	$1,182	$60,860,160
Open water: urban/suburban lake	44	274,503	1,696	$15,730	$26,678,606
Open water: urban/suburban river	42	95,900	592	$28,715	$16,999,208
Unvalued terrestrial	99	220,065,180	1,359,482		$0
Urban herbaceous greenspace	31	1,246,272	7,699	$15,557	$119,771,788
Wetlands:non-urban,non-coastal	51	385,396,838	2,380,841	$1,846	$4,394,908,075
Wetlands:urban/suburban	52	3,634,414	22,452	$33,122	$743,655,144
Wetlands:coastal	53	3,046,656	18,821	$1,399	$26,330,579
Total			20,907,754		$14,667,458,391
*open water :unclassified is given the value of the lowest open water category, which is river					

Figure 3. Average ecosystem service value per acre by pixel

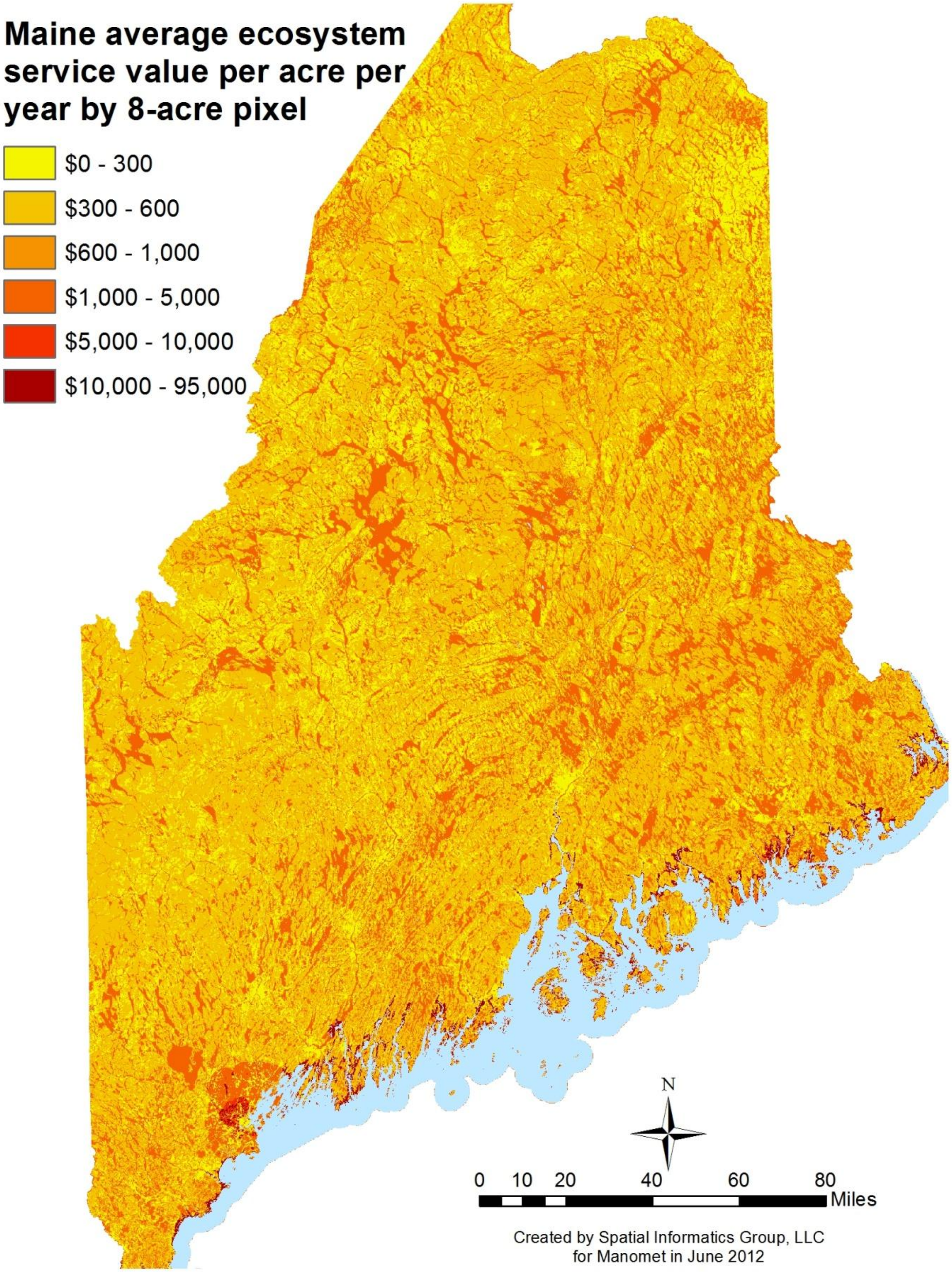


Figure 4. Total ecosystem service value per year by county

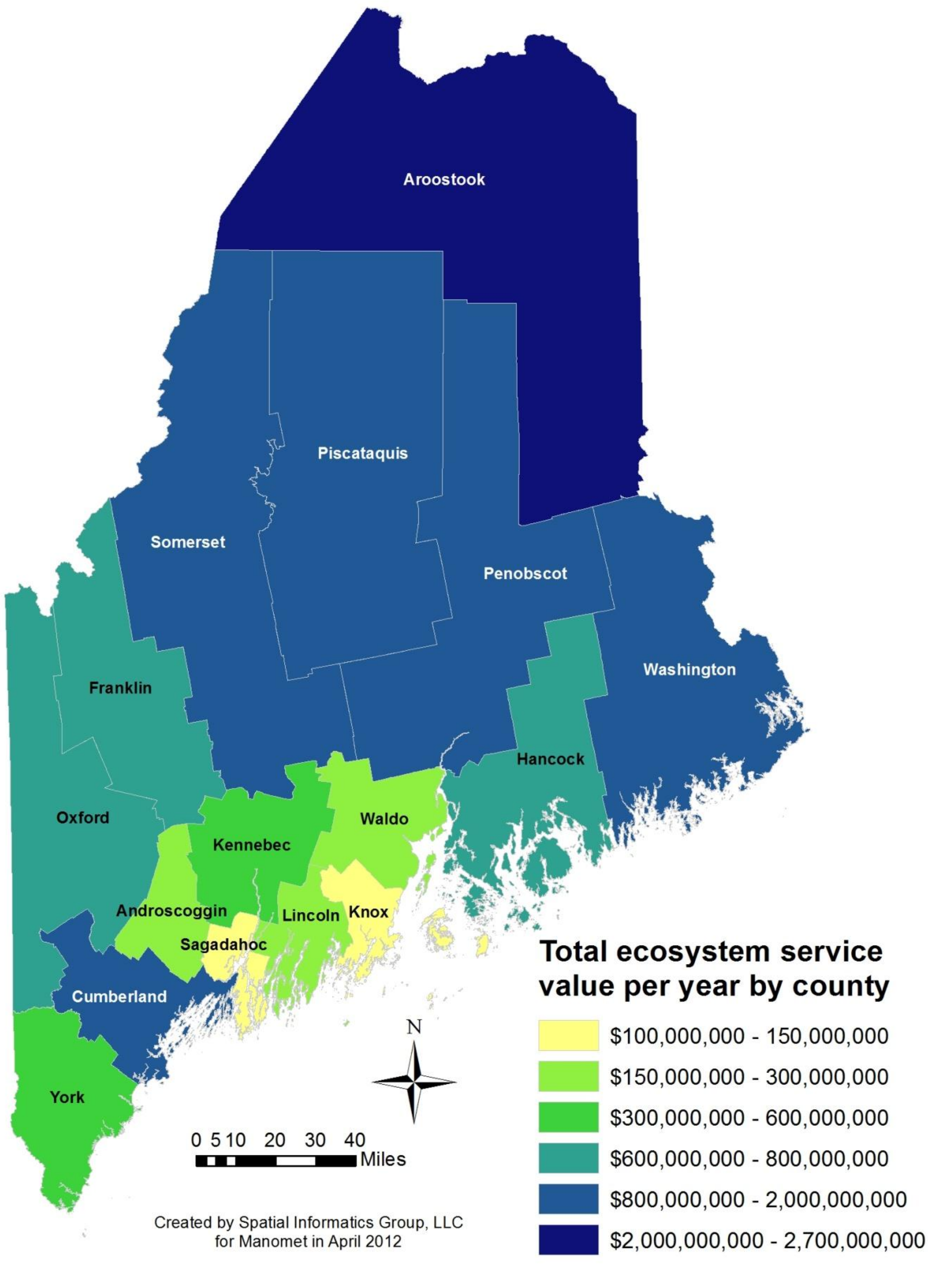


Figure 5. Average ecosystem service value per acre per year by county

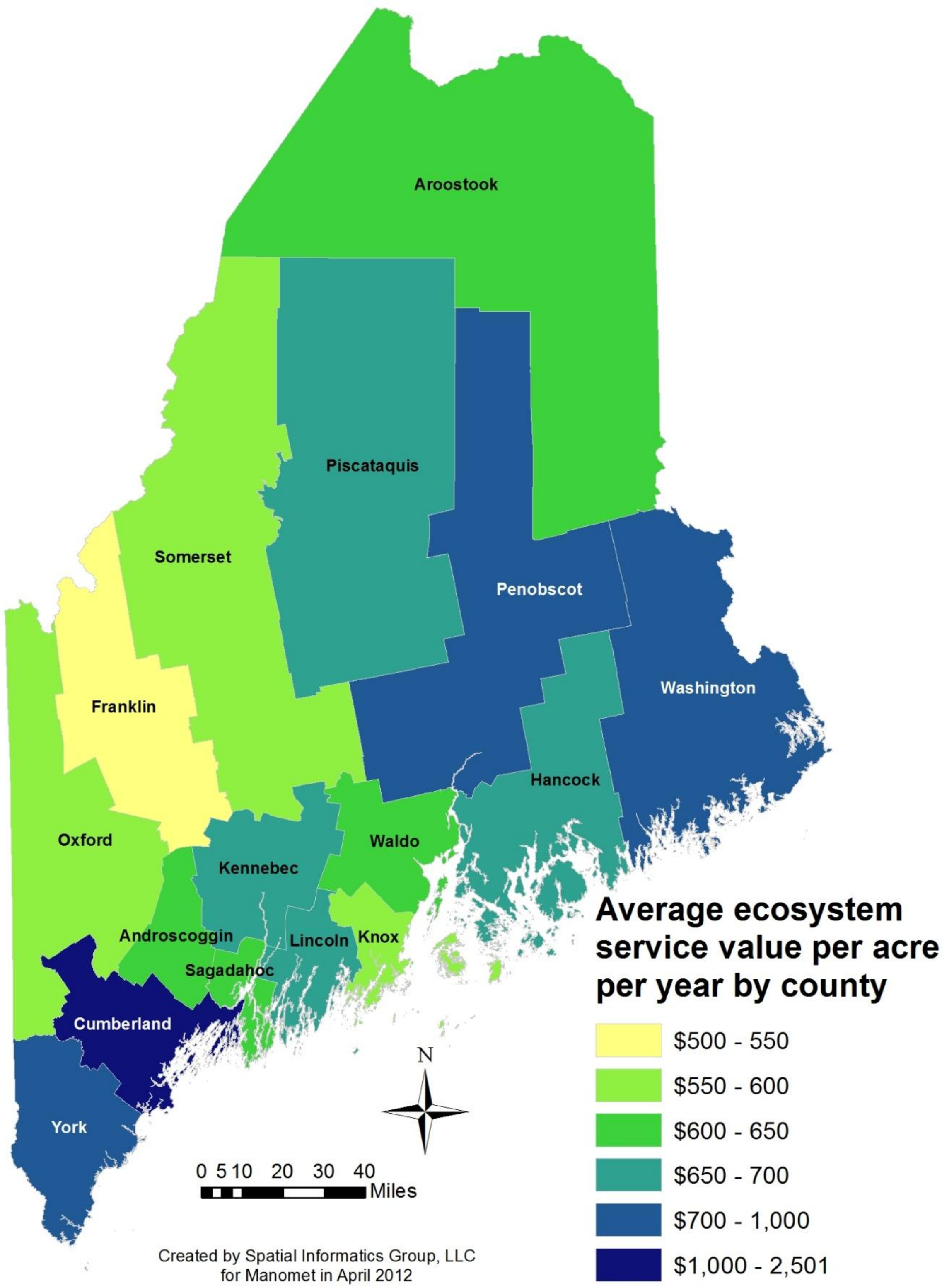


Figure 6. Total ecosystem service value per year by HUC-10 watershed

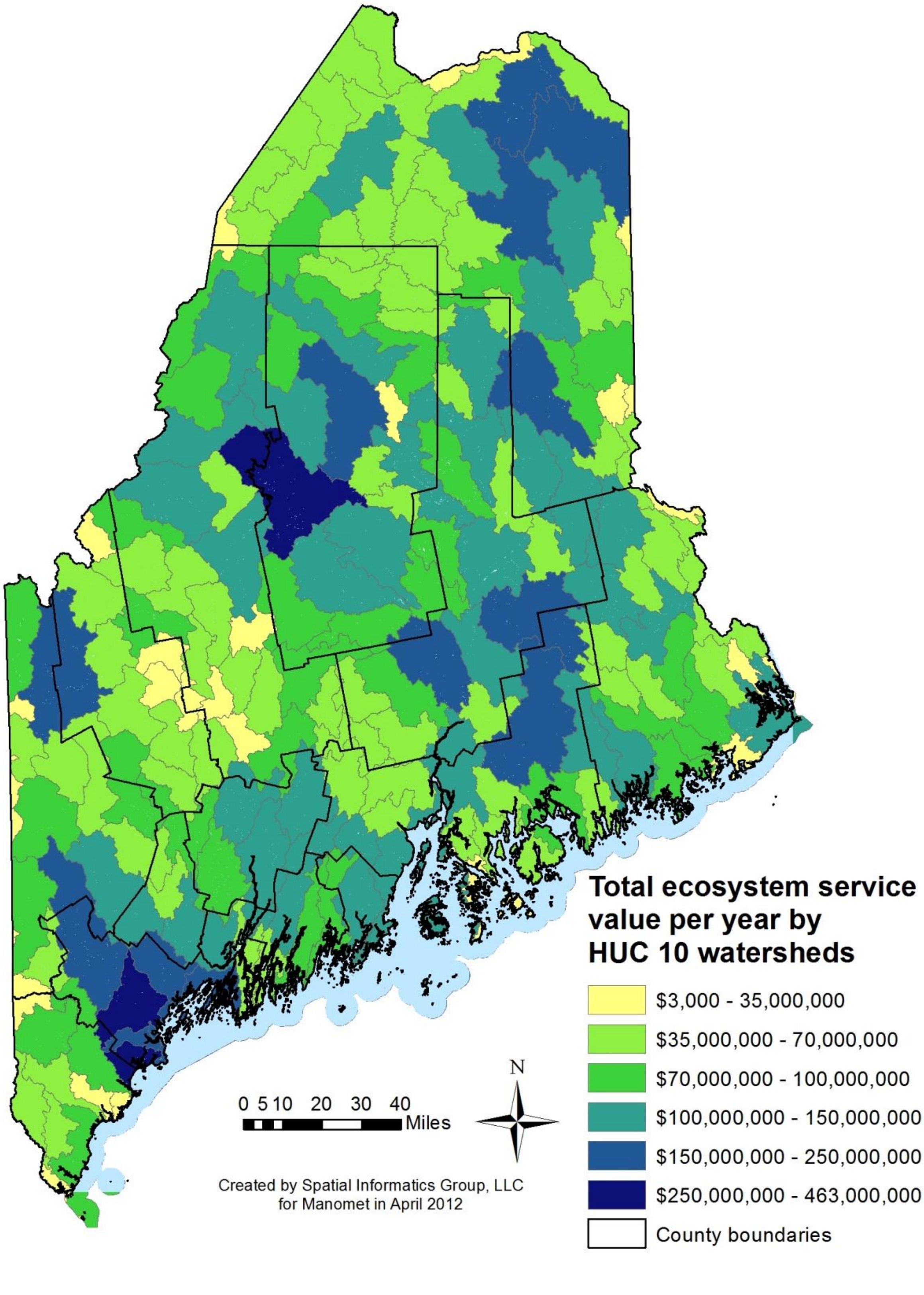


Figure 7. Average ecosystem service value per acre per year by HUC-10 watershed

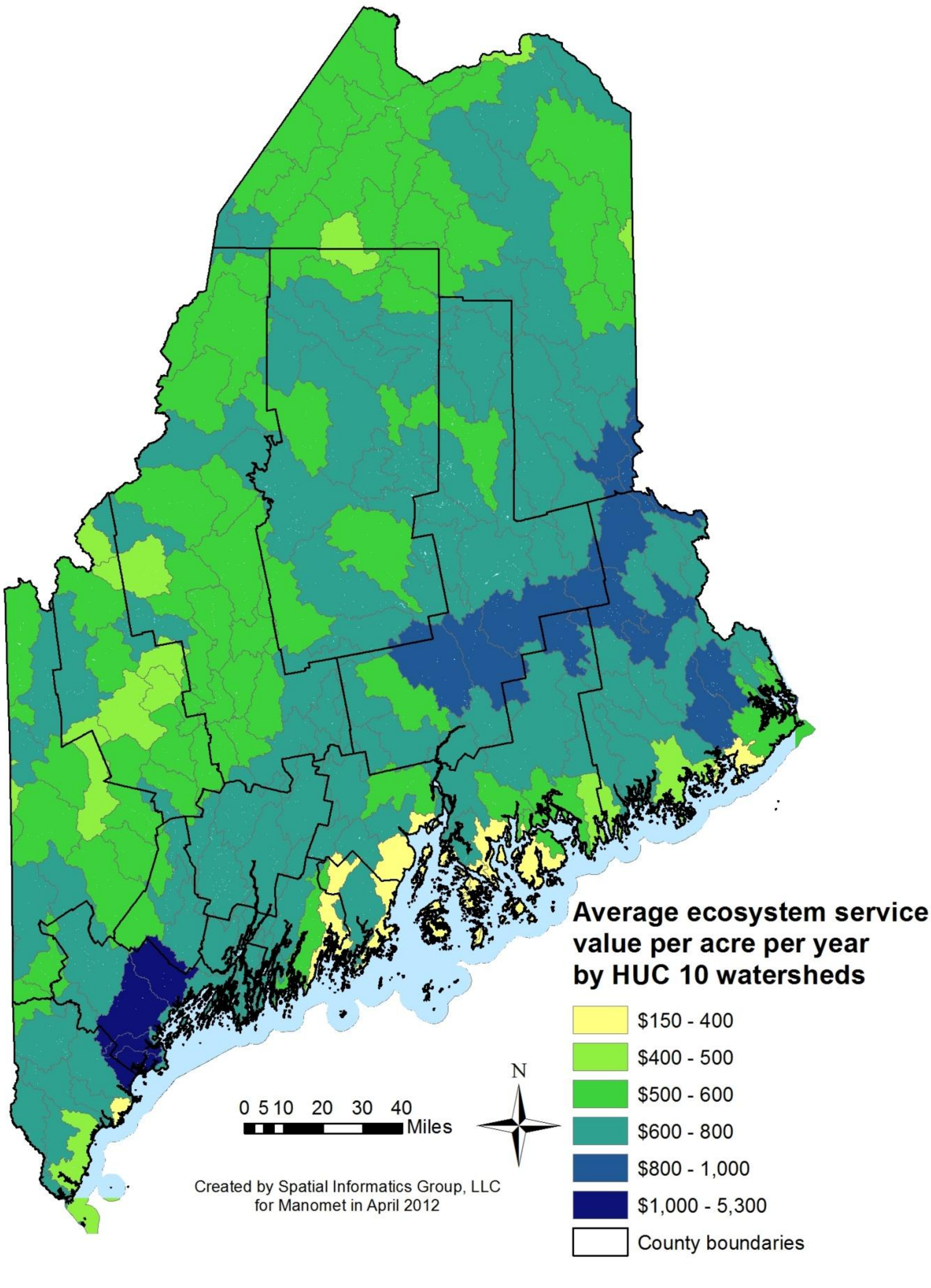


Figure 8. Total ecosystem service value per year by parcel for Sebago Lake area

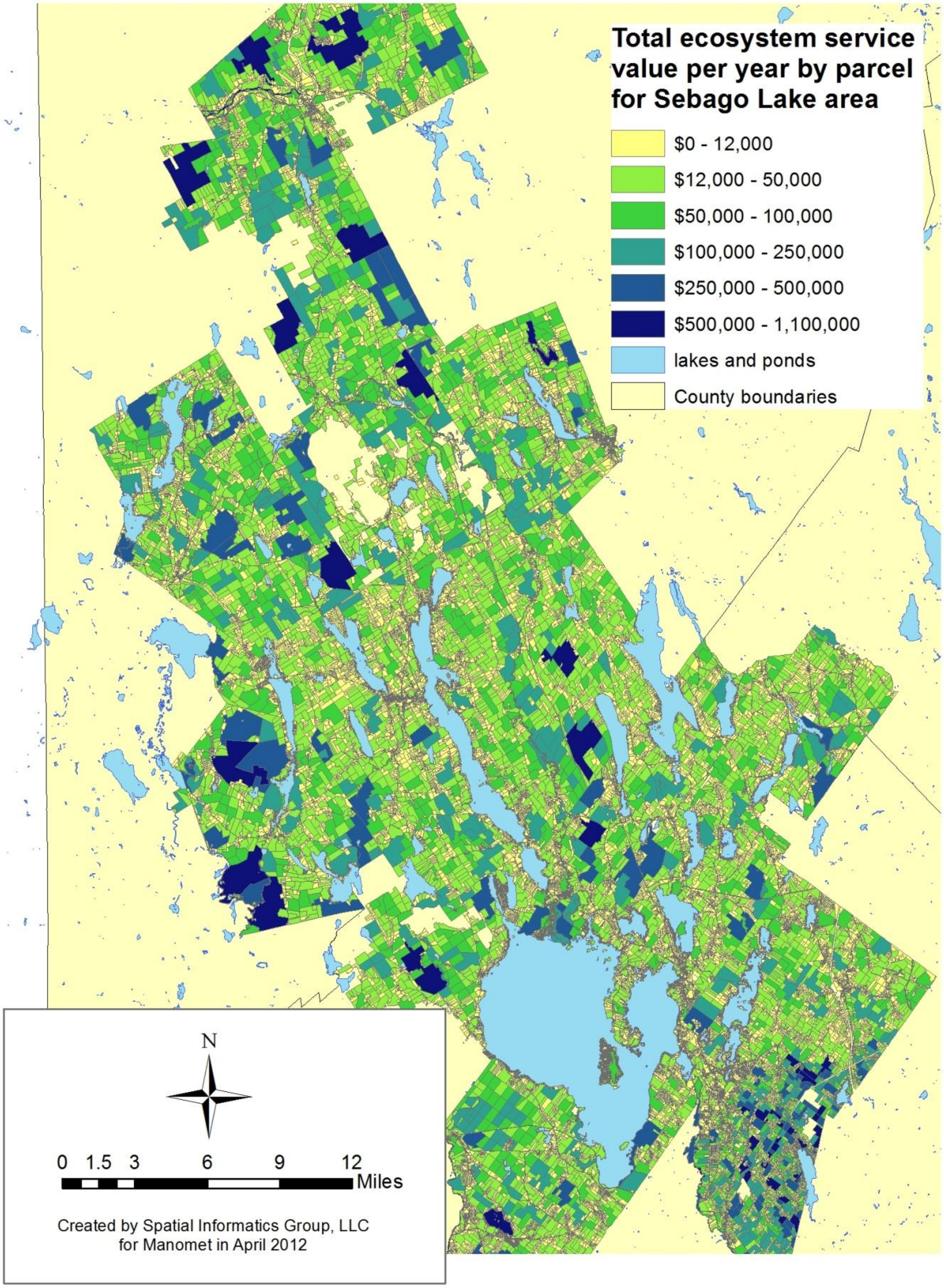


Figure 9. Average ecosystem service value per acre per year by parcel for Sebago Lake area

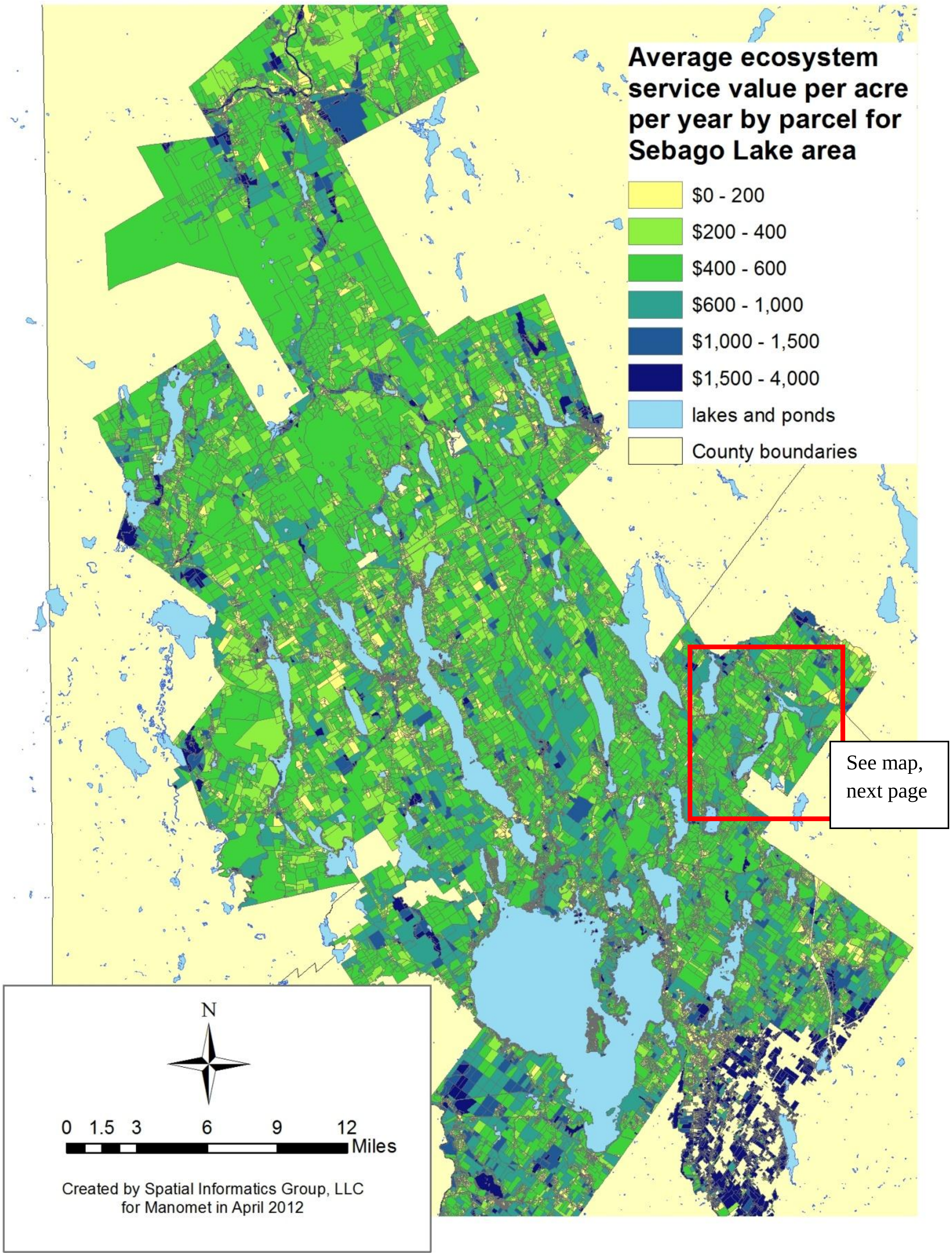
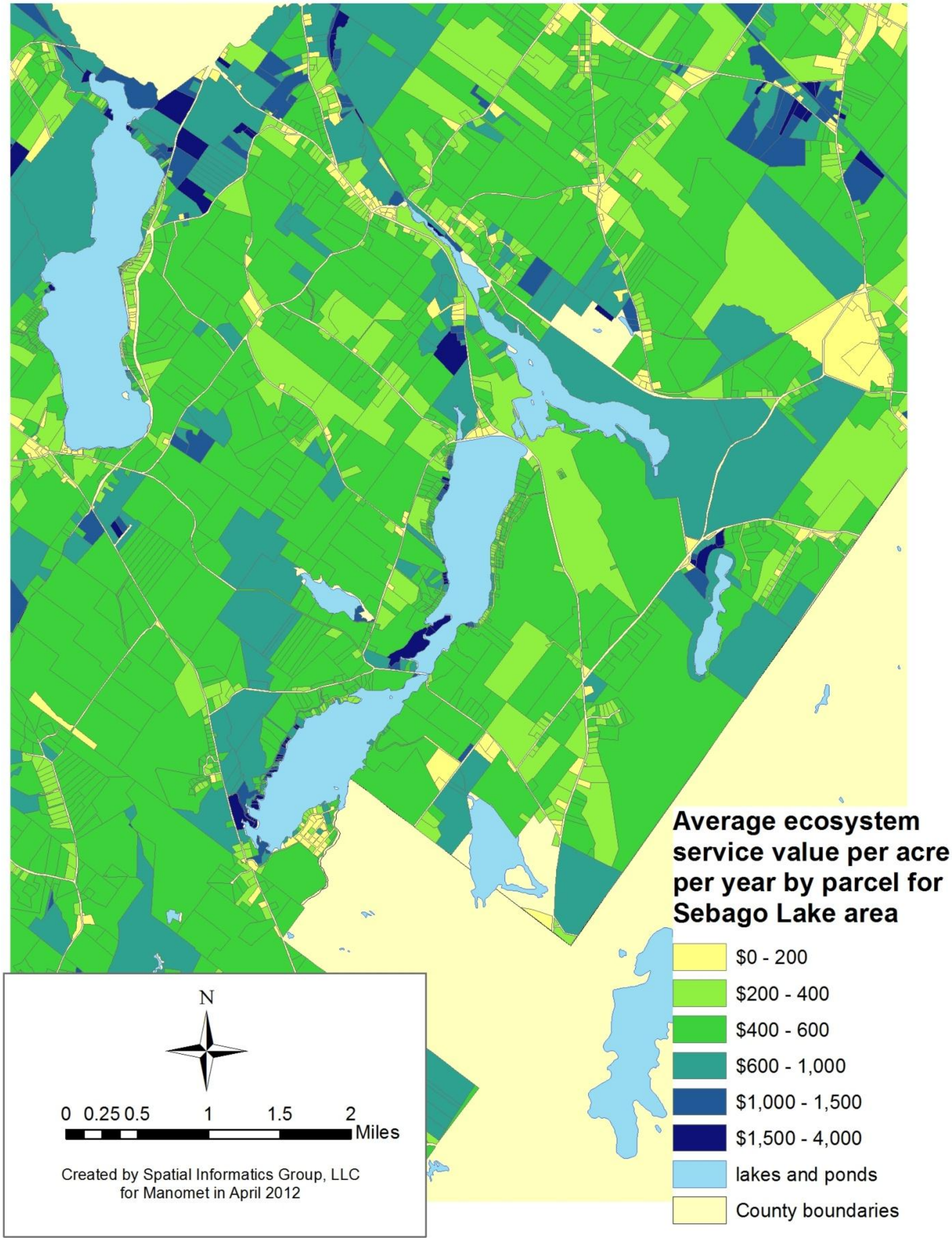


Figure 10. Average ecosystem service value per acre per year by parcel for Sebago Lake area: enlarged view



Discussion

This project generated estimates of the yearly flow of ecosystem service values for Maine as well as maps of the geographic distribution of these values. It estimates almost $15 billion of yearly flow of services emanating from Maine's ecosystems. The figures estimated in this study are probably major underestimates, as many ecosystem services are poorly understood and poorly valued. Hence, these should probably be considered as lower bound estimates. But even as lower bounds, the estimated values are quite high. In particular, the high value of urban-proximate ecosystems is evidenced visually in Figure 5, which shows that the highest valued areas are located just around the greater Portland area.

The patterns that emerge in the map are driven by differences in estimated value per acre. Besides beaches, which had by far the highest value per acre, the highest value cover types were all the urban or suburban types, including rivers, wetlands, forests and herbaceous open space. This is a function of the fact that valuation studies conducted in urban and suburban contexts tended to result in much higher marginal valuation estimates. This is consistent with our expectations, since ecosystems in close proximity to large groups of human beneficiaries should yield larger calculable benefits than ecosystems with only limited connectivity to beneficiaries. An exception to this rule is with carbon sequestration, for it is a benefit that is realized regardless of where the ecosystem is located. Consequently, urban and non-urban locations of the same ecosystem type have the same atmospheric regulation service values. For all areas not designated as "urban" or "suburban" a lower set of values is given for each ecosystem type. The fact that values are greater than zero assumes that there is some population of beneficiaries, but that the number or density of them is lower.

Clearly these assignments of value require a large number of assumptions. They assume that all areas of land classified in the same category are identical. So, for instance, all "non-urban, non-riparian forests" are assumed to be uniform, even though that category certainly contains enormous variation across successional stage, species composition, stand height, and biomass. The lack of valuation estimates on these different dimensions of, in this case, forests, coupled with a lack of GIS data on such characteristics means that such variability simply cannot be taken into account. Further, we must assume a static level of beneficiaries across the non-urban landscape although obviously the distribution of population is highly heterogeneous. Hence, in some remote areas where ecosystems have minimal connectivity with any beneficiary group, values will be overestimated, while in others where larger (but still "non-urban") communities depend heavily on surrounding ecosystems (but they don't meet the "urban" or "suburban" threshold), they will be undervalued. Unfortunately we lack the necessary precision from the literature to further break down our valuation estimates based on finer population density categories.

Within urban and suburban areas we also assume uniformity to the flow of benefits even though the population can vary enormously within these categories. That is, a city like Portland would not be expected to yield the same per acre valuations for an ecosystem as a larger city, like Boston.

Furthermore, the designation of urban and suburban classes does not take into account actual connectivity—rather it is based on a simple buffer distance. In reality, an ecosystem within such a buffer that is assumed to provide, say, a hydrologic service, may be hydrologically unconnected to that urban system, while a much more distance ecosystem located outside the buffer but hydrologically upstream from that community may provide significant hydrologic services to that community. Finally, value transfer is unable to adequately account for the difference in visitation to ecosystems for recreational or aesthetic purposes. Maine's landscape (particularly along the coast) clearly has high touristic value. While we did account for the high recreational value of beaches, our approach otherwise did not account for hot spots of visitation—that is, places where the beneficiaries come to the ecosystem, rather than the ecosystem benefiting those who live in proximity. Doing so would require detailed data on visitation rates.

To properly address the complexities of the relationships between ecosystems and beneficiaries, dynamic spatial modeling[21] would be needed that accounts for the variable provision, flow and consumption of ecosystem services across the landscape, a type of modeling that exists but is much more complex and costly and requires vastly greater amounts of data than we used. In addition to addressing the spatial flow of services, this type of spatial modeling would also help address how spatial pattern of ecosystems impacts the flow of ecosystem services, as has been well established in the ecological literature.[22] Such modeling does not necessarily replace, but can complement value transfer analysis.

The lack of incorporation of existence value (see Methods section above) in this value transfer (and in most ecosystem service valuation), highlights an important gap in this type of analysis. This does not mean we discount the importance of more "intangible" values associated with more remote landscapes, but rather we believe these values are too abstract and subjective to estimate in dollar terms and must be considered in a different framework. If these alternate forms of value are ignored, use of the monetary ecosystem service valuation framework can result in perverse outcomes. For instance, this framework would always show that it is more worthwhile to develop communities in remote areas because it brings beneficiaries in proximity to those ecosystems, thus making them seem more valuable. Clearly, this is not an outcome that natural resource managers are seeking. Yet until existence values can be adequately considered in this economic framework (which may be impossible), it will yield some results that must be taken cautiously. This does not mean that economic valuation should be forgone, but rather that it should be used complimentarily with other approaches.

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[21] See for instance the ARIES framework: Villa, F., M. Ceroni, et al. (2009). ARIES (Artificial Intelligence for Ecosystem Services): A new tool for ecosystem services assessment, planning, and valuation. . 11th Annual BIOECON Conference on Economic Instruments to Enhance the Conservation and Sustainable Use of Biodiversity, Venice, Italy. http://www.ucl.ac.uk/bioecon/11th_2009/Villa.pdf.

[22] Alberti, M. (2005). "The effects of urban patterns on ecosystem function." International Regional Science Review **28**(2): 168-192.

Even for the more quantifiable services that are utility-based, there still is a bias in what is represented in the literature. In general, it is skewed toward studies of recreation, aesthetic/amenity, and other cultural services because it is largely driven by economists and not ecologists. That means that there is almost certainly an under-accounting of the value of more biophysical services, such as nutrient regulation, soil regulation, disturbance avoidance, water supply regulation, etc.

Despite all these shortcomings, however, value transfer can still be an extremely useful decision support tool. It provides a relatively low-cost and intelligible way of summarizing complex information about ecosystems over very large areas. While it is not appropriate as a decision tool for managing individual pieces of land, and certainly should never be used as a tool to justify that a natural areas is "of little value," it is an excellent tool for painting a broad-strokes picture of large landscapes and identifying areas where there is a high likelihood of critical ecosystem service delivery. It is particularly helpful in watershed management, as it can help identify watersheds and sub-watersheds that provide important hydrologic services. In other words, it points to where more detailed research and data collection should focus and where alteration of the landscape is likely to have the highest negative impact. It also can help identify areas where wide-scale restoration investments might be justified.

If budgets allow, primary valuation research should always be the preferred strategy over value transfer for quantifying the value of ecosystem goods and services. In Maine, for instance, this would involve studying land values or stated preferences to better account for its unique coastal aesthetics and its marquis value as a tourist destination. It would also involve doing detailed accounting and engineering studies of water supply or flood control systems to determine the avoided and replacement cost values of preserving forests, riparian areas, and wetlands upstream from communities. Such research would result in very precise, location-specific estimates of the value of at least some ecosystem services. However, given how expensive primary studies can be (particularly for a suite of ecosystem services or ecosystem types), the value transfer method represents a cost-effective "second-best" strategy and a starting point for more detailed study. While value transfer is far from perfect, we believe that it is better than the status quo approach of assigning a value of zero to ecosystem services.

How, then, can the results of value transfer be used as a tool in management decisions? At the simplest level, managers can use the resulting data and maps to visually assess patterns in the landscape. Or, using more sophisticated overlay analysis, queries could be run to identify high ecosystem service value areas where the proportion of protected land is low or where the threat of degradation is high. This in turn could be used to help prioritize lands for conservation and acquisition. Results could also be used to help inform investments in ecological restoration. Simple simulations could be done to estimate the return on investment for large-scale restoration projects. Results could also potentially be used to inform traditional cost benefit analyses.

But perhaps the greatest utility of value transfer comes as a component of policy scenario analysis. Value transfer easily allows inputs to be changed to represent hypothetical conditions, expressed with different land cover. The bottom line ecosystem service value under this hypothetical condition can be easily compared to actual baseline conditions. For instance, this framework could be used for scenario analysis in municipal land use planning to assess the hidden costs associated with buildout projections under different zoning and planning scenarios. This would allow policy makers to look not only at predicted aggregate changes in welfare, but also at the spatial distribution of these effects under each scenario. Another example would be evaluation of policies with wide-ranging effects, like reductions to the minimum width of streamside protection buffers. GIS analysis could simulate how development might then eat away at those ecosystems, allowing the two conditions to be compared. Or, it could be used to assess the benefits of land acquisition by comparing ecosystem service flows under baseline conditions to a hypothetical condition where the areas under contention are represented as developed.

To date, the ecosystem services framework has had little impact on actual public decision-making. Among the few fledgling efforts at integrating ecosystem services into public policy are Costa Rica's payment for ecosystem service (PES) scheme in which the government pays private landowners to not cut down rainforest or to undertake reforestation. This system gives financial incentives for land management that promotes four services: greenhouse gas regulation (sequestration), hydrological services, biodiversity protection, and scenic beauty. Private owners of forested land are given payments over five years but relinquish "ecosystem service rights" over a 20 year period under an easement. This program is funded by a tax on fuel as well as the sale of carbon offsets and hydropower credits. However, all forests are treated the same for payment purposes regardless of composition and prices paid are not based on ecosystem service valuation, but rather on opportunity cost. Today nearly 300,000 hectares are registered in this program and the country's deforestation rate has dropped significantly, but most of this drop in deforestation has been attributed to land conservation and not to the PES scheme.

The closest program to this in the US is the USDA's Conservation Reserve Program, which pays farmers on environmentally sensitive land to keep that land out of intensive production but, again, payments are not based on ecosystem service values. A slightly more sophisticated PES program is under development in Lombok, Indonesia, where the World Wildlife Fund is working with the government to develop a system where upland forest owners get paid not to cut down the forest by downstream agriculturalists. There are other examples of policies designed to manage for single ecosystem services—most notably carbon forest offset regulations. In this scheme, landowners get a payment for reforestation, based on the market price of carbon which, in theory, should reflect its social cost.

Despite this peripheral use of ecosystem service-based concepts, there are no good examples of governments using valuations of the whole suite of ecosystem services to help assess tradeoffs and inform policy. Nonetheless, there is strong interest in moving in this direction among many in government. Currently, various federal agencies including the Environmental Protection Agency, US Geological Survey and US Department of Agriculture have established offices or task forces to better integrate consideration of ecosystem services into agency procedures and policies (an example is the USDA's Office of Environmental Markets), but these initiatives are generally under-resourced and have yet to see tangible outcomes in public policy. And, in Canada, the Ontario Ministry of Natural Resources has been conducting extensive research on how ecosystem services could be factored into natural resource management decisions. In other words, we are at a critical phase now in which decision makers are assessing whether this framework actually meets their needs.

In Maine, there is much potential for the use of an ecosystem services framework given how extensive, diverse and important its ecosystem are. Not only is its landscape covered with vast acreages of forests, lakes, wetlands, and coastlines, but its primary industry is tourism, at nearly $10 billion per year in sales of goods and services and $270 million in sales tax revenue from this source.[23] A 2001 survey found that ecotourism rates in Maine were nearly twice the national average and that "the natural environmental, and related outdoor recreation activities were key defining interests or components of Maine trips."[24] This study also found that Maine ranked 25th in the nation in terms as a destination for outdoor trips. Hence, preserving this environmental bounty is key not only to maintaining ecosystem services for residents, but also for helping support and grow Maine's biggest industry. In other words, in Maine, protecting these vital ecosystem services also means promoting long term viability of the economy. It is highly recommended that primary studies be conducted to better quantify the unique tourism, recreation and aesthetic value of Maine's landscape. This information could then be used effectively to lobby for environmental protections and to implement schemes that compensate landowners for those types of protection.

Hence, Maine is an excellent place to explore the potential use of ecosystem service assessment and valuation. This value transfer analysis represents one small step which will hopefully lead to more research, collaboration and discussion.

[23] http://umaine.edu/tourism/rural-tourism-opportunities/tourism-and-the-maine-economy/

[24] Maine Office of Tourism. 2002. Travel and Tourism in Maine: 2001 Visitor Study. Presentation. Quote is from slide 133.

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Appendix 1. GIS methods for deriving land cover classes

This document gives a detailed description of each land cover class in the typology with basic descriptions of how GIS data were processed to create them. The MELCD land cover layer was used as the foundation which other classes were built upon. However, a number of other layers were used to incorporate information not in the land cover layer. So, for instance, we developed an overlay showing urban, suburban and rural areas so that we could subdivide forests, wetlands, and rivers based on their context. We also subdivided non-urban forests into those areas in and not in stream buffers. Further, we reclassified many of the existing classes in the MELCD. Finally, the MELCD land cover layer did not differentiate water pixels based on whether they were rivers or lakes. We used polygon overlays to determine which pixels were lakes versus rivers, but many pixels remained unidentified.

11. Agriculture:
    Class description: Areas suitable for row crops outside of designated urban areas. Includes MELCD classes “cultivated crop” (MELCD class 6) and “blueberry field” (MELCD class 22). Created using RECLASS function.

12. Grassland/pasture/hayfield:
    Likely areas for pasture or hayfields, or native grasslands outside of urban areas. Includes MELCD classes “pasture/hay” (MELCD class 7) and “grassland/herbaceous” (MELCD class 8). Created using RECLASS function. Urban herbaceous pixels were later reclassed as “urban herbaceous greenspace” (see 31 below).

21. Forest: non-urban:
    Areas of forest cover located outside of designated urban, suburban (see forest: urban and forest: suburban), riparian or hedgerow areas. Includes MELCD classes “deciduous forest” (MELCD class 9), “evergreen forest” (MELCD class 10), and “mixed forest” (MELCD class 11). Created using RECLASS function.

22. Forest: urban:
    Areas of forest cover as defined above in designated urban areas. Urban areas are designated as areas in or within 2km of a Census block group with a population density greater than 386 people/sq km (1000 people/sq. mile) located within a municipality of 50,000+ people. This is based on the US Census definition of an urban area, which includes areas with population density greater than 1000 people/sq mile (386/sq km) located within jurisdictions of 50,000+. This layer was created by querying for municipalities greater than 50,000 people using the Maine Office of GIS Town boundaries layer (METWP24). Select by location was then used to select block groups inside those towns and a subset of that selection was then made for block groups greater than 386 people/sq km. A 2 km buffer was then made around those block groups using the BUFFER function. The buffer polygon was then combined with the state outline layer

(created by dissolving the block group boundaries layer) using the UNION function and a new variable was created in that layer where “urban” polygons were set to 1 and all others to 0. This was then rasterized at a 30 meter resolution based on this newly created variable. The resulting raster layer had a value of 1 for urban areas and 0 for non-urban.The CONDITIONAL function was used in Raster Calculator to recode all forest pixels overlaying pixels with a value of 1 in the urban areas layer.

23. Forest: Suburban:
    Areas of forest cover as defined in class 21 above that are located in designated suburban areas. Suburban areas are designated as in or within 5km of a Census block group with a population density greater than 100 people/sq km located within a municipality of 50,000+ people or in a municipality that shares a border with a 50,000+ municipality. The 100 person/sq km criterion was based on an article by Pozzi and Small.[1] This layer was created by querying for municipalities greater than 50,000 people using the Maine Office of GIS Town boundaries layer (METWP24). Select by location was then used to select block groups inside those towns and a subset of that selection was then made for block groups greater than 100 people/sq km. A 5 km buffer was then made around those block groups using the BUFFER function. The buffer polygon was then combined with the state outline layer (created by dissolving the block group boundaries layer) using the UNION function and a new variable was created in that layer where “urban” polygons were set to 1 and all others to 0. This was then rasterized at a 30 meter resolution based on this newly created variable. The resulting raster layer had a value of 1 for urban areas and 0 for non-urban. The CONDITIONAL function was used in Raster Calculator to recode all forest pixels overlaying pixels with a value of 1 in the suburban areas layer.

24. Forest adjacent to rivers/streams:
    Areas of forest cover located within 30 meters of the banks of water courses present in ESRI’s 1:100,000 USA streams and rivers layer (note that we had intended to use the National Hydrography dataset, but this contained streams down to a very low order and only part of the state had the necessary data to identify the stream order of particular segments). Used the BUFFER function to buffer river and stream lines, then combined with the state boundary layer using UNION. A new variable was created in that layer where “stream buffer” polygons were set to 1 and all others to 0. This variable was then rasterized. The CONDITIONAL function was used in Raster Calculator to recode all forest pixels overlaying pixels with a value of 1 in the stream buffer layer. If a forested pixel was both adjacent to stream and within an urban or suburban area, it was only counted as urban or suburban. This was controlled by the order in which classes were coded. Hence, urban and suburban forest classes were coded after forest adjacent to stream.

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[1] Pozzi, F. and C. Small (2001). Exploratory analysis of suburban land cover and population density in the USA. Proceedings of the IEEE/IEPRS joint Workshop on Remote Sensing and Data Fusion over Urban Areas. Rome, Italy.

27. Forest: light partial cut or regenerating
    Lightly cut or otherwise regenerating forest with majority canopy cover. Consists of "light partial cut" (MELCD class 24; forests with 20-50% canopy removal between 1995 and 2001) and "regenerating forests" (MELCD class 26) regenerating forests with canopy increases during that period) classes. Created by using the RECLASS function.

28. Forest: heavy partial cut
    Recently intensively cut forest. Consists of "heavy partial cut" class (MELCD class 25).

31. Urban herbaceous greenspace:
    Open grassy and otherwise herbaceous land in urban areas. Similar to class 12 above, but located in a designated urban area. The class was defined using the CONDITIONAL function in raster calculator to recode all pixels with a pixel value of 12 that also overlaid urban areas (see class 22 above for definition of urban layer).

40. Open water: unclassified:
    After all water pixels had been classified to the greatest degree possible with the given data, known water pixels that could not be further classified were lumped in this category

41. Open water: river
    Areas of open water (MELCD class 21) within the banks of wide perennial rivers. Created by selecting all river polygons from the National Hydrography Dataset "areas" feature class. This includes rivers that are wide enough to be represented with double lines (areas) as opposed to single lines (dimensionless). These polygons were then combined with the state outline layer using UNION and a new field was created designating rivers as 1s and everything else as zeros. This variable was then rasterized and the CONDITIONAL function was used to update the land cover layer with this new class wherever there was a value of 1.

42. Open water: urban/suburban river:
    Areas of open water (MELCD class 21) within the banks of wide perennial rivers (see above) that are also located in designated urban or suburban areas. This was created by running a CONDITIONAL function in raster calculator to recode all pixels designated as open water:river that also overlaid pixels designated as urban or suburban (see class 22 above for definition of urban layer).

43. Open water: inland lake
    Areas of open water (MELCD class 21) within perennial inland lakes and reservoirs. Created by selected all lake polygons from the National Hydrography Dataset "areas" feature class. These polygons were then combined with the state outline layer using UNION and a new field was created designating lakes as 1s and everything else as zeros. This variable was then rasterized

and the CONDITIONAL function was used to update the land cover layer with this new class wherever there was a value of 1.

44. Open water: urban/suburban lake
    Areas of open water (MELCD class 21) within perennial inland lakes and reservoirs in urban or suburban areas. This was created by running a CONDITIONAL function in raster calculator to recode all pixels designated as open water:inland lake that also overlaid pixels designated as urban or suburban (see class 22 above for definition of urban layer).

45. Open water—Estuaries and Tidal Bays:
    Areas of open water (MELCD class 21) that are significant marine embayments, estuaries or coves. Created by selecting all estuary polygons from the National Hydrography Dataset "areas" feature class. These polygons were then combined with the state outline layer using UNION and a new field was created designating lakes as 1s and everything else as zeros. This variable was then rasterized and the CONDITIONAL function was used to update the land cover layer with this new class wherever there was a value of 1.

51. Wetlands: non-urban, non-coastal
    Includes freshwater wetlands, bogs, marshes, swamps, and fens not in urban/suburban areas. It was created by selecting all vegetated freshwater wetland polygons from the National Wetlands Inventory data set. This included all wetlands coded as riverine, palustrine and lacustrine. These polygons were then combined with the state outline layer using UNION and a new field was created designating wetlands as 1s and everything else as zeros. This variable was then rasterized and the CONDITIONAL function was used to update the land cover layer with this new class wherever there was a value of 1.

52. Wetlands: urban/suburban
    Wetlands, bogs, marshes, swamps, and fens in urban/suburban areas, including those considered coastal (because of higher valuation estimate). This was created by running a CONDITIONAL function in raster calculator to recode all pixels designated as wetland: non-urban, non-coastal that also overlaid pixels designated as urban or suburban (see class 22 above for definition of urban layer).

53. Wetlands: coastal
    Wetlands, bogs, marshes, and fens designated as coastal but not located in urban/suburban areas. This included all wetlands coded as marine or estuarine that did not have an unconsolidated or rock bottom and were not reefs. Polygons with these codes were selected from the National Wetlands Inventory data set. These polygons were then combined with the state outline layer using UNION and a new field was created designating wetlands as 1s and

everything else as zeros. This variable was then rasterized and the CONDITIONAL function was used to update the land cover layer with this new class wherever there was a value of 1.

61. Beach

    Open and treed sand barrens/dunes located near the coastline. Created using 1:24,000 scale data on surficial geology from the Maine Geological Survey. All quadrangles containing coastline were downloaded and merged. Polygons were selected that were coded as “marine shoreline deposits—sand and gravel on modern ocean beaches,” “marine shoreline deposits—sand to gravel beaches,” “marine shoreline deposits—sand to gravel beaches and associated sand dunes,” “Marine shoreline deposit, beach - Sand, some gravel and minor silt. Coastal settings of active beach construction,” “Marine shoreline deposit (beach) - sand and gravel deposited by marine processes along the ocean shore,” “Dune deposits - Sand dunes adjacent to modern beaches,”” Marine shoreline deposits - Modern beach deposits consisting of sand, pebbles, and cobbles. Formed during the reworking of older surficial sediments by the ocean,” “Marine shoreline deposits - Sand to gravel beaches,” “Dune deposits - Sand dunes adjacent to modern beaches,” and “Marine shoreline deposit (beach) - Sand and/or gravel, and minor silt. Developed along the present coast. 0.5 to 5 m thick. May include sand dunes in places.” These were exported to a new layer and combined with the state outline layer using UNION. A new field was created designating wetlands as 1s and everything else as zeros. This variable was then rasterized and the CONDITIONAL function was used to update the land cover layer with this new class wherever there was a value of 1.

Appendix 2. **Detailed listing of all individual valuation estimates, broken down by source study and ecosystem service**

Land Cover	Ecoservice	Year	Author	Min Est	Max Est	Single Est	Average	Units
Spatial Analysis								
Agriculture								
	Gas Regulation							
		2008	Wilson, S.J.			11.17	11.17	
							11.17	*per acre per Year*
	Recreation							
		2007	Knoche, S. and Lupi, F.			48.76	48.76	
							48.76	*per acre per Year*
	Other Cultural							
		2004	Olewiler, N.	2.97	11.89		7.43	
		1999	Alvarez-Farizo, B., Hanley, N., Wright, R. E. and MacMillan, D.			5.15	5.15	
		1994	Bowker, J.M. and Didychuk, D.D.	12.88	41.87		27.37	
		1988	Turner, M. G., Odum, E. P., Costanza, R. and Springer, T. M.			98.10	98.10	
		1985	Bergstrom, J., Dillman, B. L. and Stoll, J. R.			30.30	30.30	
				2.97	**41.87**		**33.67**	*per acre per Year*
	Pollinations and Seeding							
		1992	Southwick, E. E. and Southwick, L.	2.71	9.64		6.18	

Land Cover	Ecoservice	Year	Author	Min Est	Max Est	Single Est	Average	Units
		1989	Robinson, W. S., Nowogrodzki, R. and Morse, R. A.			13.54	13.54	
				2.71	**9.64**		**9.86**	*per acre per Year*
				2.71	**41.87**		**103.46**	***per acre per Year***
Alpine								
	Habitat Refugium							
		2007	Gret-Regamey, A.; Bebi, P.; Bishop, I. and Schmid W.	4.06	10.02		7.04	
				4.06	**10.02**		**7.04**	*per acre per Year*
				4.06	**10.02**		**7.04**	***per acre per Year***
Beach near structure								
	Disturbance Regulation							
		2001	Parsons, G. R. and Powell, M.			9,157.45	9,157.45	
		1995	Pompe, J. J. and Rinehart, J. R.	3,554.58	21,725.87		12,640.22	
				3,554.58	**21,725.87**		**10,898.84**	*per acre per Year*
	Recreation							
		2008	Wilson, S.J.			48.14	48.14	
		2004	Nunes, P. and Van den Bergh, J.	774.42	1,122.35		948.39	
		2003	Hanley, N., Bell, D. and Alvarez-Farizo, B.			13,411.45	13,411.45	
		1998	Kline, J. D. and Swallow, S. K.	39,624.10	49,343.41		44,483.75	
		1992	Silberman, J., Gerlowski, D. A. and Williams, N. A.			28,493.30	28,493.30	
		1990	Ecologistics			64,905.57	64,905.57	

Land Cover	Ecoservice	Year	Author	Min Est	Max Est	Single Est	Average	Units
				774.42	**49,343.41**		**25,381.77**	*per acre per Year*
	Aesthetic and Amenity							
		2006	Costanza, R., Wilson, M., Troy, A., Voinov, A., Liu, S., and D'Agostino, J.			52,058.67	52,058.67	
		2006	Costanza, R., Wilson, M., Troy, A., Voinov, A., Liu, S., and D'Agostino, J.			37,557.31	37,557.31	
		2000	Taylor, L. O. and Smith, V. K.	29.66	76.03		52.85	
		2000	Taylor, L. O. and Smith, V. K.	494.40	1,267.15		880.78	
		1995	Pompe, J. J. and Rinehart, J. R.	1,853.09	3,734.61		2,793.85	
		1991	Edwards, S. F. and Gable, F. J.			251,773.25	251,773.25	
				29.66	**3,734.61**		**57,519.45**	*per acre per Year*
				29.66	**49,343.41**		**93,800.05**	***per acre per Year***
Forest: adjacent to stream								
	Gas Regulation							
		2008	Tol, Richard			71.08	71.08	
							71.08	*per acre per Year*
	Disturbance Regulation							
		1999	Rein, F. A.	18.90	86.41		52.66	
				18.90	**86.41**		**52.66**	*per acre per Year*
	Soil Regulation							
		1999	Rein, F. A.	102.61	450.96		276.79	

Land Cover	Ecoservice	Year	Author	Min Est	Max Est	Single Est	Average	Units
				102.61	**450.96**		**276.79**	*per acre per Year*
	Nutrient Regulation							
		2008	Wilson, S.J.			182.53	182.53	
							182.53	*per acre per Year*
	Water Supply							
		2008	Wilson, S.J.			586.50	586.50	
		1999	Rein, F. A.	130.97	573.82		352.40	
				130.97	**573.82**		**469.45**	*per acre per Year*
	Recreation							
		1999	Rein, F. A.	74.26	322.69		198.48	
				74.26	**322.69**		**198.48**	*per acre per Year*
	Habitat Refugium							
		2002	Amigues, J. P., Boulatoff, C., Desaigues, B., Gauthier, C. and Keith, J. E.			14.75	14.75	
		2002	Amigues, J. P., Boulatoff, C., Desaigues, B., Gauthier, C. and Keith, J. E.	17.58	411.76	64.66	64.66	
		2001	Kenyon, W. and Nevin, C.			510.94	510.94	
		1989	Willis, K. G. and Benson, J. F.	45.69	79.07		62.38	
				17.58	**411.76**		**163.18**	*per acre per Year*
				17.58	**573.82**		**1,414.16**	***per acre per Year***
Forest: non-urban								
	Gas Regulation							

Land Cover	Ecoservice	Year	Author	Min Est	Max Est	Single Est	Average	Units
		2008	Tol, Richard			71.08	71.08	
							71.08	*per acre per Year*
	Nutrient Regulation							
		2008	Wilson, S.J.			182.53	182.53	
							182.53	*per acre per Year*
	Recreation							
		2008	Wilson, S.J.			129.01	129.01	
		2005	Hunt, L.M., Boxall, P., Englin, J., and Haider, W.			0.01	0.01	
		2000	Haener, M. K. and Adamowicz, W. L.			1.51	1.51	
		2000	Scarpa, R., Chilton, S. M., Hutchinson, W. G. and Buongiorno, J.			3.37	3.37	
		1993	Shafer, E. L., Carline, R., Guldin, R. W. and Cordell, H. K.			3.02	3.02	
		1991	Willis, K. G.	76.75	131.58		104.17	
		1991	Willis, K. G.	31.52	57.57		44.55	
		1991	Willis, K. G.	17.82	19.19		18.50	
		1991	Willis, K. G.	335.80	615.41		475.61	
		1991	Willis, K. G.	1.37	5.48		3.43	
		1991	Willis, K. G. and Garrod, G. D.			13.11	13.11	
		1989	Prince, R. and Ahmed, E.	1.06	1.36		1.21	
				1.06	**615.41**		**66.46**	*per acre per Year*
	Habitat Refugium							

Land Cover	Ecoservice	Year	Author	Min Est	Max Est	Single Est	Average	Units
		2000	Haener, M. K. and Adamowicz, W. L.			36.52	36.52	
		1998	Haener, M.K. and Adamowicz, W.L.	49.46	86.71		68.08	
				49.46	**86.71**		**52.30**	*per acre per Year*
	Other Cultural							
		2008	Sverrisson, D., Boxall, P. and Adamowicz, V.	16.31	35.63		25.97	
		1988	Turner, M. G., Odum, E. P., Costanza, R. and Springer, T. M.			20.75	20.75	
		1988	Turner, M. G., Odum, E. P., Costanza, R. and Springer, T. M.			158.48	158.48	
		1988	Turner, M. G., Odum, E. P., Costanza, R. and Springer, T. M.			218.85	218.85	
				16.31	**35.63**		**106.01**	*per acre per Year*
				1.06	**615.41**		**478.38**	***per acre per Year***
Forest: suburban								
	Gas Regulation							
		2008	Tol, Richard			71.08	71.08	
							71.08	*per acre per Year*
	Nutrient Regulation							
		2008	Wilson, S.J.			182.53	182.53	
							182.53	*per acre per Year*

Land Cover	Ecoservice	Year	Author	Min Est	Max Est	Single Est	Average	Units
	Water Supply							
		2008	Wilson, S.J.			586.50	586.50	
							586.50	*per acre per Year*
	Recreation							
		1996	Bateman, I. J., Diamand, E., Langford, I. H. and Jones, A.			1,299.78	1,299.78	
		1996	Bateman, I. J., Diamand, E., Langford, I. H. and Jones, A.			730.21	730.21	
		1994	Maxwell, S.	28.51	56.63		42.57	
				28.51	**56.63**		**690.86**	*per acre per Year*
	Aesthetic and Amenity							
		2003	Kwak, S. J., Yoo, S. H. and Han, S. Y.	684.95	2,462.30		1,573.63	
				684.95	**2,462.30**		**1,573.63**	*per acre per Year*
	Other Cultural							
		1988	Turner, M. G., Odum, E. P., Costanza, R. and Springer, T. M.			88.67	88.67	
							88.67	*per acre per Year*
				28.51	**2,462.30**		**3,193.26**	***per acre per Year***
Forest: urban								
	Gas Regulation							
		2008	Tol, Richard			71.08	71.08	
							71.08	*per acre per Year*
	Nutrient Regulation							

Land Cover	Ecoservice	Year	Author	Min Est	Max Est	Single Est	Average	Units
		2008	Wilson, S.J.			182.53	182.53	
							182.53	*per acre per Year*
	Water Supply							
		2008	Wilson, S.J.			586.50	586.50	
							586.50	*per acre per Year*
	Recreation							
		2001	Tyrvainen, L.			2,117.22	2,117.22	
		2001	Tyrvainen, L.			20,880.50	20,880.50	
		2001	Tyrvainen, L.			2,381.92	2,381.92	
		2001	Tyrvainen, L.			1,433.53	1,433.53	
		2001	Tyrvainen, L.			5,653.85	5,653.85	
		2001	Tyrvainen, L.			4,202.58	4,202.58	
		1995	Bennett, R., Tranter, R., Beard, N. and Jones, P.			415.54	415.54	
							5,297.88	*per acre per Year*
	Other Cultural							
		1988	Turner, M. G., Odum, E. P., Costanza, R. and Springer, T. M.			88.67	88.67	
							88.67	*per acre per Year*
	Pollinations and Seeding							
		2006	Hougner, C., Colding, J., and Soderqvist, T.	1,185.34	5,305.82		3,245.58	
				1,185.34	**5,305.82**		**3,245.58**	*per acre per Year*

Land Cover	Ecoservice	Year	Author	Min Est	Max Est	Single Est	Average	Units
				1,185.34	**5,305.82**		**9,472.24**	***per acre per Year***
Grassland/ pasture								
	Gas Regulation							
		2008	Wilson, S.J.			10.96	10.96	
		2004	Olewiler, N.	3.32	9.96		6.64	
		2004	Olewiler, N.	1.34	4.00		2.67	
				1.34	**9.96**		**6.76**	*per acre per Year*
	Disturbance Regulation							
		2004	Olewiler, N.	0.78	2.78		1.78	
				0.78	**2.78**		**1.78**	*per acre per Year*
	Soil Regulation							
		2004	Olewiler, N.	0.78	4.28		2.53	
		2004	Olewiler, N.	0.21	0.87		0.54	
				0.21	**4.28**		**1.54**	*per acre per Year*
	Nutrient Regulation							
		2004	Olewiler, N.	0.93	16.51		8.72	
				0.93	**16.51**		**8.72**	*per acre per Year*
	Recreation							
		2004	Olewiler, N.	13.18	57.61		35.39	
		2004	Olewiler, N.	3.95	16.24		10.09	
				3.95	**57.61**		**22.74**	*per acre per Year*
	Habitat Refugium							

Land Cover	Ecoservice	Year	Author	Min Est	Max Est	Single Est	Average	Units
		1989	Willis, K. G. and Benson, J. F.	28.49	38.92		33.70	
				28.49	**38.92**		**33.70**	*per acre per Year*
	Other Cultural							
		2008	Sverrisson, D., Boxall, P. and Adamowicz, V.	16.31	35.63		25.97	
		1999	Alvarez-Farizo, B., Hanley, N., Wright, R. E. and MacMillan, D.			19.22	19.22	
		1988	Turner, M. G., Odum, E. P., Costanza, R. and Springer, T. M.			98.10	98.10	
				16.31	**35.63**		**47.76**	*per acre per Year*
				0.21	**57.61**		**123.00**	***per acre per Year***
Open water: estuaries/ tidal bays								
	Disturbance Regulation							
		1992	Hayes, K. M., Tyrrell, T. J. and Anderson, G.	1,233.70	2,357.96		1,795.83	
		1992	Hayes, K. M., Tyrrell, T. J. and Anderson, G.	1,309.97	2,036.27		1,673.12	
				1,233.70	**2,357.96**		**1,734.48**	*per acre per Year*
	Nutrient Regulation							
		1997	Whitehead, J. C., Hoban, T. L. and Clifford, W. B.	6.64	25.59		16.12	
		1995	Goffe, L.			19.18	19.18	
				6.64	**25.59**		**17.65**	*per acre per Year*

Land Cover	Ecoservice	Year	Author	Min Est	Max Est	Single Est	Average	Units
	Recreation							
		2002	Johnston, R. J., Grigalunas, T. A., Opaluch, J. J., Mazzotta, M. and Diamantedes, J.			19.17	19.17	
		2002	Johnston, R. J., Grigalunas, T. A., Opaluch, J. J., Mazzotta, M. and Diamantedes, J.			266.04	266.04	
		2002	Johnston, R. J., Grigalunas, T. A., Opaluch, J. J., Mazzotta, M. and Diamantedes, J.			349.59	349.59	
		1997	Whitehead, J. C., Hoban, T. L. and Clifford, W. B.	10.45	97.62		54.04	
		1989	Bockstael, N. E., McConnell, K. E. and Strand, I. E.			112.79	112.79	
				10.45	**97.62**		**160.33**	*per acre per Year*
	Aesthetic and Amenity							
		2002	Johnston, R. J., Grigalunas, T. A., Opaluch, J. J., Mazzotta, M. and Diamantedes, J.			98.89	98.89	
							98.89	*per acre per Year*
	Habitat Refugium							
		2003	Armstrong, D. A., Rooper, C. and Gunderson, D.	24.74	138.52		81.63	
		1994	Kahn, J. R. and Buerger, R. B.	4.95	10.93		7.94	
		1989	Buerger, R. and Kahn, J. R.			1.26	1.26	
				4.95	**138.52**		**30.28**	*per acre per Year*
				4.95	**2,357.96**		**2,041.62**	***per acre per Year***

Land Cover	Ecoservice	Year	Author	Min Est	Max Est	Single Est	Average	Units
Open water: inland lake								
	Nutrient Regulation							
		1985	Sutherland, R. and Walsh, R. G.			217.63	217.63	
							217.63	*per acre per Year*
	Recreation							
		1997	Rollins, K., Wistowsky, W., and Jay, M.			5.83	5.83	
		1997	Rollins, K., Wistowsky, W., and Jay, M.			23.91	23.91	
		1997	Rollins, K., Wistowsky, W., and Jay, M.			8.44	8.44	
		1993	Cordell, H. K. and Bergstrom, J. C.			1,057.12	1,057.12	
		1993	Cordell, H. K. and Bergstrom, J. C.			1,725.89	1,725.89	
		1993	Cordell, H. K. and Bergstrom, J. C.			3,015.72	3,015.72	
		1993	Cordell, H. K. and Bergstrom, J. C.			1,695.06	1,695.06	
		1989	Young, C. E. and Shortle, J. S.			329.34	329.34	
		1986	Kealy, M. J. and Bishop, R. C.	23.10	87.20	23.98	23.98	
		1985	Mullen, J. K. and Menz, F. C.			4,384.14	4,384.14	
		1984	Ribaudo, M. and Epp, D. J.	210.00	266.29		238.15	
		1979	Bouwes, N. W. and Scheider, R.			588.87	588.87	
		1971	Burt, O. R. and Brewer, D.			2,650.50	2,650.50	
				23.10	**266.29**		**1,211.30**	*per acre per Year*

Land Cover	Ecoservice	Year	Author	Min Est	Max Est	Single Est	Average	Units
	Aesthetic and Amenity							
		1989	d'Arge, R. and Shogren, J.F.			329.02	329.02	
		1989	d'Arge, R. and Shogren, J.F.			105.10	105.10	
		1989	d'Arge, R. and Shogren, J.F.			198.78	198.78	
		1989	Young, C. E. and Shortle, J. S.			85.44	85.44	
							179.59	*per acre per Year*
	Other Cultural							
		2000	Forsyth, M.	4.10	13.72		8.91	
				4.10	**13.72**		**8.91**	*per acre per Year*
				4.10	**266.29**		**1,617.44**	***per acre per Year***
Open water: river								
	Recreation							
		2000	Ahn, S., De Steiguer, J. E., Palmquist, R. B. and Holmes, T. P.	14.93	136.19		75.56	
		1997	Rollins, K., Wistowsky, W., and Jay, M.			5.83	5.83	
		1997	Rollins, K., Wistowsky, W., and Jay, M.			23.91	23.91	
		1997	Rollins, K., Wistowsky, W., and Jay, M.			8.44	8.44	
		1987	Desvousges, W. H., Smith, V. K. and Fisher, A.			5,753.19	5,753.19	
				14.93	**136.19**		**1,173.39**	*per acre per Year*
	Other Cultural							

Land Cover	Ecoservice	Year	Author	Min Est	Max Est	Single Est	Average	Units
		2000	Forsyth, M.	4.10	13.72		8.91	
				4.10	**13.72**		**8.91**	*per acre per Year*
				4.10	**136.19**		**1,182.30**	***per acre per Year***
Open water: urban lake								
	Nutrient Regulation							
		1985	Sutherland, R. and Walsh, R. G.			217.63	217.63	
							217.63	*per acre per Year*
	Water Supply							
		2003	Brox, J.A., Kumar, R.C., and Stollery, K.R.			568.17	568.17	
							568.17	*per acre per Year*
	Recreation							
		2002	Mathews, L. G., Homans, F. R. and Easter, K. W.			5,692.52	5,692.52	
		1993	Shafer, E. L., Carline, R., Guldin, R. W. and Cordell, H. K.			2,213.26	2,213.26	
		1993	Shafer, E. L., Carline, R., Guldin, R. W. and Cordell, H. K.			11,619.63	11,619.63	
		1977	Gramlich, F. W.	27,335.55	51,811.05		39,573.30	
				27,335.55	**51,811.05**		**14,774.68**	*per acre per Year*
	Aesthetic and Amenity							
		1989	d'Arge, R. and Shogren, J.F.			329.02	329.02	
		1989	d'Arge, R. and Shogren, J.F.			105.10	105.10	
		1989	d'Arge, R. and Shogren, J.F.			198.78	198.78	

Land Cover	Ecoservice	Year	Author	Min Est	Max Est	Single Est	Average	Units
		1989	Young, C. E. and Shortle, J. S.			85.44	85.44	
		1982	Rich, P. R. and Moffitt, L. J.			86.25	86.25	
							160.92	*per acre per Year*
	Other Cultural							
		2000	Forsyth, M.	4.10	13.72		8.91	
				4.10	**13.72**		**8.91**	*per acre per Year*
				4.10	**51,811.05**		**15,730.31**	***per acre per Year***
Open water: urban/ suburban river								
	Nutrient Regulation							
		1977	Oster, S.			12,026.24	12,026.24	
							12,026.24	*per acre per Year*
	Water Supply							
		2003	Brox, J.A., Kumar, R.C., and Stollery, K.R.			568.17	568.17	
							568.17	*per acre per Year*
	Recreation							
		2002	Mathews, L. G., Homans, F. R. and Easter, K. W.			5,692.52	5,692.52	
		1996	Garrod, G. D. and Willis, K. G.			21,072.42	21,072.42	
		1993	Shafer, E. L., Carline, R., Guldin, R. W. and Cordell, H. K.			2,213.26	2,213.26	
		1993	Shafer, E. L., Carline, R., Guldin, R. W. and Cordell, H. K.			11,619.63	11,619.63	
		1977	Gramlich, F. W.	27,335.55	51,811.05		39,573.30	

Land Cover	Ecoservice	Year	Author	Min Est	Max Est	Single Est	Average	Units
				27,335.55	**51,811.05**		**16,034.23**	*per acre per Year*
	Aesthetic and Amenity							
		1982	Rich, P. R. and Moffitt, L. J.			86.25	86.25	
							86.25	*per acre per Year*
				27,335.55	**51,811.05**		**28,714.88**	***per acre per Year***
Urban herbaceous greenspace								
	Aesthetic and Amenity							
		2006	Costanza, R., Wilson, M., Troy, A., Voinov, A., Liu, S., and D'Agostino, J.	11,925.70	13,177.21		12,551.45	
		1974	Hammer, T.R., Coughlin, R.E., and Horn, E.T.			13,992.00	13,992.00	
				11,925.70	**13,177.21**		**13,271.73**	*per acre per Year*
	Other Cultural							
		1988	Turner, M. G., Odum, E. P., Costanza, R. and Springer, T. M.			88.67	88.67	
							88.67	*per acre per Year*
				11,925.70	**13,177.21**		**13,360.40**	***per acre per Year***
Wetland: urban/ suburban (fresh or salt)								
	Gas Regulation							

Land Cover	Ecoservice	Year	Author	Min Est	Max Est	Single Est	Average	Units
		2008	Wilson, S.J.			5.01	5.01	
							5.01	*per acre per Year*
	Disturbance Regulation							
		1997	Leschine, T.M., Wellman, K.F., and Green, T.H.	904.63	1,357.66		1,131.15	
		1997	Leschine, T.M., Wellman, K.F., and Green, T.H.			4,774.04	4,774.04	
		1997	Leschine, T.M., Wellman, K.F., and Green, T.H.	4,114.56	5,903.75		5,009.16	
		1981	Thibodeau, F. R. and Ostro, B. D.			5,754.57	5,754.57	
				904.63	**5,903.75**		**4,167.23**	*per acre per Year*
	Nutrient Regulation							
		2000	Bystrom, O	1,257.83	2,703.29	1,635.87	1,635.87	
		1993	Gren, I. M.			15.94	15.94	
		1990	Lant, C. L. and Roberts, R. S.	23.10	28.97		26.03	
		1981	Thibodeau, F. R. and Ostro, B. D.			2,925.59	2,925.59	
				23.10	**2,703.29**		**1,150.86**	*per acre per Year*
	Water Supply							
		1981	Thibodeau, F. R. and Ostro, B. D.			17,374.12	17,374.12	
							17,374.12	*per acre per Year*
	Recreation							
		1986	Anderson, G. D. and Edwards, S. F.	2,421.03	4,697.52		3,559.28	

Land Cover	Ecoservice	Year	Author	Min Est	Max Est	Single Est	Average	Units
		1981	Thibodeau, F. R. and Ostro, B. D.	369.15	6,634.32		3,501.73	
				369.15	**6,634.32**		**3,530.51**	*per acre per Year*
	Aesthetic and Amenity							
		2000	Bishop, R.C., Breffle,W.S., Lazo, J.K., Rowe, R.D., and Wytinck, S.M.	210.63	2,000.96	1,089.59	1,089.59	
		2000	Bishop, R.C., Breffle,W.S., Lazo, J.K., Rowe, R.D., and Wytinck, S.M.	434.76	1,547.30	995.08	995.08	
		2000	Bishop, R.C., Breffle,W.S., Lazo, J.K., Rowe, R.D., and Wytinck, S.M.	375.35	866.81	608.93	608.93	
		2000	Mahan, B. L., Polasky, S. and Adams, R. M.			37.02	37.02	
		1991	Rivas, V. and Cendrero, A.			15,259.16	15,259.16	
		1986	Anderson, G. D. and Edwards, S. F.			7,886.42	7,886.42	
		1981	Thibodeau, F. R. and Ostro, B. D.	25.87	82.80		54.34	
				25.87	**2,000.96**		**3,704.36**	*per acre per Year*
	Other Cultural							
		1996	Randall, A. and de Zoysa, D.	79.70	6,299.47		3,189.59	
				79.70	**6,299.47**		**3,189.59**	*per acre per Year*
				23.10	**6,634.32**		**33,121.67**	***per acre per Year***
Wetlands: non-urban, non-coastal								

Land Cover	Ecoservice	Year	Author	Min Est	Max Est	Single Est	Average	Units
	Gas Regulation							
		2008	Wilson, S.J.			5.01	5.01	
							5.01	*per acre per Year*
	Nutrient Regulation							
		2008	Wilson, S.J.	573.79	1,749.86		1,161.83	
		2004	Brauer, I.			10.31	10.31	
		2000	Bystrom, O	2,432.77	5,228.44	3,163.95	3,163.95	
		1993	Gren, I. M.			15.94	15.94	
		1990	Lant, C. L. and Roberts, R. S.	23.10	28.97		26.03	
		1989	Lant, C. L. and Tobin, G.			1,811.26	1,811.26	
		1989	Lant, C. L. and Tobin, G.			164.51	164.51	
				23.10	**5,228.44**		**907.69**	*per acre per Year*
	Recreation							
		2008	Wilson, S.J.			129.01	129.01	
		1993	Shafer, E. L., Carline, R., Guldin, R. W. and Cordell, H. K.			99.06	99.06	
		1990	Whitehead, J. C.	1,066.65	2,144.18		1,605.41	
		1981	Kreutzwiser, R.			203.76	203.76	
		1981	Kreutzwiser, R.			215.24	215.24	
				1,066.65	**2,144.18**		**450.50**	*per acre per Year*
	Aesthetic and Amenity							
		1996	Doss, C. R. and Taff, S. J.			520.89	520.89	
		1996	Doss, C. R. and Taff, S. J.			762.92	762.92	
		1990	Lant, C. L. and Roberts, R. S.	21.24	28.91		25.08	

Land Cover	Ecoservice	Year	Author	Min Est	Max Est	Single Est	Average	Units
				21.24	**28.91**		**436.29**	*per acre per Year*
	Habitat Refugium							
		1992	van Kooten, G. C. and Schmitz, A.			50.96	50.96	
		1992	van Kooten, G. C. and Schmitz, A.			7.42	7.42	
		1989	Willis, K. G. and Benson, J. F.	15.44	28.49		21.96	
				15.44	**28.49**		**26.78**	*per acre per Year*
	Other Cultural							
		1991	Whitehead, J. C. and Blomquist, G. C.	9.23	30.13		19.68	
				9.23	**30.13**		**19.68**	*per acre per Year*
				9.23	**5,228.44**		**1,845.95**	***per acre per Year***
Wetlands: salt/coastal								
	Gas Regulation							
		2008	Wilson, S.J.			5.01	5.01	
							5.01	*per acre per Year*
	Disturbance Regulation							
		2008	Costanza, R., Perez-Maqueo, O., Martinez, M.L., Sutton, P., Anderson, S.J., and Mulder, K.			371.06	371.06	
							371.06	*per acre per Year*
	Recreation							
		2008	Wilson, S.J.			129.01	129.01	

Land Cover	Ecoservice	Year	Author	Min Est	Max Est	Single Est	Average	Units
		1993	Shafer, E. L., Carline, R., Guldin, R. W. and Cordell, H. K.			99.06	99.06	
		1990	Whitehead, J. C.	1,066.65	2,144.18		1,605.41	
		1981	Kreutzwiser, R.			203.76	203.76	
		1981	Kreutzwiser, R.			215.24	215.24	
				1,066.65	**2,144.18**		**450.50**	*per acre per Year*
	Aesthetic and Amenity							
		1996	Doss, C. R. and Taff, S. J.			520.89	520.89	
		1996	Doss, C. R. and Taff, S. J.			762.92	762.92	
		1990	Lant, C. L. and Roberts, R. S.	21.24	28.91		25.08	
				21.24	**28.91**		**436.29**	*per acre per Year*
	Habitat Refugium							
		1978	Batie, S. S. and Wilson, J. R.			116.85	116.85	
							116.85	*per acre per Year*
	Other Cultural							
		1991	Whitehead, J. C. and Blomquist, G. C.	9.23	30.13		19.68	
				9.23	**30.13**		**19.68**	*per acre per Year*
				9.23	**2,144.18**		**1,399.39**	***per acre per Year***

Restrictions: All figures are in 2006 USD.

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