THE UNIVERSITY OF MAINE
Senator George J. Mitchell
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An Economic Case for the Sebago Watershed Water & Forest Conservation Fund

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Executive Summary

The 282,000-acre Sebago Lake watershed provides drinking water to more than 200,000 users in the greater Portland, Maine region. The watershed contains abundant forests and cold water lakes and streams, and is considered by many to be an exemplary case of intact forests filtering clean drinking water, while providing myriad co-benefits for Maine citizens. The Portland Water District (PWD) has federal filtration exemption – just one of about 50 watersheds in the US with this designation – and invests in watershed protection through acquisitions and conservation easements in partnership with local and regional conservation organizations. The Sebago Lake watershed faces the threat of water quality impairment through loss of forest cover, primarily due to anticipated development. Between 1987 and 2009, the watershed saw about a 3.5% loss in forest cover (CCSWCD 2015), and increasing population growth in the greater Portland region brings increased risks of development and reductions in water quality. Currently, only 10% of the watershed's area is protected from development. As a result, the Sebago Clean Waters partnership seeks cost-effective and efficient options to increase the pace and extent of conservation so as to avoid future water quality infrastructure costs and to protect the watershed's many natural values, including its water quality.

This paper provides details on answers to six specific questions related to determining the economic feasibility of scaling up investments in forest conservation that would secure water quality and other ecosystem services in the Sebago Lake watershed over the next 30 to 50 years. The study utilizes the latest economic approaches and current land use, ecosystem service and conservation information to evaluate the benefits and costs of natural water filtration and its complementary benefits.

1. ***At what level of forest area converted to development would the Sebago water supply be at risk of significant decreases in water quality?***

A review of recent literature indicates that the likely 'threshold' where water treatment costs start to measurably increase is when there is less than 60-90% forested area in a watershed. Our assessment found that reducing the area of forest cover in the Sebago Lake watershed from its current level of 84% down to about 76% – a pace of forest loss that is possible over the next half century given development patterns and historical rates of land use change – could lead to a noticeable increase in pollutants (nitrogen, phosphorus, sediment) that would significantly degrade lake, stream, river and wetland water quality in the watershed, particularly if that forestland were converted to various types of development. Furthermore, we anticipate that if about 10% of the current forest cover were lost, then the *entire* Sebago Lake watershed would, on average, be below state water quality standards. This would trigger the need for ameliorative water quality management throughout the watershed, rather than for a select few ponds, as is currently the case. At this level of forest loss, we estimate that nearly all lakes in the watershed could potentially become eutrophic due to nutrient enrichment (based on Trophic State Indices – TSI). However, our analysis highlights that the water quality consequences will depend strongly on where and what type of development occurs. That is, the conversion of land to urban areas with impervious surfaces poses more significant and immediate water quality risks due to elevated nutrient loading than clearing of forests for lower intensity residential development.

2. *What are the costs and benefits of protecting enough land to ensure clean water?*

We conducted an economic analysis using a range of assumptions and scenarios to estimate the potential costs and benefits of conserving forestland in the Sebago Lake watershed. These scenarios varied the cost of conserving land, the monetized value of the benefits of maintaining clean water and other ecosystem services[1] deemed important by stakeholders in the watershed that forested areas in the watershed provide, and the amount of area that could be protected. We estimate that if *all* 180,000 acres of the forest area currently not conserved were done so via a conservation easement or fee purchase, then this would yield a net benefit for the catchment even under conservative assumptions. Focusing on the amount of forestland conservation required to meet the water quality threshold (i.e., 76% forest cover for entire watershed, or about 160,000 additional acres) produces similar results. That is, we estimate that every dollar invested in forestland conservation is likely to yield between $4.80 and $8.90 in benefits, including the preservation of water quality. Additional sensitivity analysis confirmed that benefits of conservation outweighed the costs on more than 95% of the forest area. We do note however, that investing in broad forestland conservation is not costless, and that purchasing enough conservation land to meet the target of 76% forest cover in perpetuity would require about $193 million in investment.

3. *What is the value to beneficiaries of clean water and the associated co-benefits of land protection in the watershed?*

In addition to the provision of freshwater, forestland protection in the Sebago Lake watershed has the potential to provide other ecosystem services of interest to stakeholders in the region (see footnote 1). While not all of these values are recognized through a direct market transaction (e.g., purchasing timber), our analysis does illustrate that forestland conservation can provide non-market benefits through the form of providing recreation opportunities, preserving habitat, and mitigating climate change. We estimate that the total annual value of forest ecosystem services (FES) in the Sebago Lake watershed could range from $42-287 million per year, which equates to a value of $219-1486/ac/yr depending on the scenarios and assumptions used in the analysis. Our 'moderate' forest ecosystem service values scenario estimates that forests in the watershed could provide about $90 million in benefits per year, or $615/ac/yr.

4. *Is there a business case for commercial water users to invest in watershed protection to reduce future risk to their water quality?*

Yes. We estimate that if forestland continued to be at risk to development to the point that PWD would have to build a filtration plant costing about $150 million dollars, then they would increase their water rates by about 84%, on average, to offset the costs of constructing and maintaining the plant. This equates to more than $1.7 million per year in additional water charges for the top 10 consumers in the District, based on annual consumption. For the top 50 meters in the PWD, of which nearly all are connected to industrial and commercial operations, this figure increases to more than $2.1 million per annum. Thus, commercial and industrial water users in the district have a strong incentive to invest in watershed protection, such that the cost of

[1] These include provision of fuel, fiber, and freshwater, climate and water regulation, erosion control, water purification and regulation, storm protection, recreation, and provisioning of habitat.

doing so is less than the additional charges that they would face if the plant were constructed. If the top district water users used their potential cost savings for forest protection, this likely would be enough funds to invest in about 1,750-2,240 acres of forest protection per year. If all water users, including residential clients, contributed to the fund to the point that cost of doing so was equal to the annualized cost of building and maintaining the plant, then there could be enough funds to conserve up to 14,000 acres of forestland, on average, per year. At this rate, the target conservation area of 160,000 acres could feasibly be met over the next 25 years, assuming that the cost of acquiring land and establishing conservation easements remains relatively constant over time.

5. *What is the marketing value for commercial water users to invest in watershed protection?*

Our analysis, coupled with a literature review, suggests that there is minimal downside for businesses in the Sebago Lake watershed to develop a marketing plan aimed at promoting their products as 'green' because they are sourced from a protected watershed with high water quality. However, we caution that developing green credentials for their products may or may not result in a price premium for their product(s). Instead, businesses should be more concerned about the potentially large cost increases associated with building filtration plant(s) to cope should water quality further deteriorate in the Sebago Lake watershed.

6. *Are there investment grade conservation opportunities in the watershed? For example, is there real potential for existing ecosystem service markets (e.g., carbon market) to use any value of co-benefits to help pay for watershed protection?*

There has been significant growth in ecosystem service market initiatives in the US over the past 30 years. There are close to 3,000 different initiatives eliciting value from ecosystem service flows. Most of the existing $2.8 billion per annum market for ecosystem services comes from wetlands and streams ($2.2 bil/yr), followed by watershed initiatives ($0.4 bil/yr), and imperiled species and habitats ($0.2 bil/yr). New forest carbon markets have emerged in recent years, but with just $58 million per year in turnover, they are still considered relatively small. This is a voluntary market in the US meaning there is more variability in the quality of these credits and a more volatile market, at least in the short term. Some ecosystem markets or projects focus on more than one asset or service too. For example, a landowner might sell both habitat credits covering a forested area nearby on his property and wetland credits representing restoration activities on wetland areas. Given the interest for the Sebago Lake watershed to preserve water quality through the conservation of forests that have strong carbon sequestration and habitat potential, the watershed is a prime candidate for hosting one of the first multi-service 'projects' in the northeast.

1. Introduction

The Sebago Lake watershed contains abundant forests and cold water lakes and streams, and is considered by many to be an exemplary case of intact forests filtering clean drinking water, while providing myriad co-benefits for Maine citizens. The Portland Water District (PWD) has federal filtration exemption – just one of about 50 watersheds in the US with this designation – and invests in watershed protection through acquisitions and conservation easements in partnership with local and regional conservation organizations. The Sebago Lake watershed faces the threat of water quality impairment through loss of forest cover, primarily due to anticipated development. Between 1987 and 2009, the watershed saw about a 3.5% loss in forest cover (CCSWCD 2015), and increasing population growth in the greater Portland region brings increased risks of development and reductions in water quality. Currently, only 10% of the watershed's area is protected from development. As a result, the Sebago Clean Waters partnership seeks cost-effective and efficient options to increase the pace and extent of conservation so as to avoid future water quality infrastructure costs and to protect the watershed's many natural values, including its water quality.

This paper provides details on an analysis of economic benefits and costs for scaling up investments in forest conservation and subsequent ecosystem services in the Sebago Lake watershed over the next 30 to 50 years. US studies estimate the economic return on conservation investment typically ranges from $4 to 11 dollars for every dollar spent on a given conservation project (Roman and Erickson, 2017), but it is unknown whether an assessment of the Sebago Lake watershed will fall within that range. The study utilizes the well-established economic methods and current land use, ecosystem service and conservation information to evaluate the benefits and costs of natural water filtration and co-benefits such as carbon sequestration, recreation, habitat, and the provision of fuel and fiber that could be realized from watershed protection. It also provides recommendations on where investments in conservation are most likely to provide the highest returns on investment.

Specifically, we provide responses to six specific questions:

1. At what level of development (i.e., loss of forests), would the Sebago water supply be at risk of significant decreases in water quality?
2. What are the costs and benefits of protecting enough land to ensure clean water?
3. What is the value to beneficiaries of clean water and the associated co-benefits of land protection in the watershed?
4. Is there a business case for commercial water users to invest in watershed protection to reduce future risk to their water quality?
5. What is the marketing value for commercial water users to invest in watershed protection?
6. Are there investment grade conservation opportunities in the watershed? For example, is there real potential for using existing ecosystem service markets (e.g., carbon market) to capture the value of co-benefits to help pay for watershed protection?

The report is organized as follows. First, we present an overview of the methods used to conduct the analysis. Next, we present the results of our baseline and scenario analysis. We then conclude with a summary of our findings.

2. Methods

To address the six questions posed in this report, we use a mix of literature review, watershed and ecosystem service modeling, economic valuation, and benefit-cost analysis. The general approach is outlined below:

- Use the InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs) model suite, including sedimentation (SDR) and nutrient delivery (NDR) models, and carbon models and additional literature to quantify the natural capital stocks and flows of key ecosystem services in the watershed for both the current (baseline) conditions and a range of alternative scenarios. These include, but are not limited to: drinking water, recreation, carbon sequestration, water quality (nutrients, coliform bacteria and total suspended solids) and provision of fuel and fiber. The final list of ecosystem services to quantify was determined by the level of biophysical and economic data readily available, as well as relative impact that including a specific ecosystem service in the analysis may have on the estimates. We did not attempt to quantify ecosystem services that were perceived to be of little importance in the watershed or required high effort to evaluate.
- Link a series of scenarios that featured changes in forestland cover to the InVEST decision support tool. This was to estimate projected changes in water quality and other ecosystem services under different levels of forest cover based on development risk. In addition to watershed-wide estimates of land cover change effects on ecosystem services, the InVEST model also allows us to *spatially identify* those areas most likely to breach water quality thresholds. Water quality thresholds considered for this analysis was considered to be when modeling estimated that a) the average attainment values for water body-specific Total Maximum Daily Loads (TMDLs) were surpassed, b) statewide average TMDLs were surpassed (when water-body specific TMDLs were unavailable), or c) the lake became eutrophic based on Trophic State Index (TSI), which increases the risk of being classified as an impaired waterway.
- Use a 'benefits transfer' (i.e., secondary literature) approach to value the costs and benefits of the key ecosystem services in the watershed. To do so, we utilized a detailed inventory of previous economic valuation studies that are applicable to the Sebago Lake watershed. There are some potential limitations of using this approach as opposed to collecting primary data to value many of the ecosystem services within the watershed. However, given the short timeframe to conduct this analysis, this was the most appropriate methodology to use.
- Conduct a Benefit-Cost Analysis (BCA) for investing in forestland conservation in the Sebago Lake watershed. This commonly employed tool for economic analysis helps to systematically assess to what degree investing in forestland conservation provides net benefits to direct investors and a broader set of stakeholders who utilize the ecosystem services from the watershed. The BCA incorporates both market (e.g., timber, avoided cost of building a filtration plant, etc.) and non-market (e.g., habitat provision, clean air, etc.) ecosystem service values and identifies key tradeoffs and thresholds associated with varying investment options.
- Present a review of the current state of compliance, regulatory, and voluntary ecosystem markets in the US. The review identifies potential opportunities to raise funds for

watershed protection through payments for ecosystem services, including those that not directly tied to drinking water quality. It also provides insight on the marketing value for commercial water users to invest in watershed protection (e.g., "every acre conserved provides X gallons of clean drinking water per year, at a cost of $Y/gallon"), which could potentially be used to help capture a price premium or market share for their goods and services.

- The economic and ecosystem service analysis relies heavily on data, modelling, and other information that the Sebago Clean Waters (SCW) partner previously conducted and/or provided. In particular we used SCW partner data for estimating the cost of the filtration plant, specifying alternative land cover change pathways, and estimating the cost of conserving land via fee acquisition or easement.

The remainder of this section briefly details the key methods of the analysis.

2.1 Ecosystem Services and Economic Valuation

Ecosystem services may be defined as the outputs of natural systems that contribute to human welfare (e.g., Brown et al. 2007; Daily 1997; Fisher et al. 2008, 2009; Millennium Ecosystem Assessment 2005). In the same way that humans combine capital, labor and technology to produce goods and services valued by people, ecosystems combine natural capital and processes to produce ecosystem services valued by people. These services can benefit people in different ways, either directly or in combination with other inputs such as human labor or capital.

Ecosystem services are produced and consumed at various levels and spatial scales. For example, climate regulation and carbon sequestration are global, while flood protection, water supply, and pollination are generally produced and consumed locally or regionally. Ecosystem services also vary in their connection to human welfare. Services like carbon sequestration are indirect, while food, fiber, and recreational opportunities have direct connections.

Several approaches have emerged to classify ecosystem services with most of the commonly used systems have significant overlap. For this analysis, we choose to follow the Millennium Ecosystem Assessment (2005) classification (Table 1), which places ecosystem services into four categories: *provisioning* (e.g., food, fiber, freshwater), *regulating* (e.g., climate, storm protection), *cultural* (e.g., recreation, aesthetics), and *supporting* (services necessary for production of other ecosystem services, e.g., nutrient cycling, soil formation and retention).

Not all of the listed ecosystem services, however, are necessarily abundant in or important to the Sebago Lake watershed. Some of the services may produce multiple values (e.g., recreation can be aligned with educational values, inspiration, and aesthetic values). As a result, we limit our analysis to the key services in the watershed that we can quantify from both a biophysical and economic perspective. We note that our final list was reviewed by members of Sebago Clean Waters partnership to ensure that we have captured the main ecosystem services provided by forests in the watershed.

Table 1. Ecosystem Service Classification (Source: Adapted from the Millennium Ecosystem Assessment (2005)).

Provisioning *Products obtained from ecosystems*	**Regulating** *Benefits from regulation of ecosystem processes*	**Cultural** *Non-material benefits obtained from ecosystems*
Biochemical, natural medicines & pharmaceuticals Food Fiber Freshwater Fuel Genetic Resources Ornamental Resources	Air Quality Maintenance Biological Control Climate Regulation Erosion Control Human Disease Regulation Pollination Storm Protection Water Purification Water Regulation	Aesthetic Values Cultural Heritage Values Cultural Diversity Educational Values Inspiration Knowledge Systems Recreation & Ecotourism Sense of Place Spiritual & Religious Values Social Relations
Supporting *Services necessary for the production of all other ecosystem services*		
Nutrient & water cycling Primary production Production of atmospheric oxygen	Provisioning of habitat Soil formation & retention	

Ecosystem services quantified in the Sebago Lake watershed analysis

2.2 Benefit-Cost Analysis

We employ a BCA methodology to consistently compare the benefits and costs across scenarios. For our analysis, we follow a seven-step process suggested by Buncle et al. (2013), as illustrated in Figure 1.

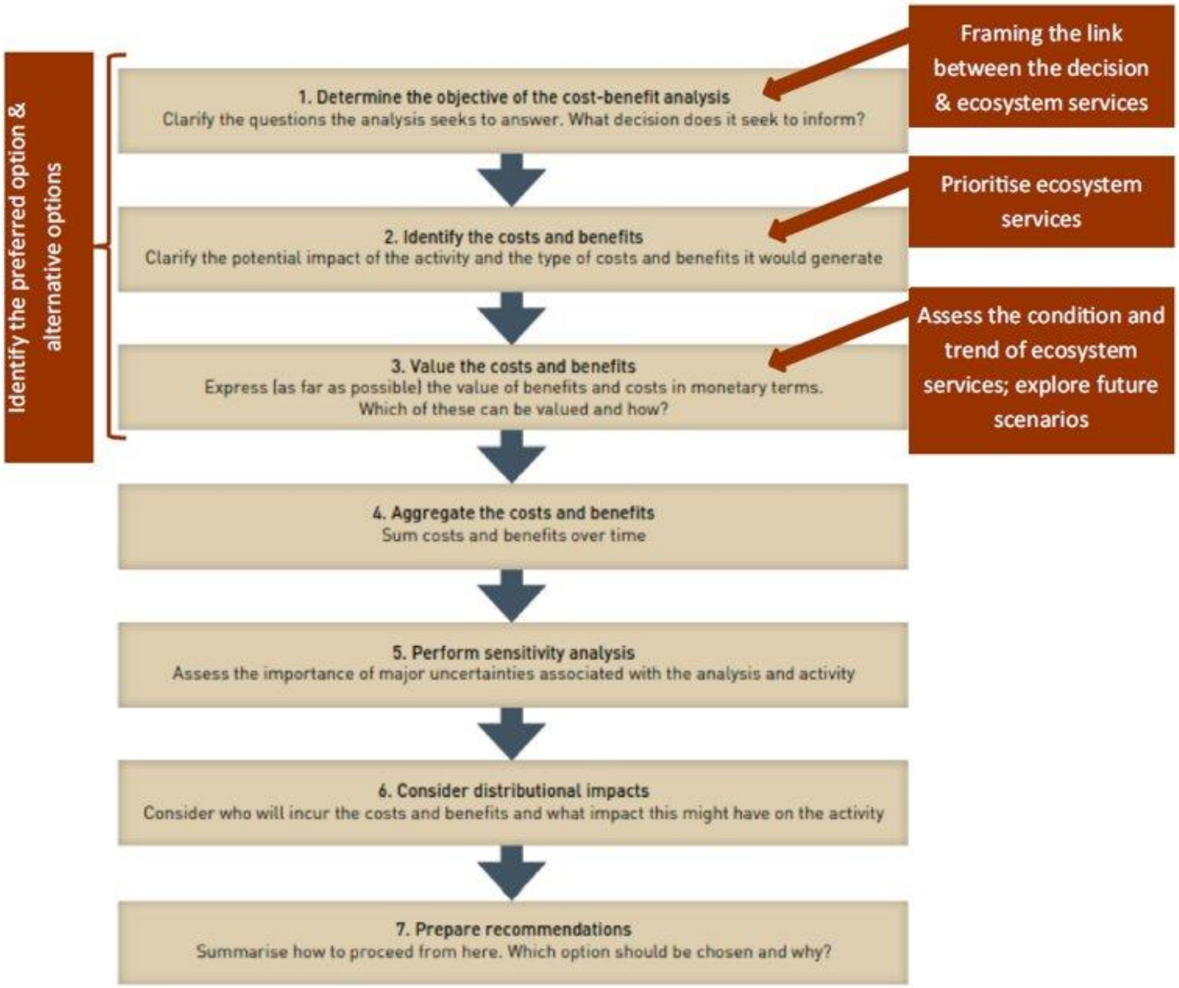

Figure 1. Benefit-Cost Analysis framework (Source: Buncle et al. (2013)).

Each option in each scenario faces a distinct set of costs and benefits. The primary benefits of each option are the avoided costs of water filtration and purification (i.e., provisioning of freshwater), recreation opportunities, habitat, carbon sequestration, provision of wood fiber and fuel, and air purification. The key costs of forest conservation in the Sebago Lake watershed are the purchase and transaction costs associated with acquiring the conservation land or establishing an easement. All costs and benefits accounted for in our study are monetized on an annual basis with the best information available. All capital and land investment costs are expected to accrue in the year of the plan being implemented.

To aggregate the benefits across the Sebago Lake watershed, our analysis assumes a 25-year timeframe and a discount rate of 6%. These figures are consistent with the metrics used to estimate the PWD's cost to construct, operate and maintain, and debt service a new filtration plant.

We then use the results of our BCA to identify which opportunities for forest conservation are likely to produce the highest return on investment to landowners and a broader set of stakeholders in the watershed.

2.3 Estimating Ecosystem Service Benefits of Forestland Conservation

2.3.1 Economic valuation

Economic valuation of ecosystem services can serve many different purposes. For example, valuation is a central component of a BCA, which is used to evaluate whether a policy or action generates positive net economic benefits. If values for ecosystem services are not quantified within a BCA, these values are often presumed to be zero (Holland et al. 2010). Even in the absence of a full-scale economic analysis, ecosystem service values can be used to quantify the benefits of individual ecosystem services to different groups. Formal environmental welfare accounting "green GDP" systems also require estimates of these values (Boyd and Banzhaf 2007). Other uses include natural resource damage assessment, the support of advocacy for environmental protection or restoration, and broader sustainability evaluations. The need for precision within each of these uses varies (Kline and Mazzotta 2012; Navrud and Pruckner 1997). In these and other cases, appropriately quantified economic values can help ensure that decisions account for the economic benefits provided by ecosystems.

There are several common techniques that can be employed for the economic valuation of ecosystem services (Troy 2012; Buncle et al. 2013). Examples include:

- **Avoided cost**: estimates the potential financial damages avoided by preserving an ecosystem and maintaining its services. For instance, if erosion-reducing forests were protected, how much damage would result downstream compared to the case where the forest was felled?
- **Replacement cost**: like avoided cost, but assumes society would not accept the potential damages resulting from an unregulated system and so would pay for some engineered substitute, like a filtration plant, in the case of water quality.
- **Contingent valuation**: uses surveys to elicit *stated preferences*, often in the form of the willingness to pay for a hypothetical or real good, service, or condition.
- **Travel cost**: uses visitation data to estimate the amount spent on recreational visits to a site and derive the value of that site or some quality associated with it (i.e., *revealed preferences*).
- **Conjoint analysis or choice experiments**: 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.
- **Hedonic pricing**: disaggregates price to reveal preferences among bidders in the housing market.

Each method requires a particular level of effort and/or cost to conduct (Figure 2). For example, food and fiber provision can be valued relatively easily from market price and quantity data often published by state or national government organizations. Local recreation or aesthetic values, however, often require more effort to estimate, as they typically use surrogate or stated-preference methods and site specific surveys, which can be costly and time consuming. As a result, the analysis should focus on quantifying and valuing the ecosystem services that are likely to have a meaningful impact on the study region. We discuss our specific approach to valuing ecosystem service benefits in the Sebago Lake watershed in section 2.2.4.

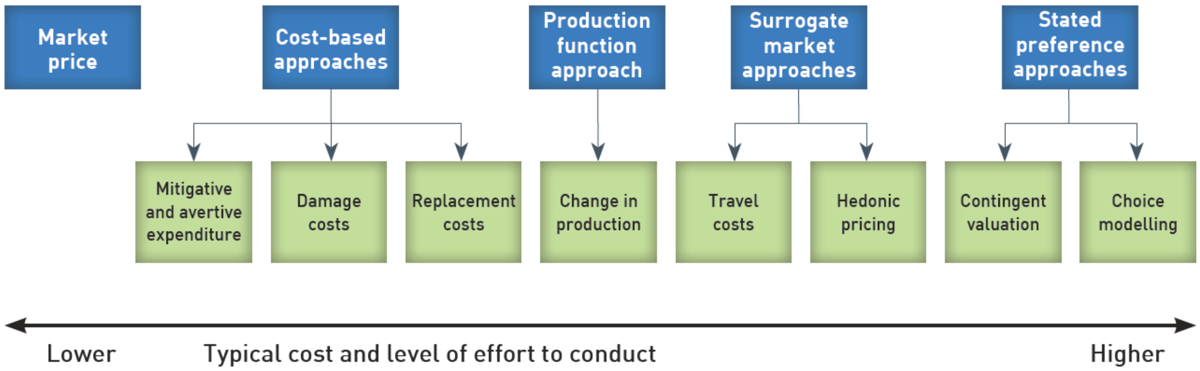

Figure 2. Methods to value ecosystem services. (Source: Buncle et al., 2013).

2.3.2 InVEST Model

We use the InVEST decision support tool to estimate the change in ecosystem services in the Sebago Lake watershed under different forest conservation and land development scenarios. The model is parameterized for this type of 'what if' analysis and researchers have used the model to conduct similar assessments in other watersheds. Wang et al. (2017) used this model to compare the return on investment (ROI) for nutrient retention by targeting private forest areas for conservation in a large Indiana watershed. Polasky et al. (2011) evaluated the impact of land-use change in Minnesota on ecosystem services and biodiversity. Kovacs et al. (2012) evaluated ROI of targeting public land conservation for the provision of ecosystem services in Minnesota. Keller et al. (2015) prioritized conservation actions based on minimizing impacts to an ecosystem services baseline.

InVEST uses a number of different models or modules to estimate the flow of ecosystem services in a given area. For example, the Water Purification Nutrient Retention model estimates the contribution of vegetation and soil to purifying water resources through intercepting nonpoint sources of nutrient pollutants based on a simplification of well-known hydrological and biophysical relationships (InVEST, 2018). The model operates on an annual average basis with data formats in GIS raster grids, GIS shapefiles, and tabular data.

Three InVEST sub-models were run were run for this analysis: Carbon Storage, Nutrient Delivery Ratio (NDR), and Sediment Delivery Ratio (SDR). These three models were used to estimate four environmental outputs in the watershed: 1. Carbon (C) storage, 2. Nitrogen (N) loss to waterways, 3. Phosphorus (P) loading to Waterways, and 4. Sediment loss to waterways. The baseline or 'current' land cover for Sebago Lake used in our analysis was the most recent data available from the National Land Cover Database (2011), which is recorded at the 30m pixel level. We aggregate most of the model outputs to the parcel level as that is likely resolution that land conservation investments will be made. More details on the data and assumptions used for the InVEST modeling are listed in Appendix 1.

2.3.3 Land use change scenarios

Our assessment uses a scenario approach to estimate the potential risk to water quality and other ecosystem services from converting forestland to development (e.g., residential, commercial, etc.) in the Sebago Lake watershed[2]. The scenarios follow a staged-development approach to estimate the potential increase in nitrogen (N), phosphorus (P), and sediment (S) from non-point sources, where different degrees of forestland is converted based on their likelihood of being developed in the next 25 years (i.e., *development risk*).

To identify the parcels most at risk of development, we used Development Suitability Scores calculated by Meyer et al. (2014) as part of the Maine Landuse Futures community mapper project[3]. This was done by calculating the average development suitability scores for all pixels in the watershed and then aggregating the scores up to the parcel level. Development suitability scores were estimated based on stakeholder-derived factors that drive development (Meyer et al. 2014). These factors include proximity to roads and rates of urban growth in the region. The parcels most at risk of development were typically in the southern portion of the watershed, closer to Portland. These parcel development risk scores were then used to rank all 26,000 parcels in the watershed to create a parcel-by-parcel development risk index.

Estimating the impacts to water quality from converting forest to development in InVEST were based on the following steps:

1. Run InVEST with the current land use map to estimate baseline N, P, and S
2. Convert all forestland in InVEST to development based on the highest development intensity potential the parcel could support.
3. Estimate difference between N, P, and S loss rates for the baseline and full conversion scenarios.
4. Convert a specific percentage of parcels 'back' to forest based on their development risk ranking to assess the relative change in water quality from conserving the forest and protecting the watershed from additional development.

Using this development risk index approach, we developed a series of seven scenarios that ranged from converting 5% of the forested parcels currently not conserved, to a 100% conversion to development. We note that these scenarios do not necessarily simulate actual development pathways, but rather follow a logical method that allows us to try and identify thresholds or break points in water quality degradation at certain rates of development. As a result, developed lands were converted to 'high intensity' development (i.e., NLCD land use classification code 24), reflecting increased impervious surfaces.

We specifically ran the following set of scenarios through InVEST:

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[2] N.B., we recognize that there are other potential forest land use change threats in the watershed, such as agriculture. However, the scope of this study was focused on forest loss to development, which has been the primary impact in recent decades (CCSWCD, 2015).

[3] http://www.mainelandusefutures.org/

- **Dev S0:** Baseline scenario with 2011 Land Use Land Cover. (same as Env S0)
- **Dev S1:** 100% conversion of all non-conserved forests in the watershed to High Intensity Development, except for existing conserved/protected lands (NLCD code 24).
- **Dev S2:** Conversion of 80% of parcels[4] with highest Development Risk Index to High Intensity Development, except for existing conserved/protected lands. All other parcels reflected current land-use (NLCD code 24).
- **Dev S3:** Conversion of 60% of parcels with the highest Development Risk Index to High Intensity Development, except for existing conserved/protected lands. All other parcels reflected current land-use (NLCD code 24).
- **Dev S4:** Conversion of 40% of parcels with highest Development Risk Index to High Intensity Development, except for existing conserved/protected lands. All other parcels reflected current land-use (NLCD code 24).
- **Dev S5:** Conversion of 20% of parcels with highest Development Risk Index to High Intensity Development, except for existing conserved/protected lands. All other parcels reflected current land-use (NLCD code 24).
- **Dev S6:** Conversion of 5% of parcels with highest Development Risk Index to High Intensity Development, except for existing conserved/protected lands. All other parcels reflected current land-use (NLCD code 24).

The distribution of major LULC categories for each scenario is presented in Figure 3, while the spatial for some of the scenarios is presented in Figure 4. We note that not all forestland in the watershed is likely to be converted in the next 50 or even 100 years; however, using this staggered approach does allow us to systematically estimate potential impacts to water quality and other ecosystem services under different degrees of forest loss. As a result, the S6 scenario reflects the development of a small fraction of the watershed which is likely to be developed in the next 20 years based on historic trends, while the S1 scenario reflects the complete conversion of non-conserved lands in the watershed (the worst-case scenario) to development, and thus the upper bound in terms of impacts from land use change.

The collective results of these scenarios can be coupled with the ecosystem service benefit valuation approach to help prioritize which parcels to invest in sooner than later based on the net benefit that they provide to the Sebago Lake watershed. The degree to which land is conserved will ultimately depend on the budget available for conservation as well as the number of parcels that are estimated to provide net benefits.

We note that earlier drafts of this report included alternative scenarios that focused on impacts if land were converted based on their relative impact on water quality due to nutrient and sediment loading (i.e., environmental risk). While these scenarios were not required for the final analysis, we have included the InVEST model output in Appendix 3 as a reference for how sensitive the estimates are to alternative parameterization, particularly the assumption about what level of development intensity forestland is converted to.

[4] N.B., not all parcels are the same size. Thus, conserving 20% of the parcels does not result in conserving 20% of the remaining forestland.

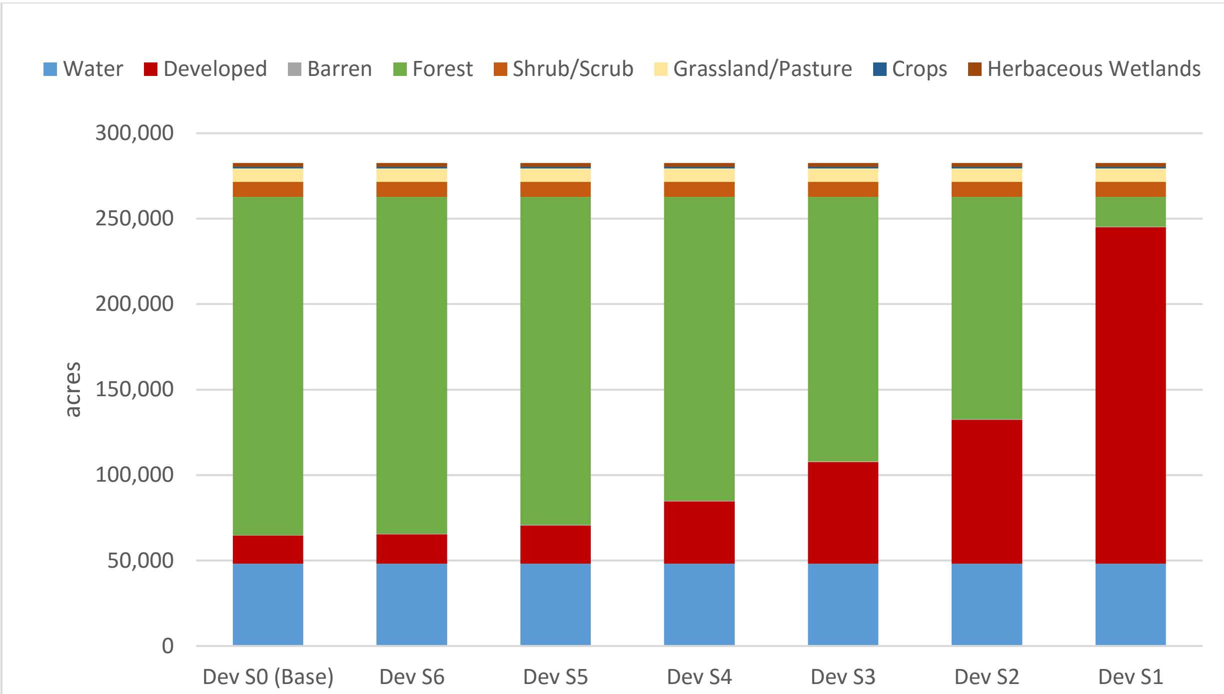

Figure 3. Sebago Lake watershed land use by Development Risk scenarios.

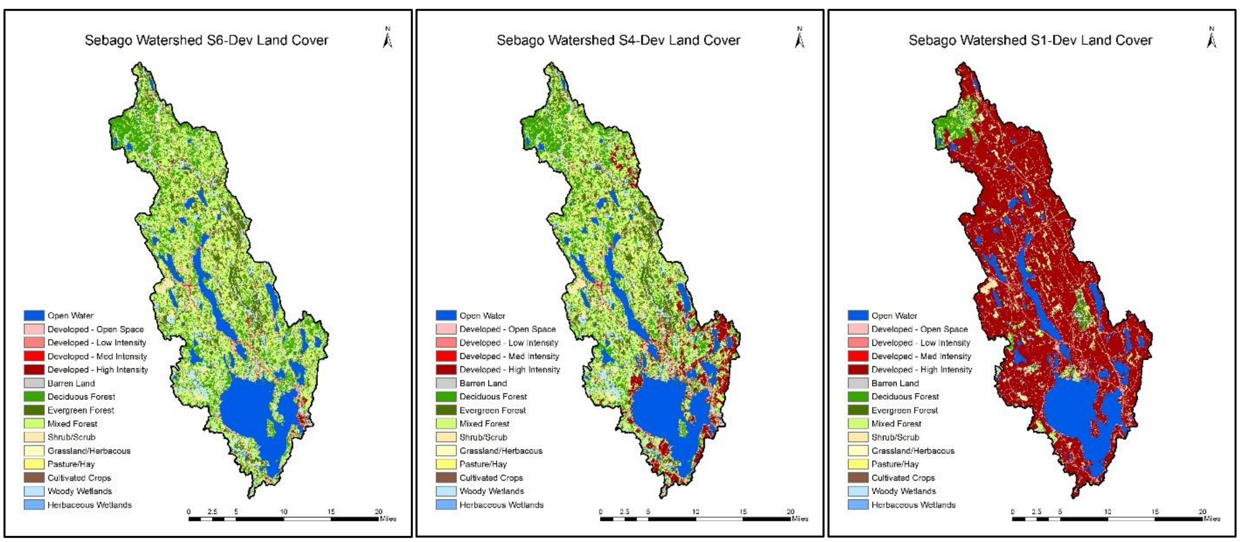

Figure 4. Dev S6, Dev S4 and Dev S1 scenarios show different levels and patterns of development.

2.3.4 Valuing ecosystem service benefits

Valuation of ecosystem services in specific study sites can be costly in terms of time and money. As a result, it is common practice in ecosystem services valuation to use estimates generated at other research sites that are contextually similar to the site of interest, in this case the Sebago Lake watershed. This methodology is referred to as "benefits transfer" or "values transfer."

We primarily use the benefit transfer approach to monetize the values associated with ecosystem goods and services in the Sebago Lake watershed. The method is broadly defined as the use of research results from preexisting primary studies at one or more sites (often called study sites) to predict welfare estimates, such as willingness to pay (WTP), for other, typically unstudied sites which are often referred to as policy sites (Johnston and Wainger 2015). Researchers most often use this approach when time, funding, data availability or other constraints preclude high-quality primary research, which was the case for this study. The increasing focus among government agencies and others on the quantification of ecosystem service values (e.g., President's Council of Advisors on Science and Technology 2011), combined with a lack of time and resources required for high-quality primary research, has led to the increasing use of benefit transfer to quantify these values (Bateman et al. 2011; Wainger and Mazzotta 2011).

Other studies have used similar methods to estimate the value of ecosystem services at the global (e.g., Costanza et al. 2014; de Groot et al. 2012) and regional scale (Sills et al. 2017), including Maine (Troy, 2012). For example, Troy (2012) used a benefits transfer approach based on values taken from studies in temperate areas of central and eastern North America, northern Europe, and New Zealand to estimate the value of non-provisioning ecosystem services for the entire state of Maine. Using parcels in the Sebago Lake area as a case study, Troy (2012) estimated that the average forested parcel in the watershed can generate $12,000 or more per annum, where the value is based on the sum of at least seven ecosystem services[5]. This parcel-level estimate is equivalent to about $500/ac/yr for forested areas of the catchment.

We follow a similar approach as Troy (2012) in terms of defining our geographical boundary for collecting data for our benefits transfer application. That is, we first limited the range of non-market valuation studies for the study's set of forest ecosystem services to the northeast US and eastern Canada. When information was still lacking, we then extended our range to all temperate forests in the US and Canada. Key sources of information, which all included a wide range of studies to consider, included the Environmental Valuation Research Inventory (EVRI)[6], the USGS Benefit Transfer Toolkit[7], the Oregon State University Recreation Use Values Database[8], the Natural Assets Information System (NAIS) estimates published in Troy (2012), and recent summary papers by de Groot et al. (2012), Weber (2014) and Nolander and Lundmark (2016). Furthermore, we used stumpage price and harvest data from the Maine Forest Service (2018) to estimate the value of fiber and fuel provision. The value of forest carbon sequestration was estimated using the US Government's (2016) estimates of the social cost of carbon (SCC), which is the carbon value that agencies use when conducting economic analyses of proposed federal regulations.

To the extent possible, we tried to measure ecosystem services at the highest resolution possible, to account for the potential variation in services provided across the watershed. For example, values related to N, P, and S (water purification) were all estimated as kilograms per parcel because they were estimated at that resolution in InVEST. On the other hand, ecosystem services associated with recreation and air purification could only be estimated at a per acre basis (Table 2). Furthermore, we note that in many cases, there could be several metrics used to quantify a

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[5] i.e., Gas regulation, disturbance regulation, soil regulation, nutrient regulation, water supply, recreation, habitat refugium

[6] https://www.evri.ca/en

[7] https://my.usgs.gov/benefit-transfer/

[8] http://recvaluation.forestry.oregonstate.edu/

specific ecosystem service. For example, the value of forests in regulating N, P, and S losses can be collectively used to estimate impacts to water related ecosystem services (i.e., water purification and storm protection).

Table 2. Ecosystem Services and associated metrics used to quantify them for the Sebago Lake watershed.

Ecosystem Service	Metric	Unit	Methodology
Fiber and fuel provision	Sawlogs	$/MBF	Market price
	Pulpwood	$/green ton	Market price
Water purification & erosion control	N retention	$/lb	Avoided cost, replacement cost, market price of water supply, choice experiments
	P retention	$/lb	
	Sediment retention	$/ton	
Climate regulation	Carbon sequestration	$/tCO2e	Avoided cost, market price of carbon
Air quality maintenance	Air pollutant removal	$/Acre	Avoided cost, replacement cost
Recreation & ecotourism	Recreation	$/Acre	Travel cost, contingent valuation, choice experiments
Provisioning of habitat	Habitat	$/Acre	Contingent valuation, choice experiments

The total monetized ecosystem service value of a given area can be estimated by multiplying the physical ecosystem service metric by the unit value and then summing over all ecosystem services that the area provides. For example, if forest-based recreation values is estimated to be $50/ac/yr, and a parcel has an area of 10 acres, then the total value of that forest recreation in that parcel is $1,000/yr.

The value of fuel and fiber and carbon sequestration were estimated in a slightly more detailed manner than the other ecosystem services, particularly because of how the forest accrues biomass and is irregularly harvested. For the provision of fuel and fiber, we used plot-level Forest Inventory and Analysis (USDA 2018) and regional harvest and wood processing data (MFS 2018) to estimate the average annual rate of sawlogs and pulpwood removed from a given acre of forestland. This approach assumes that there is a small but continuous flow of fuel and fiber from every parcel of timberland in the watershed. While that may not actually be the case, we believe that it is reasonable, as it is basically equivalent to annualizing a larger harvest that may occur at a set point in the future.

The InVEST model measures forest carbon stocks, or the total amount of carbon currently stored in a given stand. To be compared with the value of the other ecosystem services on an annual basis, this stock must be converted to an annual figure. We do this by applying a rental rate on the total value of the carbon stock that is equal to the study's interest or discount rate (Sohngen and Mendelsohn 2003). The approach is mathematically equivalent to applying a full payment to the yearly change in carbon stock, which is typically referred to as carbon sequestration, and thus an adequate methodology particularly in the case when we only have an estimate of the carbon stock.

The range of ecosystem service valuation estimates can vary widely across studies depending on the specific location and purpose of the research. As a result, we conducted sensitivity analysis using a low, medium, and high valuation estimates sourced from the literature to account for the potential uncertainty in our approach and estimates. Using this sensitivity analysis also allows us to identify if there are specific ecosystem services and associated values that have a key influence on the benefit-cost analysis. It also helps to isolate parcels that are estimated to have a high return on investment, even in the case where there 'low' ecosystem services 'values' are applied (e.g., forestland with high carbon stocks and/or water purification capabilities).

2.4 Estimating Costs

We identified two key costs associated with conserving forestland in the Sebago Lake watershed. The first major cost is the amount required to construct and manage a water filtration plant should the PWD lose their filtration waiver due to a consistent reduction in water quality. The second major cost is that to conserve existing forestland via fee acquisition or a conservation easement that would permanently remove development rights from a given parcel. The methodology for estimating each set of costs is detailed below.

2.4.1 Filtration Plant Costs

At present, PWD has a filtration waiver, essentially meaning that they do not need a filtration plant to treat surface water before distributing it to its customers. However, if water quality in the watershed was to deteriorate to the level that a plant was needed, this would require an investment of several million dollars. To estimate the cost of the plant, we consulted with PWD about the capital and operation and maintenance (O&M) expenditures required to build and run a 75 million gallon per day (MGD) plant, which they estimated would be an adequate capacity. These cost estimates were then compared to costs published by EPA for plants with a capacity greater than 10 MGD (EPA 2008). All plants were assumed to have a lifetime of 25 years, with the capital cost being financed at an interest rate of 6%. Regression analysis was used to confirm that the estimates provided by PWD were consistent with the literature.

The additional cost that the PWD would face by needing to construct and maintain a filtration plant was assumed to be passed through to their customers through increased rate payments. These rates and structure in which water costs are levied vary by type of customer (e.g., residential, commercial, industrial, etc). The information for this part of the analysis was provided by PWD, who also reviewed the final cost estimates.

2.4.2 Land Acquisition Costs

The study estimated land acquisition costs using records of previous fee acquisition and conservation easement (CE) transactions in the Sebago Lake watershed as well as municipal valuations of forestland. These land acquisition costs were compared to the surrounding area and greater Maine to assess whether local transactions were consistent with other areas. We assumed that land acquisition and easement costs would make up the bulk of costs for conserving forestland in the watershed quantified in the BCA. Permanently conserving land also has an opportunity cost, as the use of the land becomes more restricted. However, this component is reflected in the price paid to put the land into permanent conservation. That is, if the parcel being considered for conservation is in an area with high development potential, then this cost should be reflected in the purchase or easement costs.

Detailed data on land acquisition costs sourced from the literature are listed in Table 31 to Table 30 of Appendix 2.

2.5 Sensitivity analysis

We conduct sensitivity analysis to account for uncertainty of a range of values and assumptions employed in our assessment. Taking this approach allows us to test how consistent our findings are over a wide range of conditions, as well as identify which areas of the catchment may be affected more than others depending on the varying assumption. These include:

- Varying land cover change pathways associated with environmental and development risk to estimate the range of impacts to ecosystem services in the watershed.
- Modeling low, medium, and high 'benefit value' scenarios for monetizing the various ecosystem service values sourced from the literature.
- Adjusting the ratio of land that is conserved via fee acquisition and conservation easement.

2.6 Watershed Investment and Ecosystem Market Opportunities

We briefly reviewed the literature to identify potential watershed investment and ecosystem market opportunities to incentivize stakeholders to conserve forestland in the Sebago Lake watershed. Ecosystem markets provide opportunities particularly those for watershed restoration and forest carbon offsets. We also summarize the literature on consumers' willingness to pay for 'green' products and services from businesses following corporate social responsibility (CSR) guidelines.

3. Model Baseline

3.1 Land Cover

The Sebago Lake watershed covers approximately 282,000 acres (115,000 hectares). Excluding the 48,000 acres of open water within the watershed, nearly 234,000 ac. or 84% of the land cover in the study area is currently classified as forest (Figure 5), which is situated throughout the watershed (Figure 6). Other land covers include developed areas (7%), which are primarily concentrated in the central and southern parts of the study area, shrub/scrub (4%) and grassland/pasture (3%).

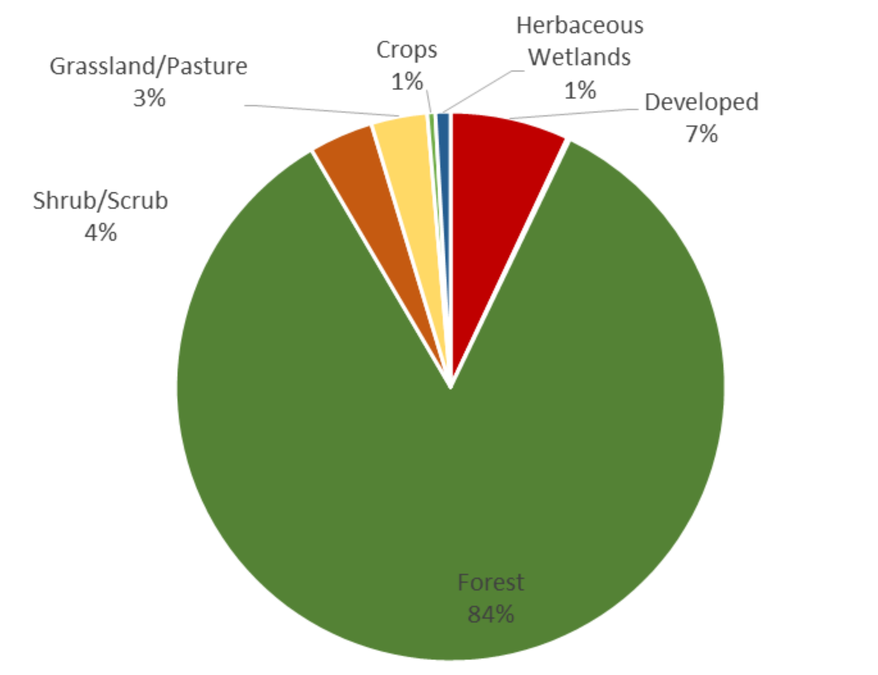


Figure 5. Aggregated distribution of Sebago Lake watershed land cover, excluding open water (Source: 2011 NLCD).

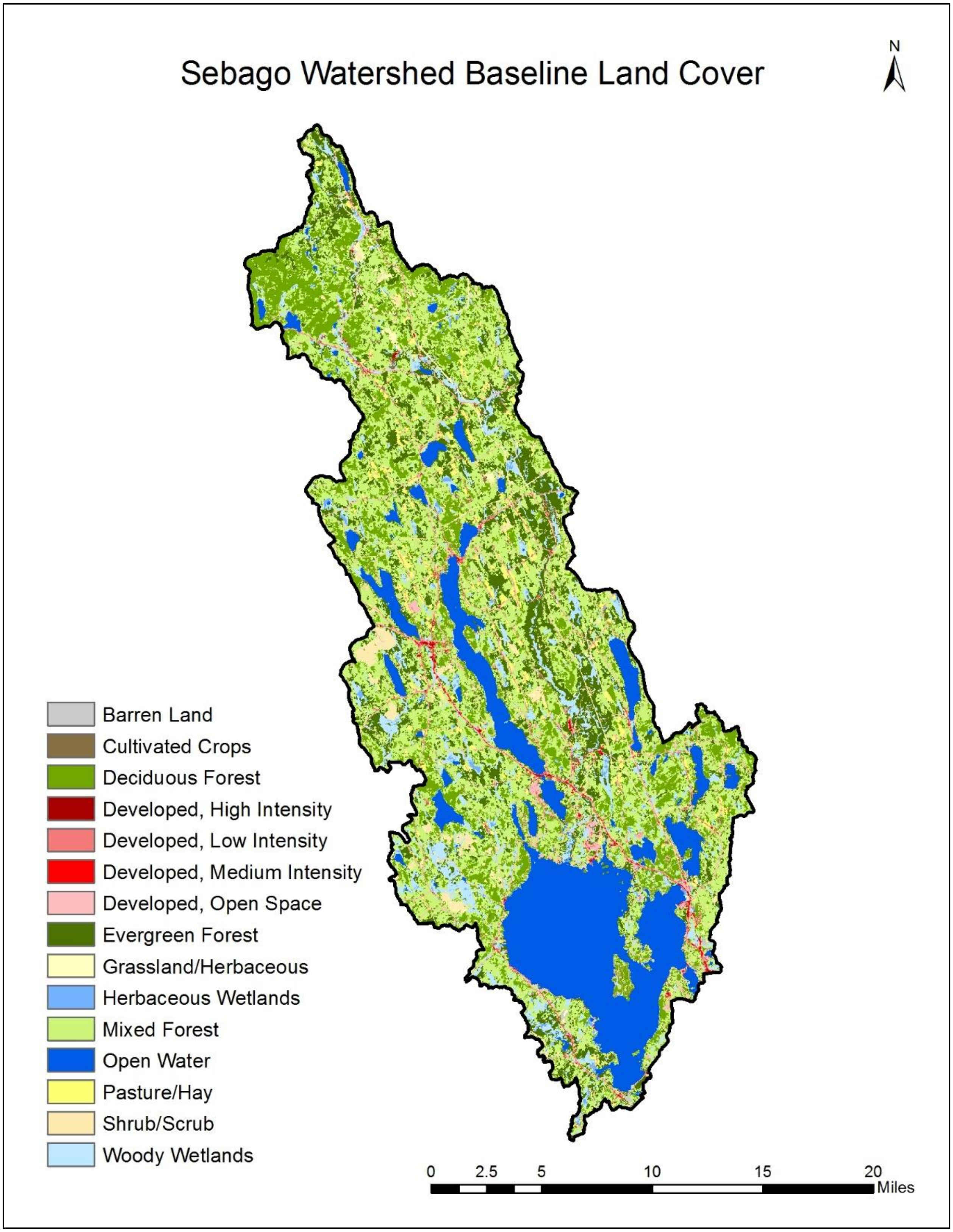


Figure 6. Spatial distribution of Sebago Lake watershed land cover (Source: 2011 NLCD).

3.2 Conserved Land

Approximately 25,000 acres of the Sebago Lake watershed is currently conserved (Maine Office of GIS, 2018). This is equivalent to about 10% of total area in the watershed, with a majority of the conserved area classified as forestland. About 74% of this land is conserved through fee acquisition, while the remainder is enrolled as conservation easements. The largest owners are the federal (38%) and state (26%) agencies (Table 3). The spatial distribution of the conservation land indicates that it is spread relatively uniformly across the watershed, with relatively large contiguous parcels located in the north and central areas and smaller parcels owned around the actual Sebago Lake in the south (Figure 7).

Table 3. Current conservation land area by owner in the Sebago Lake watershed (Source: Maine office of GIS).

Conservation Type and Owner	Federal	State	Municipal	Other	Private	Total
Conservation Easement						
Greater Lovell Land Trust	0	0	0	0	95	95
Loon Echo Land Trust	0	0	0	0	1,490	1,490
Mahoosuc Land Trust	0	0	0	0	32	32
Maine Bureau of Parks and Lands	0	3,292	0	0	0	3,292
Maine Department of Inland Fish & Wildlife	0	3	0	0	0	3
Maine Farmland Trust	0	0	0	0	320	320
Presumpscot Regional Land Trust	0	0	0	0	129	129
Western Foothills Land Trust	0	0	0	0	1,204	1,204
Conservation Easement Total	**0**	**3,295**	**0**	**0**	**3,270**	**6,565**
Fee Acquisition						
Bridgton Water District	0	0	0	95	0	95
Lakes Environmental Association	0	0	0	0	358	358
Loon Echo Land Trust	0	0	0	0	1,363	1,363
Maine Bureau of Parks and Lands	0	1,670	0	0	0	1,670
Maine Department of IFW	0	1,428	0	0	0	1,428
Maine Department of Transportation	0	46	0	0	0	46
Maine Minor Civil Division	0	0	1,301	0	0	1,301
Portland Water District	0	0	0	1,885	0	1,885
Maine Woodland Owners	0	0	0	0	109	109
The Nature Conservancy	0	0	0	0	371	371
US Department of Interior	9,421	0	0	0	0	9,421
Western Foothills Land Trust	0	0	0	0	449	449
Fee Acquisition Total	**9,421**	**3,144**	**1,301**	**1,980**	**2,650**	**18,497**
Conservation Land Total	**9,421**	**6,440**	**1,301**	**1,980**	**5,921**	**25,062**

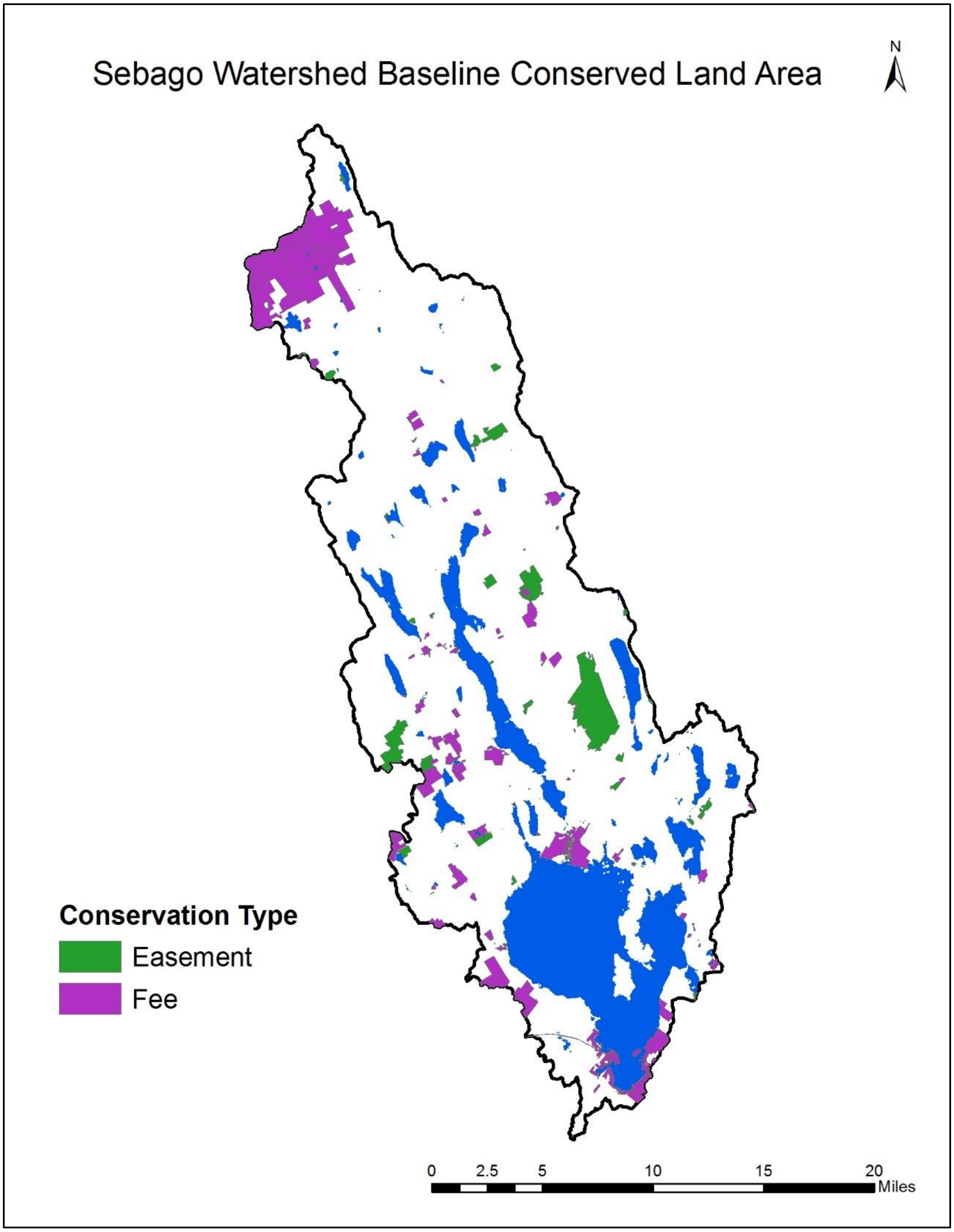


Figure 7. Spatial distribution of conserved land in Sebago Lake watershed (Source: Maine Office of GIS, 2018).

3.3 Key Environmental Outputs

We ran the InVEST model to quantify the 'baseline' (Scenario S0) N, P, and S loadings and carbon stocks under the most recent land cover data available from the National Land Cover Database (2011). Baseline estimates are that about 43,300 lb N, 14,000 lb P, and 370,000 tons S reach the waterways from non-point sources (i.e., land) in the watershed each year. In addition, InVEST estimated that the watershed's total current carbon stock is 13.5 million tons of carbon dioxide equivalent (tCO2e), which translates to about 70 tCO2e/ac. This figure is relatively close to other estimates of an average forest in Maine (Henniger et al. 2013; Butler 2018). These baseline load estimates can then be used to compare to estimates from the Development Risk scenarios.

Table 4: Sebago Lake watershed baseline (S0) ecosystem services measured in InVEST.

Indicator	Total	Mean per acre
Nitrogen Loss (lb/yr)	43,270	0.18
Phosphorus Loss (lb/yr)	13,997	0.07
Sediment (t/yr)	369,772	1.58
Carbon Stock (tCO2e)	16,415,340	70.05

The spatial distribution of the baseline InVEST estimates are shown in Figure 8. The figures indicate that there are some areas of the watershed where N, P, and S loads are all relatively high, particularly in the areas that are developed or have limited forest cover. Of course, these areas are not available for conservation. The estimates from our scenarios analysis, which is covered in the next section, will provide more insight into what future loads could be if areas currently classified as non-conserved forest are cleared.

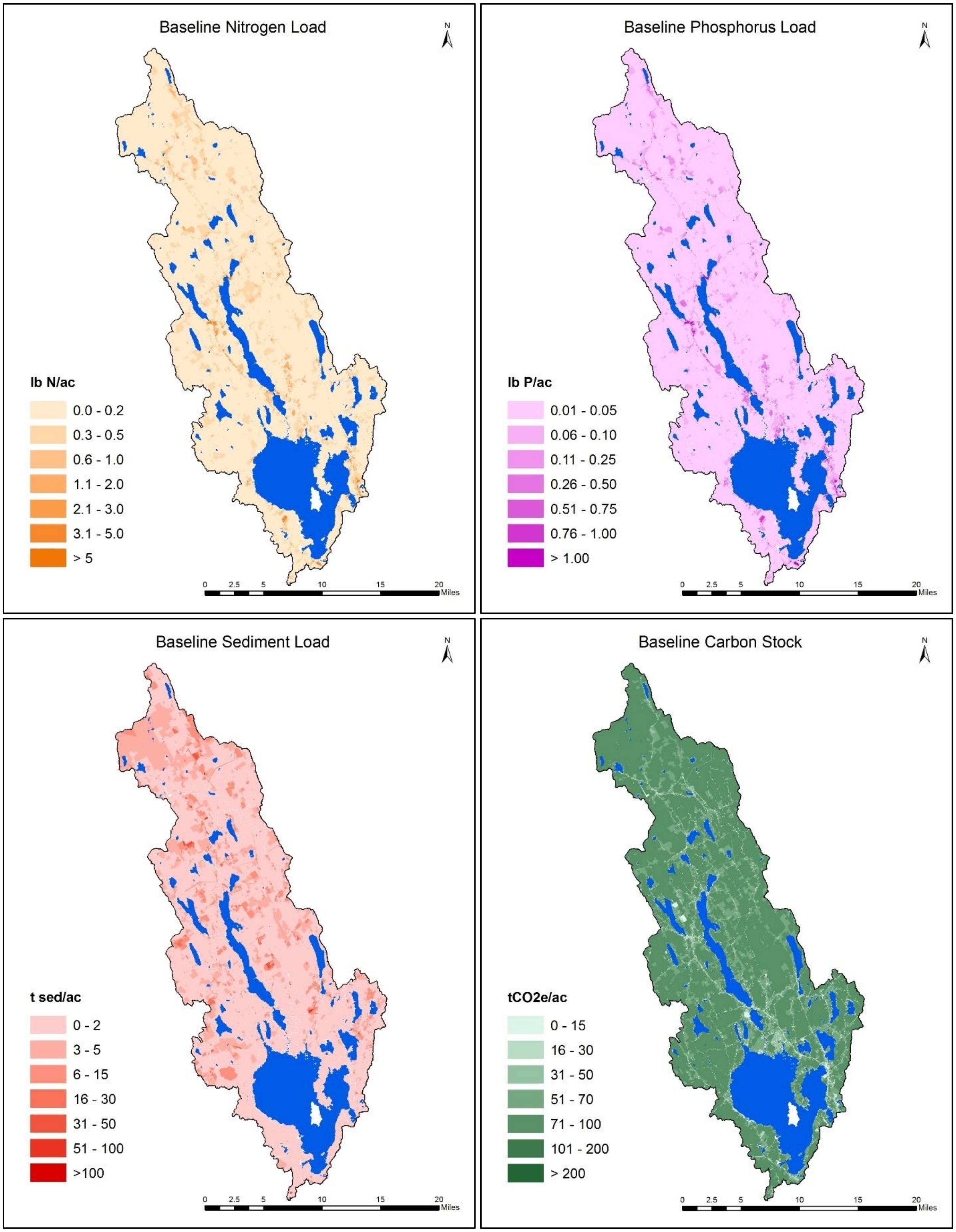


Figure 8. InVEST model estimates of N, P, and S loads and C stock in Sebago Lake watershed based on current land cover.

4. Scenario Results

4.1 Land Cover and Ecosystem Services

Modelling the Development Risk scenarios (i.e. when urban development increased in the watershed) in InVEST revealed that both nutrient and sediment loads could increase dramatically depending on the amount of forestland currently not conserved is converted to development, while carbon stocks have a noticeable decrease (Figure 9). The plot of the results indicate that the response to converting forest is relatively linear regardless of the environmental metric of concern.

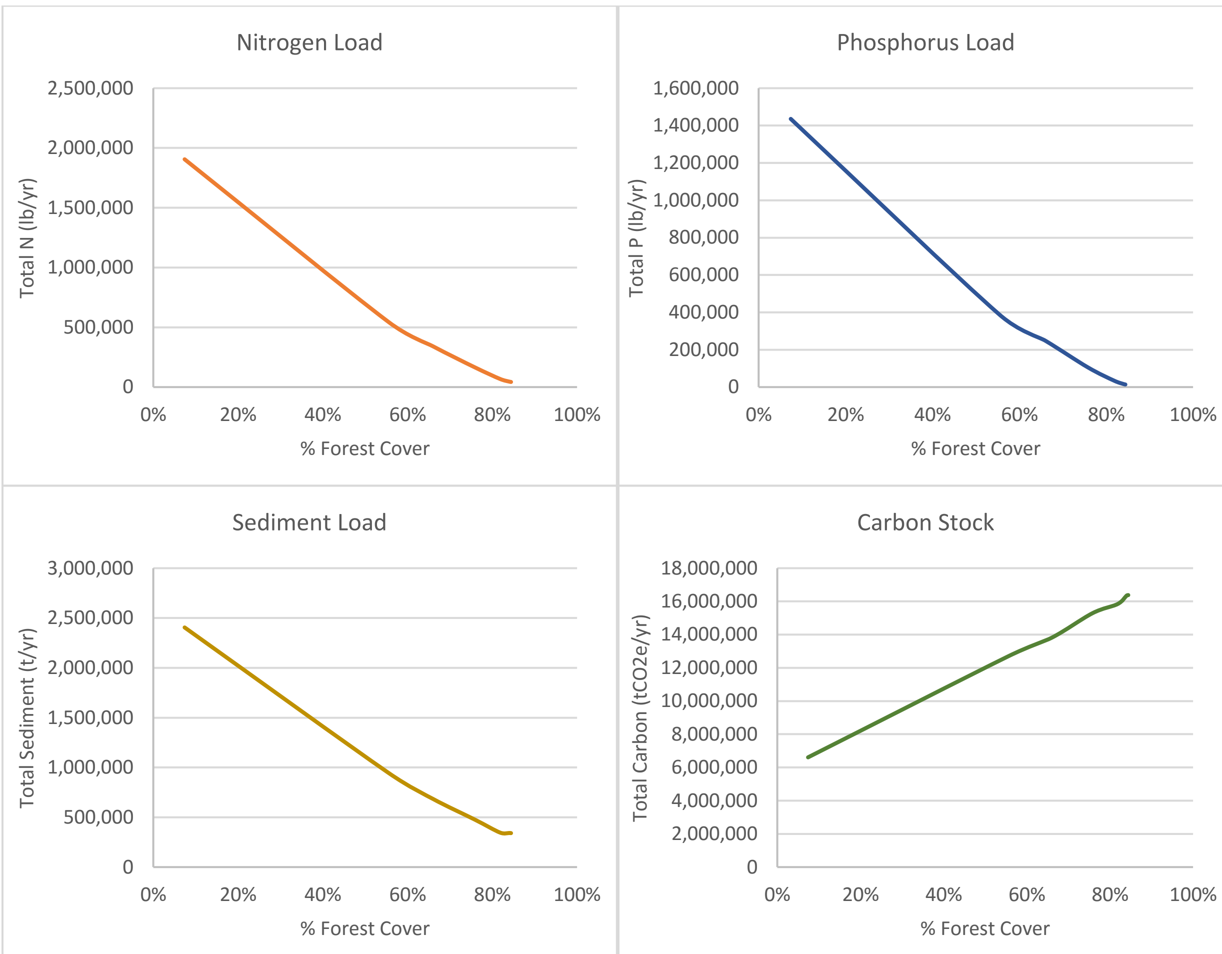


Figure 9. Estimated change in key ecosystem services from converting forestland to development

The spatial distribution of the outputs also vary by the location and amount of forest conversion, as expected (see Figure 10 and Figure 11 for the Dev 1 and Dev S4 outputs). Future development is concentrated in the more urbanized southern and eastern sections of the watershed, and thus there are higher levels of nutrient and sediment losses in those regions. This finding is particularly apparent when you look at the Dev S4 scenario outputs on the right hand side of the figures. Furthermore, the nutrient outputs are consistently negatively correlated with the carbon stock estimates, highlighting where the development is primarily occurring for the given scenario.

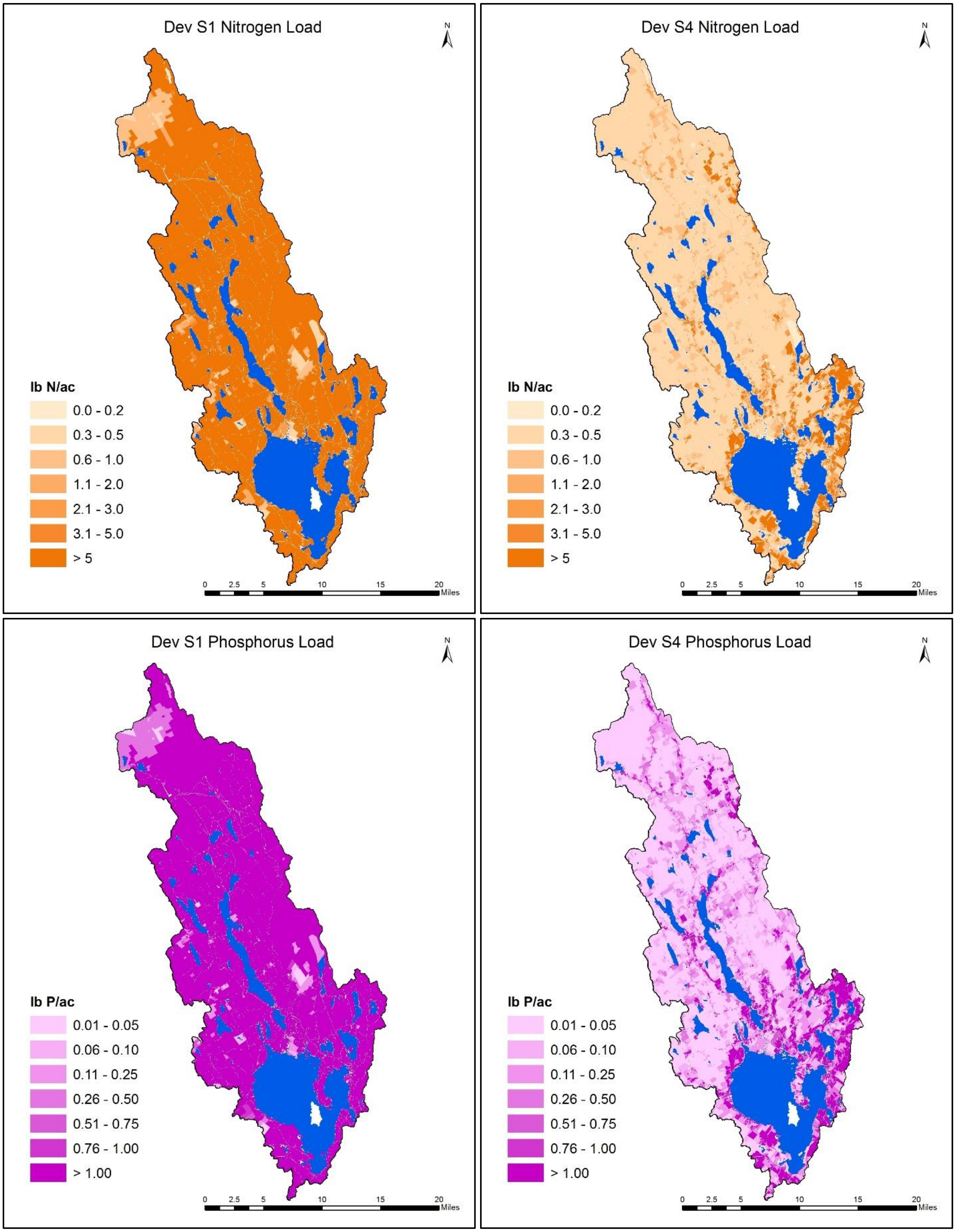


Figure 10. Spatial distribution of InVEST nutrient loading for the Dev S1 (Full conversion) and Dev S4 (76% forest cover) scenarios

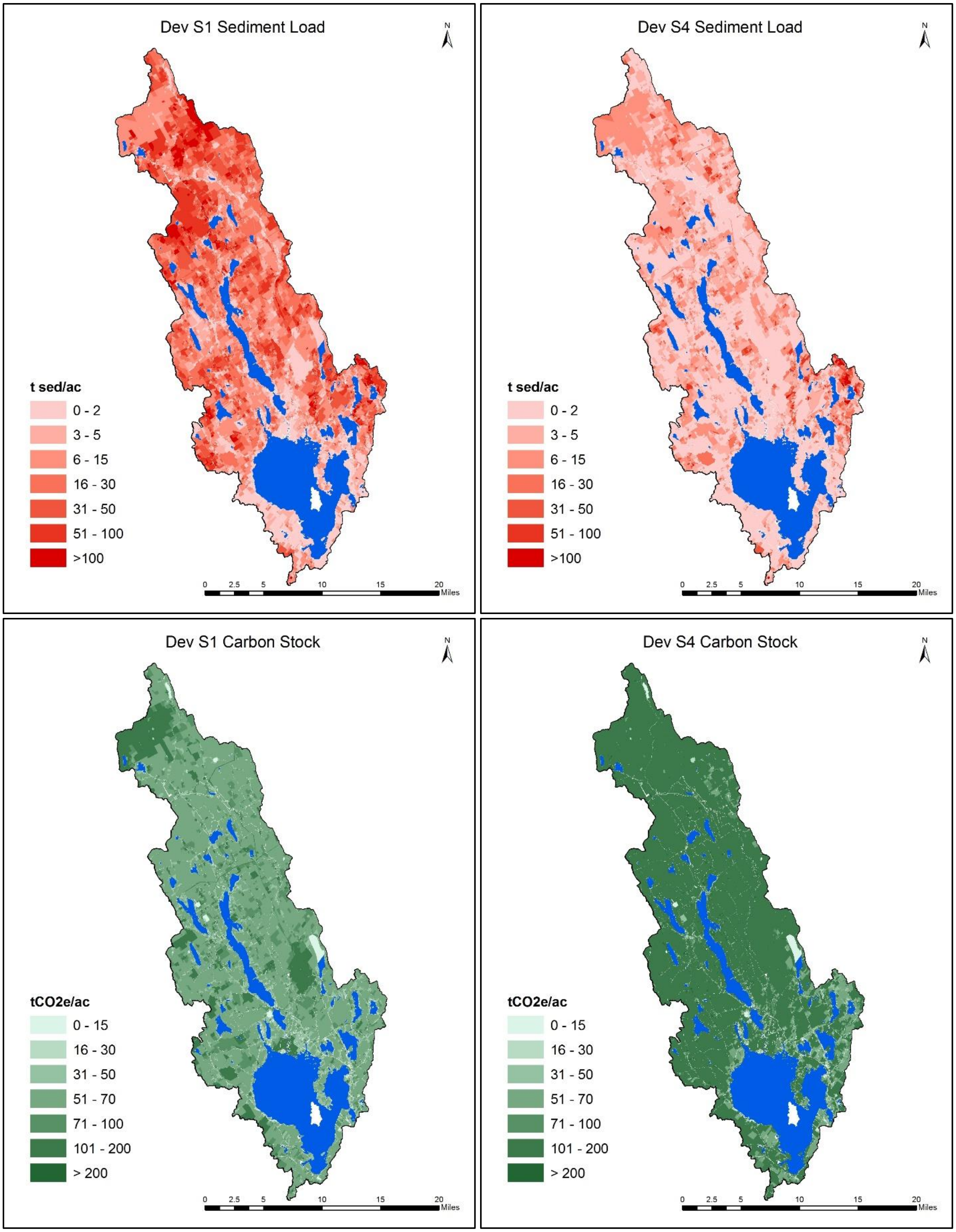


Figure 11. Spatial distribution of InVEST sediment loading and carbon stocks for the Dev S1 (Full conversion) and Dev S4 (76% forest cover) scenarios

4.1.1 Model Validation

The parametrization of InVEST for the Sebago Lake watershed used measured data from the watershed to calibrate the N and P loads in the model. However, no comprehensive sediment budget or field-based carbon stock inventory for the entire watershed exists, and thus we relied on default parameters in InVEST to parameterize and calibrate the SDR and carbon stock components (InVEST 2018). To evaluate the validity of our N loading estimates, we compared the InVEST output to regional estimates from the SPARROW watershed contaminant transport model (Moore et al. 2004; Liebman, pers comm) and a 2018 unpublished dataset of total nitrogen sampling at three river locations along Casco Bay (Gray, pers comm). We found the N load estimates were of similar magnitude to both the SPARROW modeling and N sampling results, and thus have confidence that InVEST is doing a reasonable job capturing the N loading dynamics in the watershed.

A similar exercise was conducted to assess the P loading estimates from InVEST. In 2015, the Cumberland County Soil and Water Conservation District published *The Sebago Lake Subwatershed Assessment and Prioritization* report. This report presents decades of compiled field data on phosphorus loading and Trophic State Indices for 29 sub-watersheds in the Sebago Lake watershed. InVEST's initial parameterization showed phosphorus loading of approximately half of the measured loads. Further investigation indicated that InVEST may have a P loading bias from using agricultural P losses for its default parameterization rather than P losses from urban or suburban sources, which are a more dominant land use in the Sebago Lake watershed. As a result, we adjusted the P loss parameters in InVEST to better reflect the conditions of the watershed. The sub-watershed results presented in Table 5 highlight the improved overall watershed level P loading estimates for aggregated sub-watersheds in the Sebago Lake watershed. We do note that for the "Sebago Lake and Crooked River" sub-watershed, there is still an underestimation of P loading compared to the measured loadings. Nonetheless, our re-parameterized NDR model more closely reflects the measured P loading in the catchment.

Table 5. InVEST model validation for Phosphorus loss to Sebago Lake sub-watersheds.

Sub-watershed	Actual Data (kg P yr^{-1})	Default Parameterization	Re-Parameterized Model Results
Sebago Lake and Crooked River	5802.1	2027	2906.4
Brandy Pond (Long Lake)	1151.8	653	1054.6
Muddy River	130.1	67	69.3
Panther Run	260.9	25	316.7
Peabody Pond	52.8	152	162
Willett Brook	126.6	372	611.1
Bear River	98.6	174	225.2
Total	**7524.3**	**3526**	**5120.1**

4.1.2 Risks to Water Quality

The set of scenarios modeled in this report were developed to estimate the range of impacts to water quality as a result of converting forest to developed land. Qualitatively, the level of impacts to water quality that concern us here are those that would require drinking water to be treated in a filtration plant before it could be consumed. A review of prior analyses indicates that, on average, water treatment costs start to escalate measurably in watersheds that are less than 60-70% forested (Morse et al. 2018). While the total loss of forest or full urbanization of the Sebago Lake watershed are unlikely to occur over the next 30 to 50 years, such changes would significantly alter water quality in this watershed. This leads to the question: *at what point in the Sebago Lake watershed does water quality deteriorate beyond an acceptable level?*

The actual P, N, or sediment loading that a waterbody can receive without becoming impaired depends on a large number of waterbody-specific factors, such as the depth, flushing rate, species of algae present, micronutrient availability and light regimes. Therefore, it is challenging, in the absence of specific, field-based estimates of biogeochemical and hydrodynamic parameters for all sub-watersheds, to establish a single threshold value for water quality impairment. Given this, we investigated various ways to define a generic threshold of water quality impairment that would trigger filtration plant treatment in the Sebago Lake.

Several approaches to water quality categorization are available. Specifically, Maine employs a Trophic State Index (TSI) to assess the overall productivity of a lake. The TSI of chlorophyll a*,* total P, and turbidity. More eutrophic lakes have diminished water quality. The Maine Department of Environmental Protection (DEP) works with the Portland Water District and volunteer water quality monitors to regularly monitor lakes and streams in the watershed. Recent reporting of phosphorus loads and concentrations at various points in the watershed indicated that only a few of sub-watersheds in the Sebago Lake have high productivity/eutrophic current conditions (CCSWCD, 2015).

The state of Maine also monitors and assesses water quality impairment for all waterbodies in the state. While Maine is currently working to develop numeric criteria, the state currently uses narrative water quality criteria – like swimmability and drinkability – to determine water body impairment for nutrient loading in its implementation of the Clean Water Act. Depending on the source of pollution, an impairment designation for a water body (303(d) listing) triggers the need to develop a Total Maximum Daily Load (TMDL) specific to that water body. A TMDL represents the total amount of a specific pollutant that can be in a water body from all point and non-point sources. These TMDLs represent estimates for specific waterbodies of the total amount of pollution that can be received without impairing narrative water quality criteria.

Thus, in this report we assess the question: at what level of forest loss to development would pollution loading lead to widespread non-attainment of water quality triggering broad-scale need for TMDLs for waterbodies in the watershed? We focus specifically and primarily on P loading, as it is the pollution component that is most likely to first trigger impairment of water quality in the watershed.

First, we can consider existing TMDLs for already impaired sub-watersheds in the Sebago Lake watershed, as some lakes in the watershed already exceed phosphorus TMDLs. In 2004, Maine DEP developed a Total Phosphorus TMDL and Phosphorus Control Action Plan (PCAP) for Highland Lake and in 2005 for Long Lake, both located in the upper watershed. The 2004 PCAP-TMDL for Highland Lake estimates that waterbody's natural flushing and TP processing rates are 467kg of TP per year for a 2,642 ha direct watershed, leading to a watershed-specific

TMDL of **0.18 kg P/ha/yr** (Maine DEP 2004)**.** The 2005 Phosphorus Control Action Plan and TMDL for Long Lake in the Sebago Lake Watershed found a total processing capacity for the lake of 1923 kg P annually. For a 9,324 ha direct watershed, this equates to a watershed specific TMDL of **0.21 kg P/ha/yr** (Maine DEP 2005). More recently, in 2016, Maine DEP developed a Statewide TMDL for Nonpoint Source Pollution. These are statewide average levels that essentially represent a "threshold" of water quality attainment for a "generic" water body in Maine. The 2016 Maine DEP Statewide TMDL for Nonpoint Source Pollution are **0.244 kg P/ha/yr**, **5.185 kg N/ha/yr**, and **0.03 t sediment/ha/yr.** While noting that each waterbody's processing rates, flushing rates, and biogeochemical dynamics will influence the specific TP loads that any given water body can receive without becoming impaired, the examples presented here provide us some insight as to what levels TMDL's could be established in the Sebago Lake watershed.

For Sebago Lake Watershed, the first water quality parameter that would become impaired due to development is P loading. Table 6 shows the difference in estimated mean annual outputs from InVEST for the Development Risk Scenarios. Comparing this to the TMDL figures reveals that the P loading TMDL is "triggered" between the Dev S4 and Dev S5 scenarios, or when forest cover is reduced from 84% to between 76% and 82%. Thus, about 20,000 acres of current forestland could be converted to high intensity development before water quality deteriorates to the level that widespread water quality impairment in the watershed would be experienced. Notably, the same level of forest cover would trigger TMDLs for sub-watersheds equivalent to Highland and Long Lake and for the statewide average TMDL. This gives high confidence that widespread water quality impairment for P would occur at 76% forest cover in the watershed. Nitrogen impairment, meanwhile, would not be triggered until far lower percentages of forest cover were experienced.

Table 6. Estimated InVEST outputs compared to 2016 Maine DEP TMDL

	2016 Maine TMDL	Base	Dev S6	Dev S5	Dev S4	Dev S3	Dev S2	Dev S1
N (kg/ha/yr)	***5.185***	0.21	0.22	0.32	0.80	1.63	2.62	9.13
P (kg/ha/yr)	***0.244***	0.07	0.08	0.16	0.50	1.19	1.86	6.88

Under our Development Risk Scenario modeling, the threshold for loss of water quality attainment due to impairment by phosphorus loading would be surpassed on average for the whole Sebago Lake watershed at 76% forest cover.

4.2 Monetized Benefits

We used a benefit transfer approach that aggregated estimates from a range of studies that focused on areas similar to the Sebago Lake watershed, including Maine, the Northeast and Mid-Atlantic US, and eastern Canada. The literature search a large range in the estimated unit values associated with the ecosystem services we focus on in this assessment. These values vary depending on the study focus, methodology, and location. As a result, we have chosen to use the benefit transfer method for three different levels of estimates from that literature: low, medium, and high ecosystem service valuation (Table 7). Taking this broader valuation approach allowed us to determine whether the benefit values must go over a certain level before investing in forestland conservation provides net benefits.

Table 7. Range of ecosystem service unit values applicable to Sebago Lake watershed based on benefits transfer approach.

Ecosystem Service	Metric	Unit	Low	Medium	High
Fiber and Fuel Provision	Sawlogs	$/MBF	120.00	140.00	180.00
	Pulpwood	$/green ton	7.00	13.00	25.00
Water purification & erosion control	N retention	$/lb	4.50	9.10	18.20
	P retention	$/lb	6.80	19.60	25.50
	Sediment retention	$/ton	2.00	6.40	46.00
Climate regulation	Carbon sequestration	$/tCO2e	12.00	39.00	114.00
Air Quality Maintenance	Air pollutant removal	$/acre	66.00	127.00	206.00
Recreation & Ecotourism	Recreation	$/acre	12.00	105.00	198.00
Provisioning of habitat	Habitat	$/acre	52.00	163.00	350.00

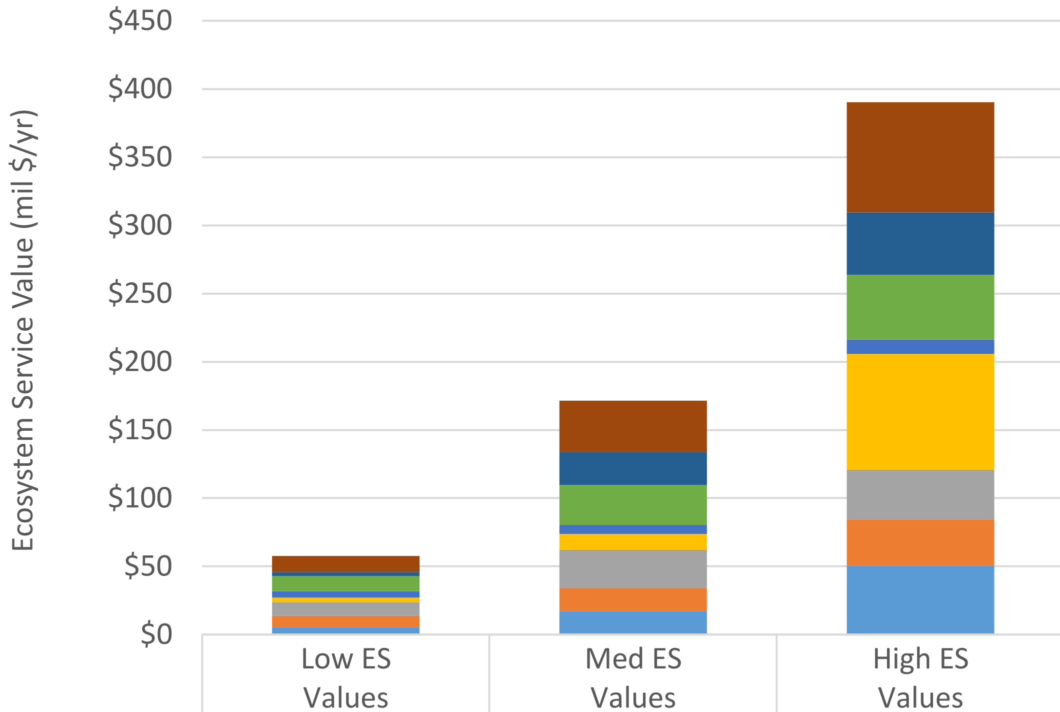
To translate these values to forestland in the Sebago Lake watershed, we quantified what the loss in these services may be if forest was converted to development, which could have large implications for a number of ecosystem services. The N, P, S and carbon estimates are measured as changes in environmental outputs from InVEST relative to the baseline scenario. That is, if a parcel of land is assumed to change under the Dev S4, scenario, then we quantify the difference in outputs between the baseline forest cover and new development. The parcel-level values are then aggregated across the entire watershed to get a total ecosystem service value for the remaining forestland technically conserved under that scenario.

4.2.1 Current Forestland Estimates

We estimate that the total baseline annual value of the selected forest ecosystem services in the Sebago Lake watershed is $58 to 390 million per year, with the 'medium' ecosystem service values giving value of about $172 million per year, or $870/ac/yr (Figure 12). This value is estimated from taking the difference between the baseline forest cover and associated environmental outputs relative to the most extreme scenario where all the forestland is converted to high intensity development. Although we acknowledge that it is highly unlikely that all of the forestland will be converted in this manner over the study period, this method allows us to adequately capture the value of N, P and S retention a C stocks from *maintaining* all current forest cover, and thus estimate a value for doing so that can be compared to the potential cost of conserving each parcel.

The range of our total value of forest ecosystem services in the watershed equates to a per acre value of $290-1,970/ac/yr ($720-4,870/ha/yr). These values are of similar magnitude as other estimates that use similar valuation methods, which are listed in Appendix 2 (e.g., de Groot et al. 2012; Costanza et al. 2014; Troy 2012). This is a positive finding given that we used similar – but not necessarily the exact same – benefits transfer estimates as these other studies ones. More details on how our study compares to the literature is discussed in section 4.2.1.

The results illustrate that forests in the Sebago Lake watershed have the potential to provide a number of relatively high value ecosystem services relative to developed land. While many of the values are not recognized in a formal marketplace, our analysis shows there is potentially significant benefits to stakeholders in the watershed for conserving land based on both the 'market' (see Box 1 for more details on Tourism and Recreation Benefits) and 'non-market' ecosystem services (e.g., air purification) that forests provide.



	Low ES Values	Med ES Values	High ES Values
Habitat Provision	$12.0	$37.6	$80.7
Recreation	$2.8	$24.2	$45.7
Air Purification	$11.1	$29.3	$47.5
Wood Supply	$4.6	$6.6	$10.5
Sediment Retention	$3.7	$11.8	$85.2
Phosphorus Retention	$9.7	$27.8	$36.2
Nitrogen Retention	$8.5	$16.9	$33.9
Carbon Sequestration	$5.3	$17.3	$50.6

Figure 12. Estimated total annual ecosystem service value of current forestland area in the Sebago Lake watershed.

The spatial distribution of ecosystem service values in the Sebago Watershed is shown in Figure 13. For ease of comparison the ecosystem service values are reported on a per acre basis across parcels and include all the ecosystem services included in this analysis. There is spatial variation across the watershed with some areas providing greater ecosystem service flows and therefore benefits. These higher values are based on (1) the high capacity of these areas to retain nutrients and sediment under forest land cover and (2) these areas have large forest timber and carbon stocks and hence could receive higher payments for their carbon sequestration and wood supply.

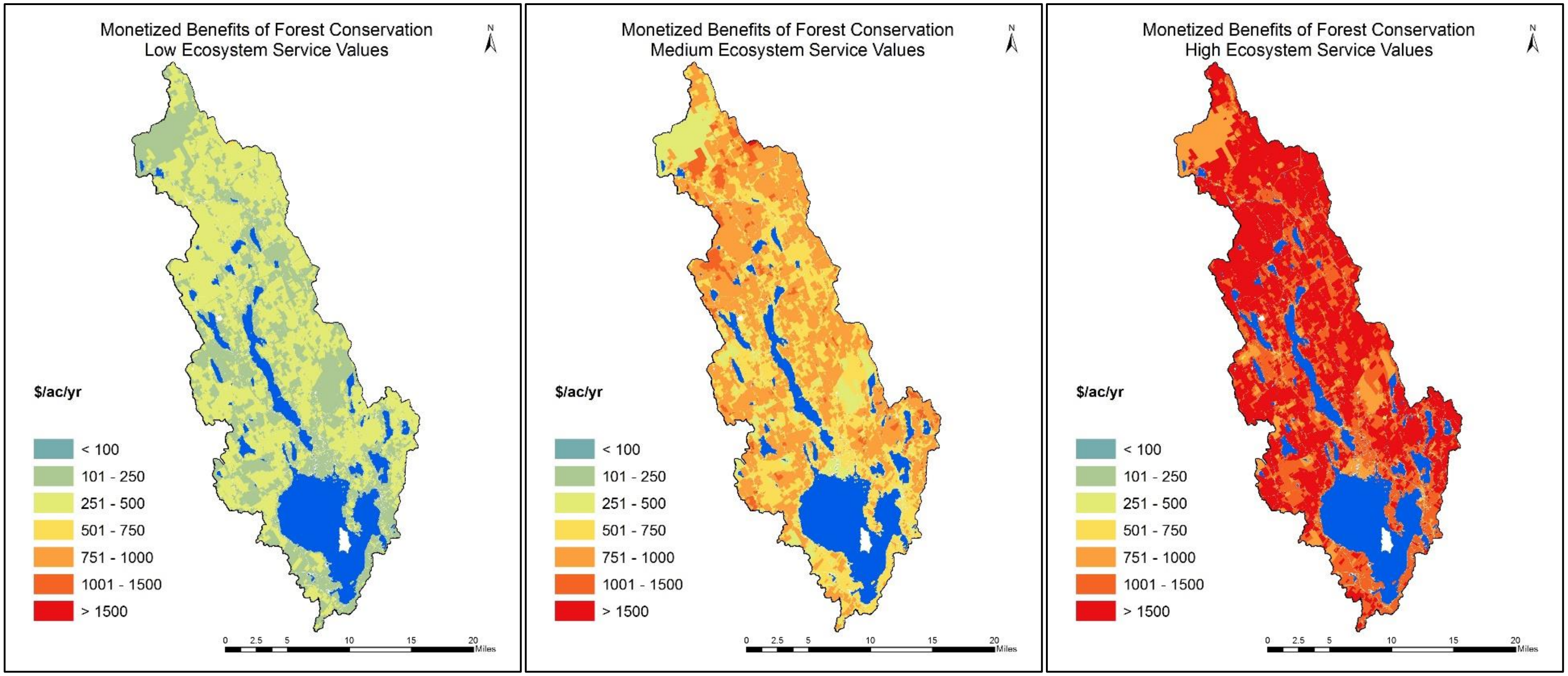


Figure 13. Spatial distribution of estimated ecosystem service benefits of forestland conservation in the Sebago Lake watershed ($/ac/yr) – current forest cover.

Box 1: Valuing Benefits of Conserved Land for Tourism & Outdoor Recreation in the Sebago Lake watershed

Maine Tourism

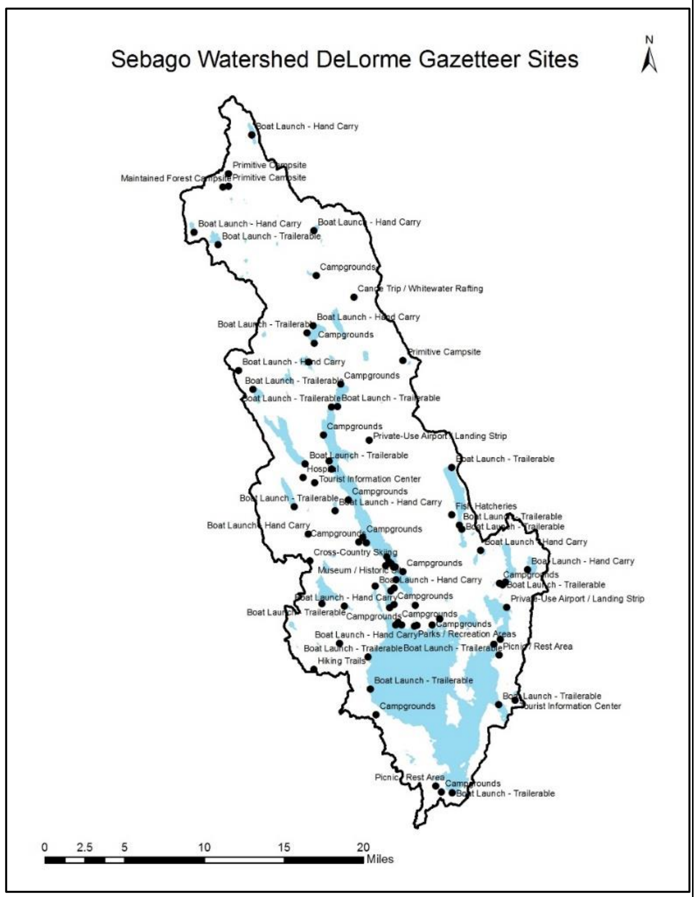
Conserved lands are a key asset and attraction for local recreation and tourism industries. Visitors to these areas spend money on things like food, lodging, and equipment in the region. In 2017, Maine attracted 36.7 million overnight and day leisure travelers – a 2.5% increase over 2016 – and supported more than 106,000 jobs in the state (Maine Office of Tourism, 2018). Visitors spent $6.0 billion on lodging, transportation, food, retails goods and recreation, equivalent to about $163 per visitor. Recreation spending accounted for more than 10 percent of all direct tourism-related spending in Maine, which is more than double the 2010 rate. Given the relative abundance of recreational opportunities in the Sebago Lake watershed, we applied these figures proportionally to the study area.

Outdoor Recreation

The entire outdoor recreation industry has a strong presence in the Sebago Lake watershed. In 2016, Maine's active outdoor recreation economy directly supported more than 76,000 jobs that earned $2.2 billion in wages and salaries, generated $548 million in annual state tax revenue, and produced nearly $8.2 billion annually in retail sales and services across the state (Outdoor Industry Association, 2017). In addition, spending on just recreational watersports in Maine was about $1.3 billion in 2016, nearly double the value of the state's total landed value of commercial seafood. Given the importance of recreational watersports in study area, our estimate of $10 million per year for outdoor recreation is likely low.

Fishing, Hunting, and Wildlife Recreation

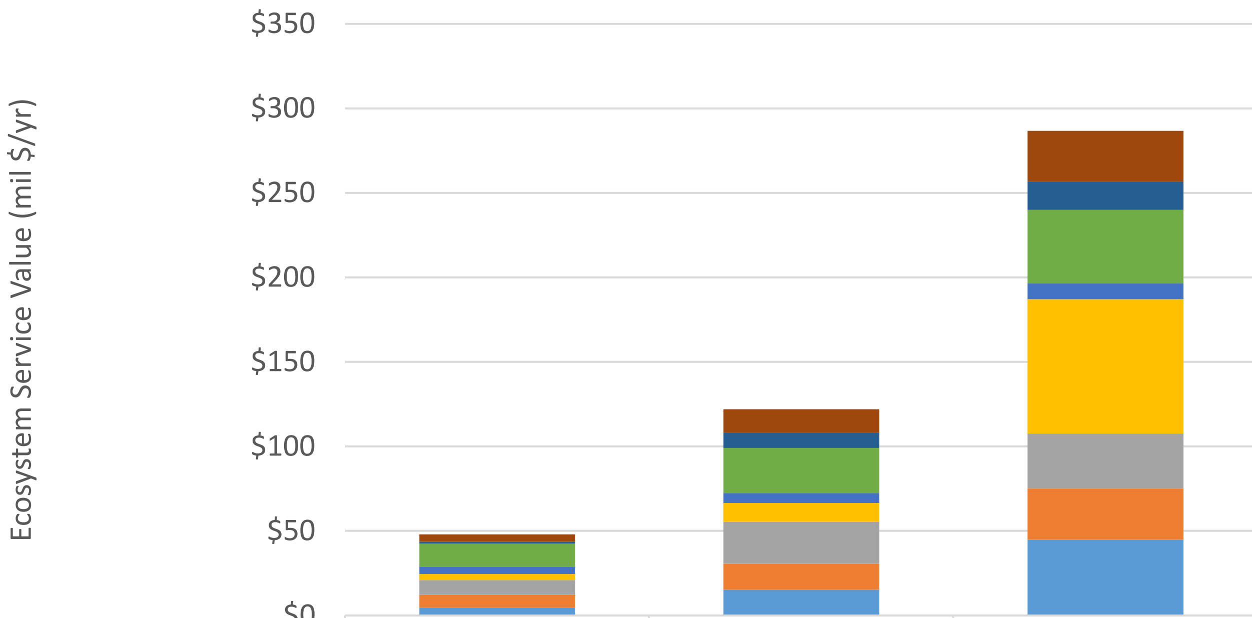
About 200,000 resident anglers in Maine contributed to $175 million of retail sales in 2011 (FWS, 2013). For Maine's 1st Congressional District, which includes most of the Sebago Lake watershed, 130,000 anglers contributed to nearly 1,600 jobs and $142 million in direct and indirect spending related to recreational fishing (Southwick Associates, 2017). This equates to about $1,100 in economic impacts per angler per year. For hunting, 141,000 Maine residents spent nearly $170 million in 2011. Given that there was a total of 2.4 million days spent hunting in the same year, this equates to about $1,200 per hunter per year, or $31 per day (FWS, 2013). Wildlife-watching had more than 400,000 Maine resident participants in 2011, of which about 20% spent their time watching around their home. These watchers spent a total of $235 million annually, equivalent to about $586 per person. Altogether, the 750,000 residents participating in fishing, hunting and wildlife recreation in Maine produce about $580 million in annual economic impacts.



Snowmobiling
Maine's snowmobile trails, many of which run through conservation land, draw tens of thousands of users every winter. The most recent study of the economic impact of snowmobiling on the Maine economy estimated that 83,800 snowmobilers, in-state and out-of-state, generated $176 million in snowmobiling-related expenses, supported 3,100 jobs, and created a total impact of $261 million (TPL, 2012). In the 2017-2018 season, about 68,300 snowmobilers from in- and out-of-state were registered in Maine. Using the figures from 1998 and adjusting for inflation, the total economic impact of these snowmobilers in Maine is estimated to be $330 million, and account for about 2,500 jobs. Given that there are about 14,000 miles of snowmobile trails in the state, this figure equates to an economic impact of about $24,000/mile (MSA, 2018). There are estimated to be at least 150 miles of snowmobile trails running through the Sebago Lake watershed, which potentially produce $3.5 million in economic output in the area each winter.

4.2.1 Dev S4 (76% forest cover) Estimates

The previous section focused on the value of the current forest cover in the Sebago Lake watershed. However, our analysis indicated that not all of this area would necessarily need to be conserved to maintain adequate water quality. Thus, we also estimate the total forest ecosystem service benefits for the scenario where forest cover is reduced from its current level of 84% to 76% (scenario Dev S4). Taking this approach, we estimate that forest ecosystem services in the Sebago Lake watershed under the Dev S4 scenario could range from $48 to 287 million per year, with the 'medium' ecosystem service values giving value of about $122 million per year (Figure 14). These figures equate to a mean of $300 to $1,780/ac/yr for the conserved areas, with a 'medium' value of about $760/ac/yr. These estimates are very similar to the current forestland values estimated in the previous section.



	Low ES Values	Med ES Values	High ES Values
Habitat Provision	$4.4	$13.9	$29.8
Recreation	$1.0	$8.9	$16.9
Air Purification	$13.9	$26.7	$43.4
Wood Supply	$4.2	$5.9	$9.5
Sediment Retention	$3.5	$11.1	$79.5
Phosphorus Retention	$8.7	$24.9	$32.4
Nitrogen Retention	$7.6	$15.2	$30.4
Carbon Sequestration	$4.7	$15.3	$44.8

Figure 14. Estimated total annual ecosystem service value of forestland conservation in the Sebago Lake watershed (Dev S4 scenario – 76% forest cover).

The spatial distribution of ecosystem service values in the Sebago Watershed across the three levels is shown in Figure 13. The figures look very similar to that of the current forest cover, with the exception of parcels that are assumed to be converted to development, primarily in the southern part of the watershed.

Figure 16 presents the spatial distribution of the scenario's 'medium' value estimates for specific groups of ecosystem services. The maps indicate that the values for water purification and erosion control are the most variable across the watershed, and can range from less than $100/ac/yr to more than $1,000 ac/yr, depending on where the parcel is located in the watershed. There is also some variation in the climate regulation and air purification map due to the different levels of forest carbon stocks in the watershed. The recreation and habitat map is consistent across the study area because the benefits transfer estimates for these services were only available at a per acre basis and thus do not take into account the potential variability in forest type and location that, in reality, would be apparent across the watershed.

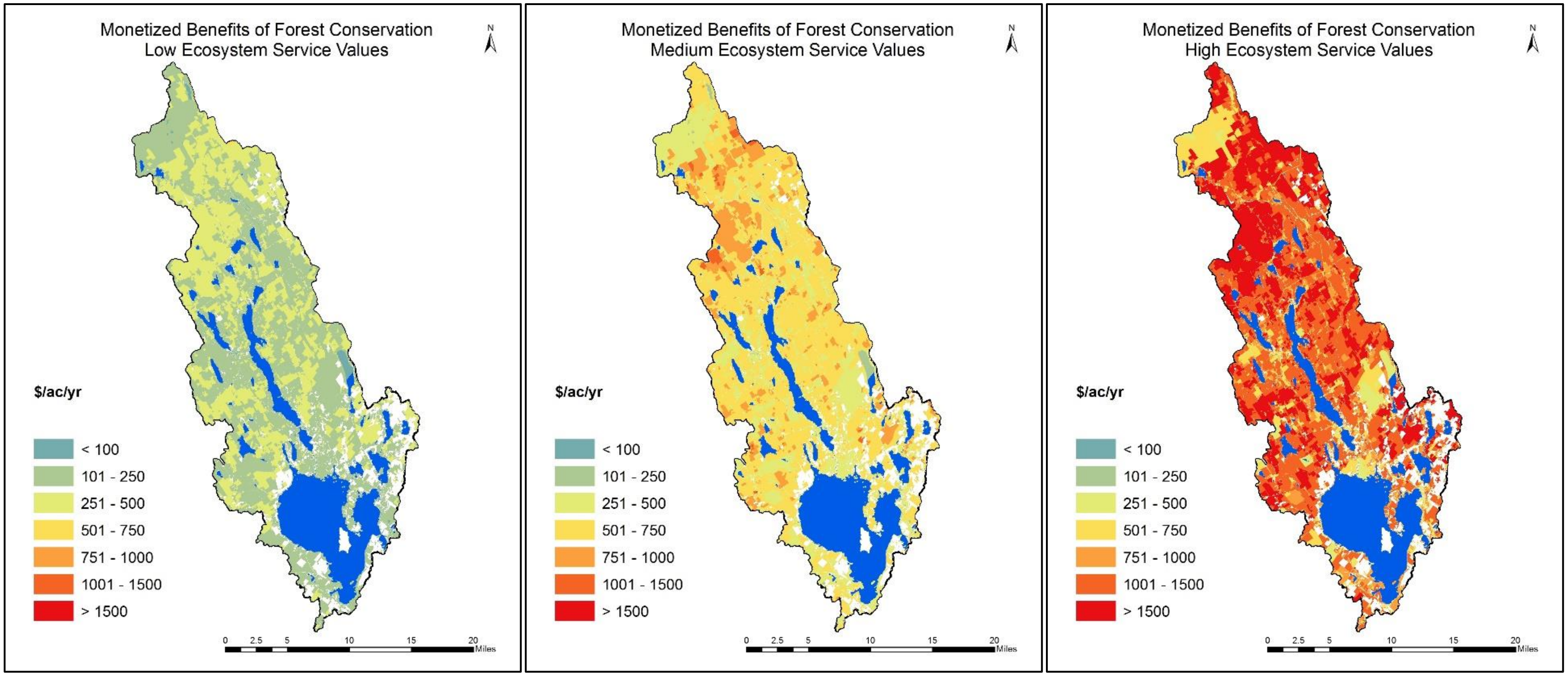


Figure 15. Spatial distribution of estimated ecosystem service benefits of forestland conservation in the Sebago Lake watershed ($/ac/yr) – 76% forest cover.

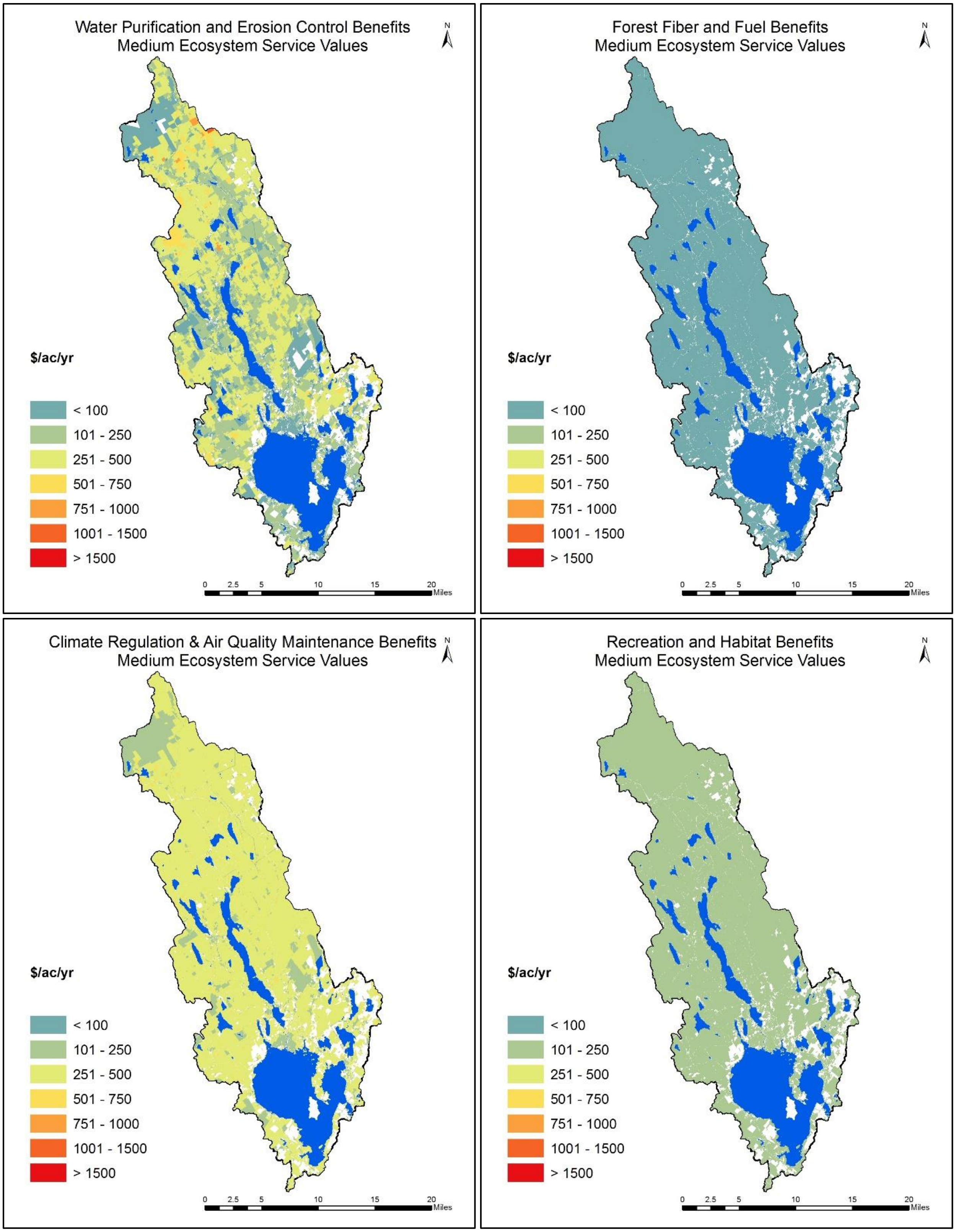


Figure 16. Monetized benefits of forestland conservation ($/ac/yr) by ecosystem service, 76% forest cover scenario.

4.2.2 Study Benefit Comparison

Many studies have used similar benefits transfer methods to estimate the value of ecosystem services at the global (e.g., Costanza et al. 2014; de Groot et al. 2012) and regional scale (e.g., Troy, 2012). This study estimated that the per acre annual value of FES in the Sebago Lake watershed ranges from $270-1,970/ac/yr depending on the benefit transfer values used, with a 'moderate' or 'medium' ecosystem service valuation approach providing a value of about $870/ac/yr.

Global studies following similar methodology estimate that temperate forests provide ecosystem services that value $194 to $1,463 (in 2016 USD)[9] per acre per year, with more recent studies citing figures closer to the higher end (e.g., Costanza et al. 2014). In terms of the value of ecosystem services in Maine, Troy (2012) estimates that the 17 million acres of forests in Maine provides an average value of about $482/ac/yr, but that this value can vary between $120 and $3,217/ac/yr depending on the type and location of the forest. At the regional level, Lichko et al. (2018) estimated that the per acre annual value of ES in the more than 700,000 acres of conservation land in Downeast Maine ranges from $199-652/ac/yr depending on how the benefits of visitor spending and employment generated from conservation land are quantified.

As another source of comparison, Sills et al. (2017) compiled a list of studies of FES across the southern US and found that the annual value of ecosystem services generated by an average acre of forestland ranged from $151/ac/year in Florida to $1,709/acre/year in Georgia. This wide variation in values reflects both methodological and study scope differences as well as differences in the value of forests across the region. For example, the Florida study focused on the value of "the components of forests that are directly enjoyed, consumed, or used to produce specific, measurable human benefits," while the Georgia study used the more general concept of "ecosystem services as the things nature provides that are of direct benefit to humans."

In all of these studies, each research group made different choices about which services to include, regardless of geographic scope. In some cases, e.g., Troy (2012), Moore et al. (2011), a study only included estimates of the non-use value of forests (e.g., aesthetic and cultural benefits), while others also included market values (e.g., provision of fuel and fiber). However, all studies estimated the value of forests for protecting water quality, regulating water flow, regulating climate change via carbon sequestration, and providing wildlife habitat or biodiversity.

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[9] All figures converted to 2016 USD for consistency.

Table 8. Summary of forest ecosystem service valuation studies.

Study	Ecosystem	Region	Value (2016$/ha)	Value (2016$/ac)
This Study	Forests - Low Val	Sebago Lake	$720	$291
This Study	Forests - Med Val	Sebago Lake	$2,142	$867
This Study	Forests - High Val	Sebago Lake	$4,873	$1,973
Lichko et al. (2018)	Conserved Lands – High	Downeast ME	$1,611	$652
Lichko et al. (2018)	Conserved Lands - Low	Downeast ME	$492	$199
deGroot et al. (2012)	Temperate Forests	Global	$3,471	$1,405
deGroot et al. (2012)	Woodlands	Global	$1,829	$741
Costanza et al. (1997)	Temperate/Boreal	Global	$480	$194
Costanza et al. (2014)	Temperate/Boreal	Global	$3,613	$1,463
Troy (2012)	Forest adj to stream	Maine	$3,519	$1,425
Troy (2012)	Heavy partial cut	Maine	$297	$120
Troy (2012)	Light partial cut	Maine	$774	$313
Troy (2012)	Non-urban forest	Maine	$1,191	$482
Troy (2012)	Suburban forest	Maine	$7,945	$3,217
Troy (2012)	All forests	Maine	$1,185	$480
Escobedo and Timilsina (2012)	Forest Stewardship Program Lands	Florida	$373	$151
Moore et al. (2011)	Private forests	Georgia	$4,221	$1,709
Paul (2011)	All forests	Virginia	$2,174	$880
Simpson et al. (2013)	All forests	Texas	$3,678	$1,489

More detailed information on the forest ecosystem service values published in some of the literature are listed in Table 21 to Table 24 of Appendix 2.

4.3 Costs

4.3.1 Filtration Plant Costs

Discussions with PWD indicated that they believe a water filtration plant for the district would need to have a capacity of 75 MGD and have a capital cost that ranged from $100 to $200 million. We used capacity and cost data (adjusted for inflation to 2018 dollars) from EPA (2008) on plants with a capacity greater than 10 MGD to construct a simple linear regression model to assess whether this estimate is reasonable. Using this regression, which has an R^2 of 0.92 (Figure 17), we estimate that a 75 MGD filtration plant constructed for the PWD would cost about $157 million (Table 9). This figure is close to the mean of the range of plant cost estimates provided by PWD ($100-200 million). Furthermore, the plant is estimated to have an annual operating and maintenance (O&M) cost of $2.70 million/yr, or about $98 per million gallons treated. Spreading the capital costs of the plant across a 25-year lifespan using a discount rate of 6%, the total annualized costs of construction, operating, and maintenance plant for a new filtration plant in the PWD are estimated at $15.01 million/yr.

Table 9. Sources of PWD Filtration Cost Estimates for plant with 25 year lifespan.

Facility	Capacity (MGD)	Capital Cost (mil $)*	Capital Cost per MGD capacity ($)	Operating (mil $/yr)	Annualized Total Cost (mil $/yr)	Source
Baltimore, MD Denitrification	180	$298	$1.65	N/A	N/A	EPA (2008)
Cox Creek, MD Denitrification	15	$31	$2.07	$0.68	$3.11	EPA (2008)
Fairfax, VA step-feed AS	67	$85	$1.27	$3.08	$9.76	EPA (2008)
Clark County, NV A/O with VFA	100	$239	$2.39	$2.39	$21.10	EPA (2008)
Kelowna, BC 3-stage Westbank	10.5	$41	$3.87	$0.35	$3.53	EPA (2008)
North Cary, NC Oxidatin ditch	12	$41	$3.38	$0.31	$3.49	EPA (2008)
Western Branch, MD 3-stage sludge	30	$62	$2.06	$2.15	$6.98	EPA (2008)
Regression-based plant in PWD	**75**	**$157**	**$1.87**	**$2.70**	**$15.01**	**Own Calculation**

* All figures adjusted for inflation to 2018 USD

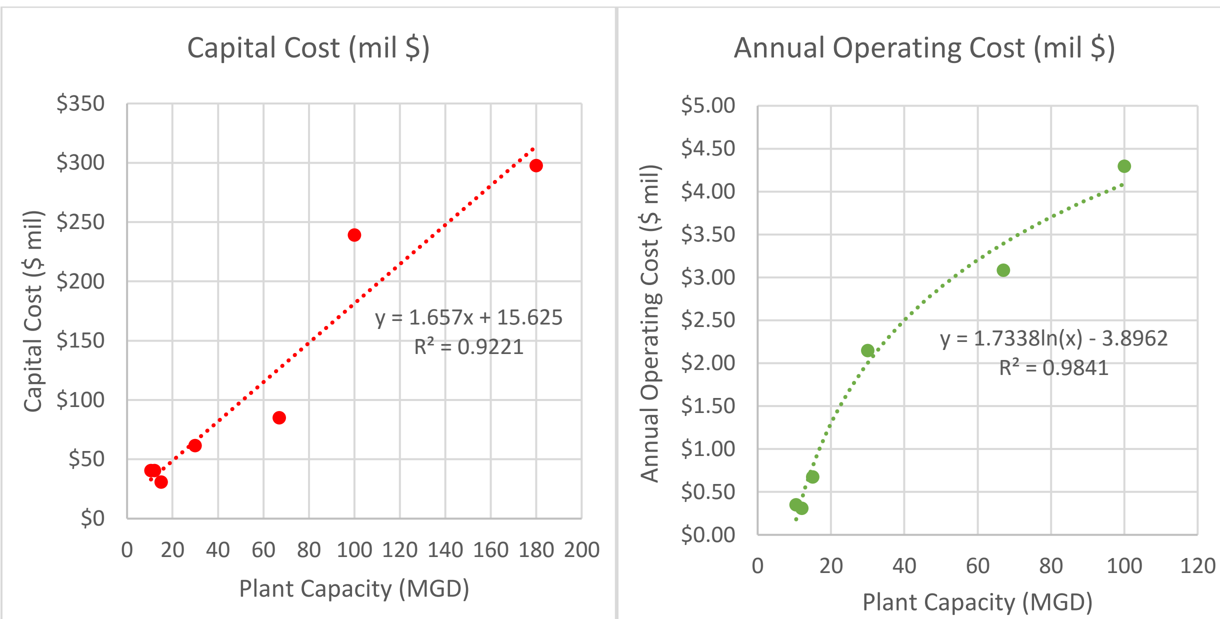

Figure 17. Total capital and annual operating and maintenance costs of a new filtration plant by capacity (MGD), based on EPA (2008) plant data.

To estimate how the cost and operation of the new filtration plant could affect the amount that consumers pay for water, we assume that the cost of the plant would be added to the PWD's annual expenses, which were $38.7 million in 2017 (PWD, 2018). Adding the additional cost of the filtration plant increases the annual cost for PWD to $53.7 million/yr. The revenue raised by PWD from water consumption charges in 2017 was $23.2 million per year (PWD, 2018). If the additional annual filtration plant costs of $15 million/yr were passed on to water users then consumers, in aggregate, would have to pay about $38.2 million per year. Therefore, for PWD to cover the cost of constructing and maintaining a filtration plant through water consumption charges then these charges would have to increase by an average of at least 64.7%[10]. Using the range of $100-200 million provided by PWD as a sensitivity analysis suggests that consumption charges could increase by 43 to 82% (Table 10). More details on how the costs could affect large water consumers in the district is discussed in Section 4.5.1.

Table 10. Estimated change in revenues required by PWD to offset cost of filtration plant. (t = 25 years, r = 6%)

Estimate	Low Plant Cost	Med Plant Cost	High Plant Cost
2017 PWD Water Revenue	$23,186,245	$23,186,245	$23,186,245
Annualized Plant Cost	$9,844,028	$15,009,664	$19,014,271
Total revenue required to offset expenses	$33,030,273	$38,195,909	$42,200,516
% Change from 2017	42.5%	64.7%	82.0%

4.3.2 Land Costs

The largest costs for land conservation is the cost of buying the land or establishing an easement.[11] Based on a number of data sources (see Appendix 2), we estimate that 80% of the cost estimates are between $800 and $2,450 per acre with a median cost around $1,350/ac (Table 11). Excluding the PWD Fee purchase dataset (Table 26), which appears to be an outlier due to the high cost for some select small waterfront parcels, the mean estimate of purchasing forestland in the watershed was $1,689/acre. More details on these data are provided in Appendix 2 (Table 26 to Table 31).

Table 11. Estimated costs of conservation land in Sebago Lake watershed.

Land Valuation Dataset	Acres	Cost/acre
PWD – Fee	52	$57,440
PWD – Grant	4,056	$1,660
TNC – Fee	1,069	$1,562
TNC – CE	734	$586
LMF and NRC Program - Oxford	9,651	$1,255
LMF and NRC Program - Cumberland	8,813	$5,947
MRS Average – Oxford	N/A	$826
MRS Average - Cumberland	N/A	$1,473
MRS Average - Androscoggin	N/A	$1,025
MRS Average - Sebago Lake	N/A	$1,196
MRS Median – Oxford	N/A	$800
MRS Median - Cumberland	N/A	$1,446
MRS Median - Androscoggin	N/A	$1,025
MRS Median - Sebago Lake	N/A	$1,000
MRS Max - Sebago Lake	N/A	$2,514

[10] N.B., this assumes that investing in the plant does not result in cost savings elsewhere in the PWD's budget. It also assumes that customers would not reduce their water consumption as a result of higher water charges. If this were the case, which is likely to happen based on economic theory, then new charges would have to be even higher.

[11] A conservation easement is when the development rights to a piece of land are sold to a third party.

Presenting these data spatially by municipality[12] shows that land in the southern part of the watershed is generally valued higher than land in the north (Figure 18). We expect that any future purchase of conservation land will likely follow a similar pattern, with land in Cumberland County costing up to twice as much as the land in Oxford County.

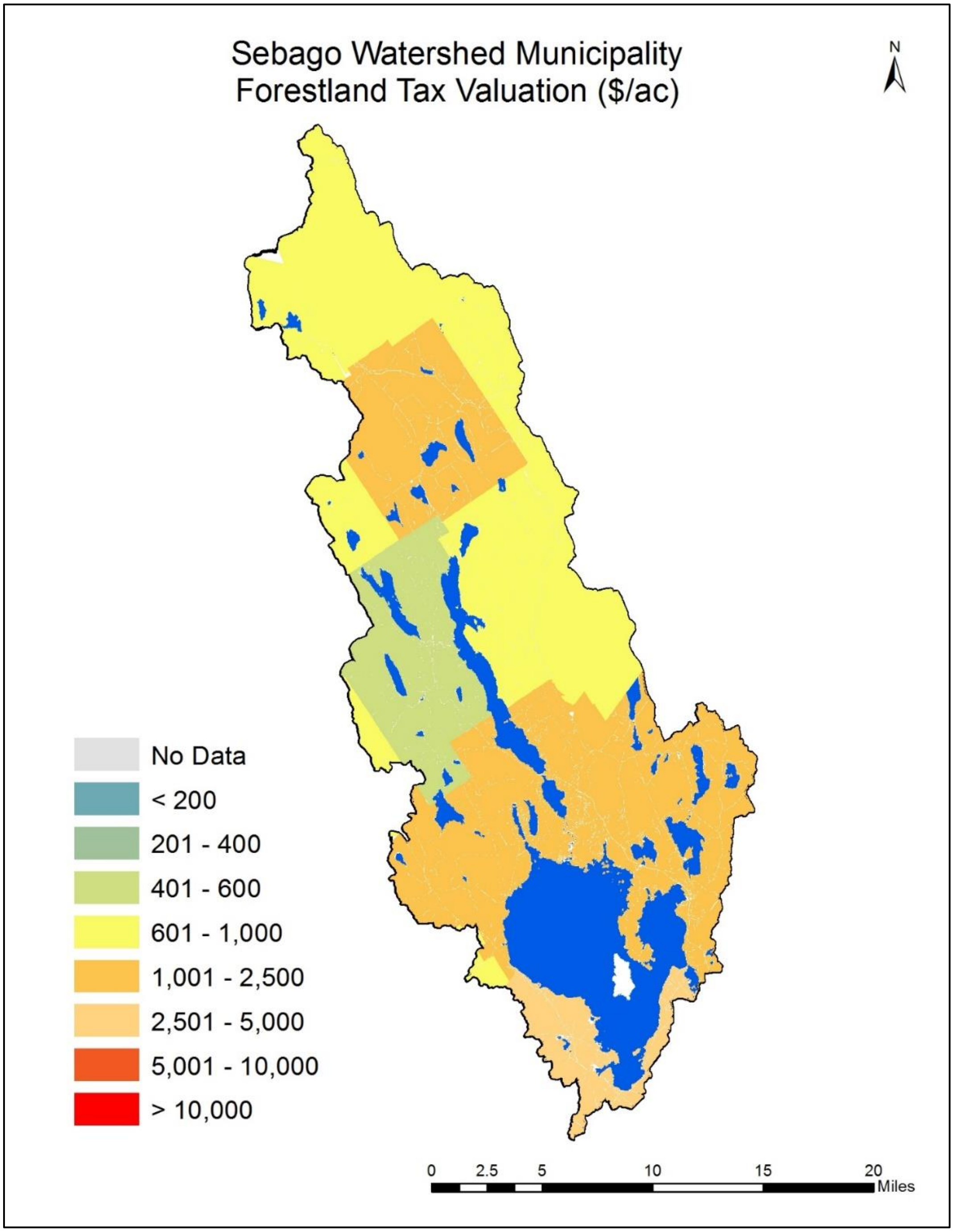

Figure 18. Average forestland value by municipality (Source: Maine Revenue Service, 2017).

[12] Municipality is the highest consistent resolution across the whole watershed.

Land can also be conserved through conservation easements. We found limited data on the cost of a conservation easement (CE) in the Sebago Lake area so extrapolated our results from a small sample. The Nature Conservancy (TNC) information on a 2012 easement over 734 acres across two tracts (i.e., Norkin and Russell) of land located on the Saco River cost $430,000 or $586/acre (Table 28). This is less than half of the cost of fee acquisition. For grants approved by the PWD between 2008 and 2015 for the purchase of CEs on 1,344 acres the average cost was $1,831/acre (Table 26). This is almost the same as the land purchase costs recorded over the same period. Additional insight from TNC supports our finding that CEs values vary broadly within a catchment. The costs depend on factors such as the encumbrances on the easement, the size of the property, and the relative value of timber versus development potential on the parcel. Smaller parcels close to a waterbody in the Sebago Lake watershed could have cost as much as 80% of the fee value cost, while large working forest easements may be closer to 40% of the fee value acquisition cost (Mark Berry, pers comm). Given the variance in these costs, we conduct a sensitivity analysis to assess the impact of adjusting the ratio or probability that land is conserved via fee acquisition or CE (i.e., 50/50, 20/80 or 80/20 fee acquisition to CE), and adjust the conservation costs accordingly. **This approach results in an estimate the 'average' cost of conserving a parcel of land in the Sebago Lake watershed could be about $950/acre.**

4.4 Benefit-Cost Analysis

Combining results from sections 4.1 to 4.3, we conducted a benefit-cost analysis (BCA) to estimate the level of investment in conservation land that will generate net benefits to landowners in the Sebago Lake watershed and downstream water users. In other words, how much economic value does investing in forest conservation in the Sebago Lake watershed provide? Furthermore, we used an economic analysis approach to prioritize investment in properties that yielded the highest net benefits. This is to help spatially determine where conservation efforts could be focused. For our analysis, we determine which parcels provide the highest net benefits using the benefit-cost ratio (BCR) metric, which essentially calculates the estimated value of benefits for each dollar invested in conserving a given parcel of land (i.e., Total monetized benefits divided by the cost of conservation). Any BCR estimate that is greater than one indicates that the benefits of investing in conservation outweigh the potential costs of doing so, assuming that all the key benefits and costs of doing so are properly accounted for.

The watershed-wide estimates for conserving *all* forestland (relative to scenario Dev S1, maximum area converted to development) indicate that even using the most conservative benefit estimates (i.e., Low Value ES values) would yield benefit-cost ratios between 2.8 to 5.2 (Table 12). This means that every $1 invested in forest conservation would yield $2.80 to $5.20 in ecosystem service benefits, including the maintenance of good water quality through nutrient and soil retention. For the medium range of ecosystem service values, the BCR increases to between 8.4 and 15.5. This suggests that investing in forest conservation could provide an order of magnitude or more in total benefits than the low ecosystem service values. As the ecosystem service values assumes that all current forestland is conserved, then the benefit-cost ratios will likely increase when areas with the highest net benefits are targeted.

Table 12. Estimated annualized benefits and costs ($/yr) of conservation land in Sebago Lake watershed under various scenario assumptions – full forest conservation. All figures reported in annualized estimates.

	High CE Cost - 80% Fee / 20% CE	High CE Cost - 50% Fee / 50% CE	High CE Cost - 20% Fee / 80% CE	Low CE Cost - 80% Fee / 20% CE	Low CE Cost - 50% Fee / 50% CE	Low CE Cost - 20% Fee / 80% CE
Low Ecosystem Service Values						
Annualized Cost (mil $)	$20.4	$19.2	$17.9	$18.7	$14.9	$11.1
Annualized Benefits (mil $)	$57.7	$57.7	$57.7	$57.7	$57.7	$57.7
Annualized Net Benefits (mil $)	$37.2	$38.5	$39.8	$38.9	$42.7	$46.6
Benefit-Cost Ratio	2.8	3.0	3.2	3.1	3.9	5.2
Medium Ecosystem Service Values						
Annualized Cost (mil $)	$20.4	$19.2	$17.9	$18.7	$14.9	$11.1
Annualized Benefits (mil $)	$171.6	$171.6	$171.6	$171.6	$171.6	$171.6
Annualized Net Benefits (mil $)	$151.1	$152.4	$153.7	$152.8	$156.7	$160.5
Benefit-Cost Ratio	8.4	9.0	9.6	9.2	11.5	15.5
High Ecosystem Service Values						
Annualized Cost (mil $)	$20.4	$19.2	$17.9	$18.7	$14.9	$11.1
Annualized Benefits (mil $)	$390.2	$390.2	$390.2	$390.2	$390.2	$390.2
Annualized Net Benefits (mil $)	$369.8	$371.1	$372.4	$371.5	$375.3	$379.2
Benefit-Cost Ratio	19.1	20.4	21.8	20.8	26.2	35.2

At the parcel level nearly all parcels in the watershed have a positive BCR, even for the low where ecosystem service values (Figure 19)[13]. BCRs are generally higher in the northern part of the catchment. This result is because the costs of acquiring conservation land is, on average, expected to be relatively lower in this part of the watershed. Furthermore, some of the forests in this area of Sebago Lake has a relatively high ecosystem service flows, particularly water purification and erosion control, as well as climate regulation (i.e., large forest carbon stocks).

Focusing on the area of forest conservation required to meet the water quality threshold (i.e., 76% forest cover for entire watershed) gives similar results (Table 13). For low ecosystem service value, the BCR ranges from 2.7 to 4.9, while the BCR for the medium value ranges from 6.7 to 12.4. These estimates are similar to the full conversion scenarios because both options require most of the forestland currently in the watershed to remain undeveloped. **In terms of area required to achieve the 76% forest conservation target, an additional 160,000 acres of forest would need to remain forested in addition to the 17,000 acres already conserved.** While we found that investing in forest conservation yields positive economic benefits for the Sebago Lake watershed, it could cost as between $125 and $230 million to reach this target, depending on the split between fee acquisition and conservation easement.[14]

[13] N.B., for ease of presentation, the spatial distribution of the analysis averages the six BCRs estimated for each scenario.

[14] N.B., the cost figures in Table 13 represents an annualized cost of conserving land through a mix of CE and fee acquisition. To get the total investment, one should divide the figure by the annualization rate of 0.07823 (based on a discount rate of 6% over 25 years)

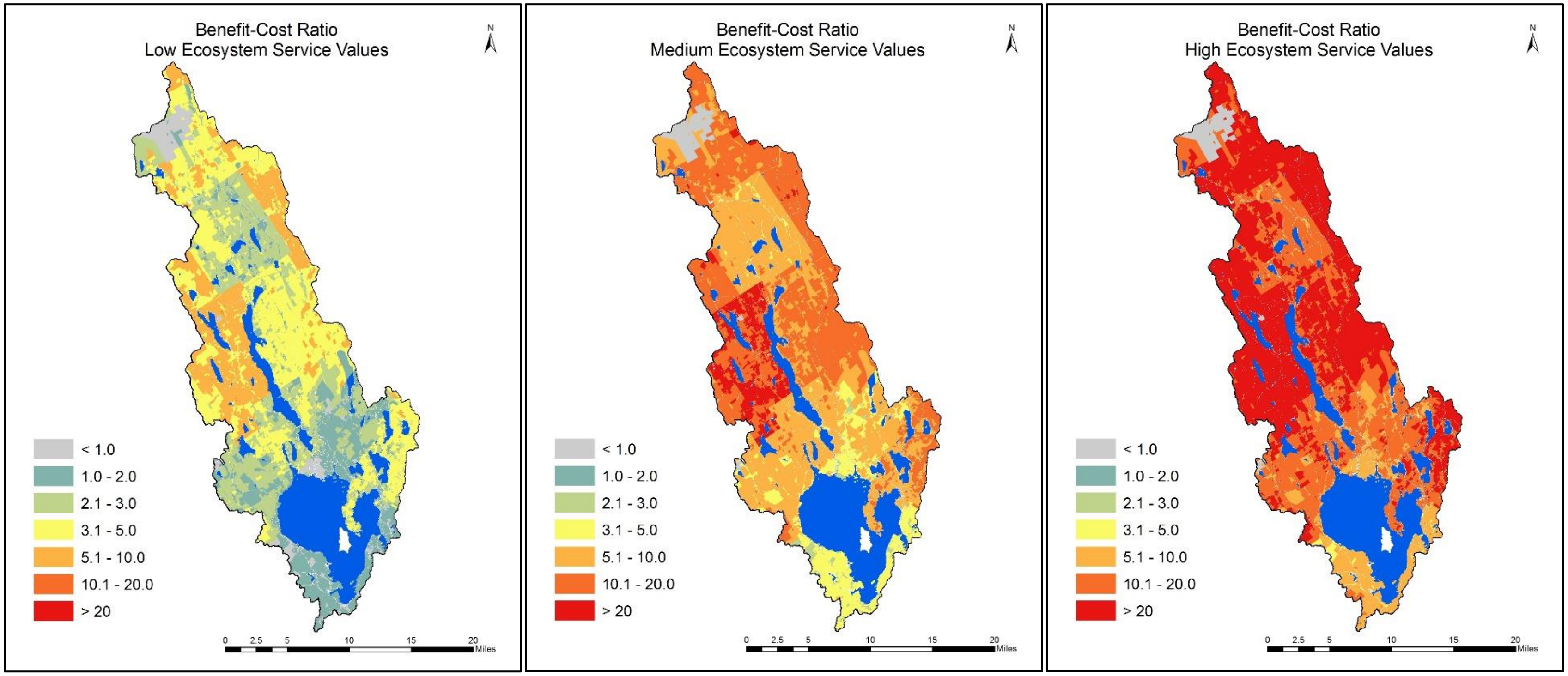

Figure 19. Benefit-cost ratio for Sebago Lake watershed forestland conservation by ES value scenario – full forest conservation (Dev S0).

Table 13. Estimated benefits and costs of conservation land in Sebago Lake watershed under various scenario assumptions – forest conservation to 76% of total watershed area (Dev S4).

	High CE Cost - 80% Fee / 20% CE	High CE Cost - 50% Fee / 50% CE	High CE Cost - 20% Fee / 80% CE	Low CE Cost - 80% Fee / 20% CE	Low CE Cost - 50% Fee / 50% CE	Low CE Cost - 20% Fee / 80% CE
Low Ecosystem Service Values						
Annualized Cost (mil $)	$18.1	$17.0	$15.8	$16.6	$13.2	$9.8
Annualized Benefits (mil $)	$48.0	$48.0	$48.0	$48.0	$48.0	$48.0
Annualized Net Benefits (mil $)	$29.9	$31.0	$32.2	$31.4	$34.8	$38.2
Benefit-Cost Ratio	2.7	2.8	3.0	2.9	3.6	4.9
Medium Ecosystem Service Values						
Annualized Cost (mil $)	$18.1	$17.0	$15.8	$16.6	$13.2	$9.8
Annualized Benefits (mil $)	$122.0	$122.0	$122.0	$122.0	$122.0	$122.0
Annualized Net Benefits (mil $)	$103.9	$105.1	$106.2	$105.4	$108.8	$112.2
Benefit-Cost Ratio	6.7	7.2	7.7	7.4	9.2	12.4
High Ecosystem Service Values						
Annualized Cost (mil $)	$18.1	$17.0	$15.8	$16.6	$13.2	$9.8
Annualized Benefits (mil $)	$286.7	$286.7	$286.7	$286.7	$286.7	$286.7
Annualized Net Benefits (mil $)	$268.6	$269.7	$270.8	$270.1	$273.5	$276.9
Benefit-Cost Ratio	15.8	16.9	18.1	17.3	21.7	29.2

Most parcels meet the BCR threshold and are worth investing in (Figure 20). However, there still a number of parcels around Sebago Lake with a BCR < 1. This may not necessarily because the cost of conserving land outweighs the benefits though. Rather, it is potentially because the land is already conserved or was not considered a 'conservation priority' under the criteria we used identify areas likely to develop in the DevS4 scenario. Dividing the BCR estimates for this scenario into quantiles reveals that the ranking of parcels to invest in based on their BCR is relatively consistent across all three ecosystem service value levels (Figure 21). In this figure, areas in dark green (i.e., 0.81 to 1.00) are estimated to be in the highest quartile and thus yield the highest net benefits from conservation.

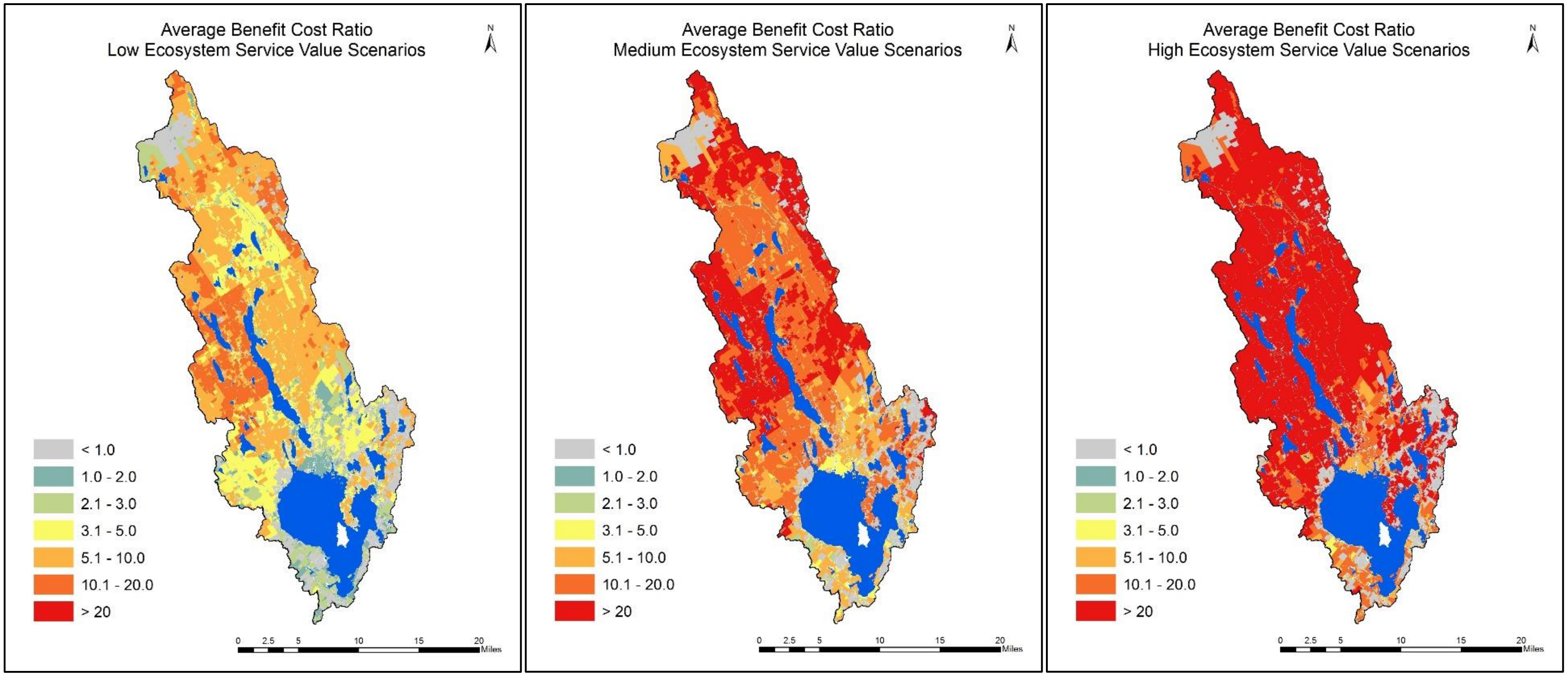

Figure 20. Benefit-cost ratio for Sebago Lake watershed forestland conservation by ES value scenario - forest conservation to 76% of total watershed area.

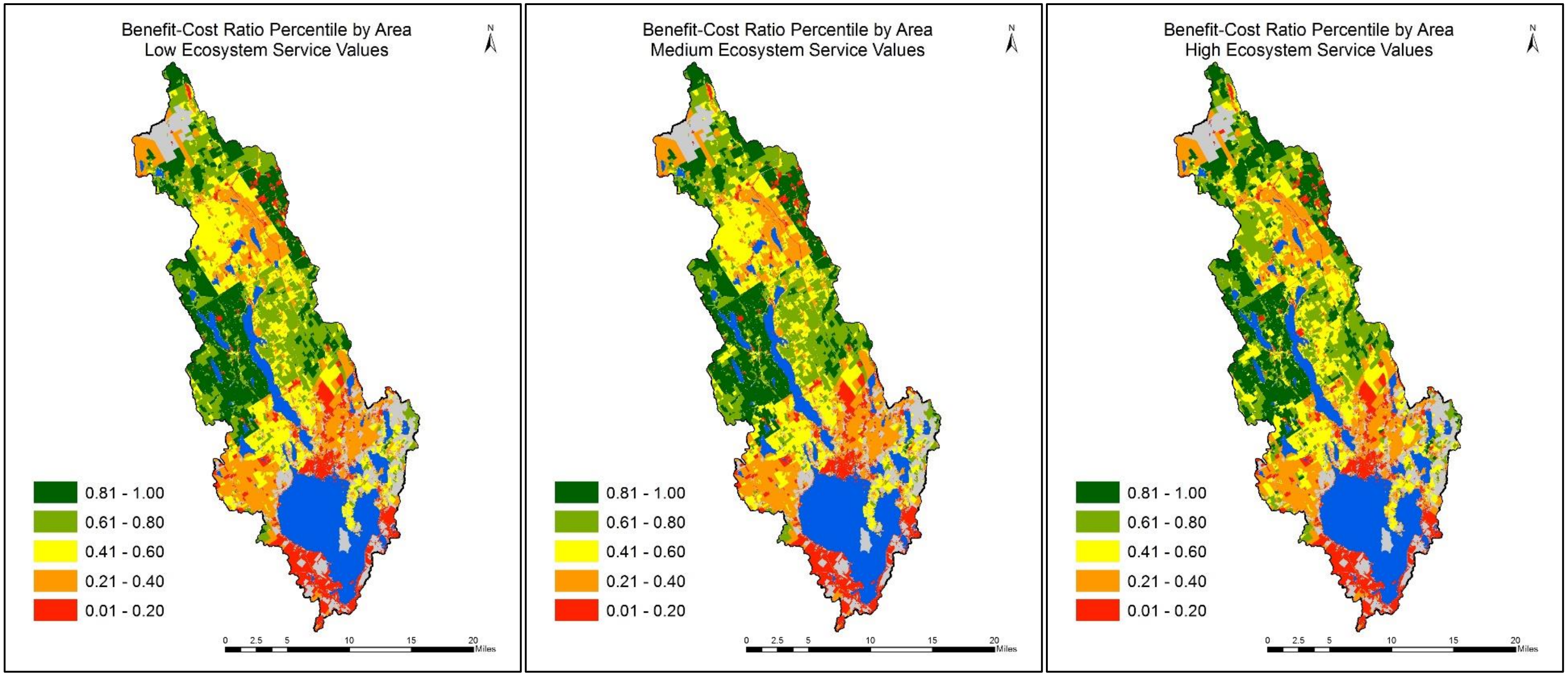

Figure 21. Benefit-cost ratio quartiles for Sebago Lake watershed forestland conservation by ES value scenario – Dev S4 scenario. Areas with values of 0.81 to 1.00 values are estimated to be in the highest quantile and thus yield the highest net benefits.

4.5 Watershed Investment and Ecosystem Market Opportunities

Our analysis has found that making an effort to conserve forestland in the Sebago Lake watershed is very likely to yield net benefits (and hence a positive ROI), especially when considering the 'value' of the multiple ecosystem services that forestlands provide. However, because the focus is on *preventing* the losses of ecosystem services associated with forest loss, many of these values are not fully realized in the current marketplace. As a result, investors in forest conservation will likely need to raise the capital necessary to acquire the land or conservation easement to keep the land forested in perpetuity. According to our analysis below, this could be around $200 million dollars to ensure that there is enough forest cover in the watershed to ensure adequate water quality and avoid constructing a filtration plant. This section explores options that stakeholders in the watershed could potentially use to help meet this objective.

4.5.1 Direct Investment by Water Users as Avoided Cost Measure

Section 4.3 estimated that if PWD had to build and maintain a filtration plant due to water quality deteriorating, water rates could increase by 38-76%, on average. Additional insight provided by PWD suggested that commercial and industrial water users could see their rates increase even more (an average of 93% for our mid-range cost estimate) due to the structure of how costs are portioned out across the water district. For large water users in the district, this increase translates to several thousands of dollars per year.

In theory, users should be willing to apply up to their expected increase in costs to fund watershed protection or other measures that can reduce their cost of water consumption. Such an investment would ultimately result in lower costs (and potentially higher marketability associated with improved 'green' branding) than if PWD had to build a filtration plant. Accounting for the annual increase in water costs faced by the top 10 water users in the PWD, equates to more than $1.9 million per year (Table 14). For the Top 50 billable meters in the PWD[15], then the increase in costs would total more than to $2.4 million/yr. Given our analysis that an average parcel of forestland in the watershed would cost about $950/acre to conserve this increase translates to 1,950-2,480 acres per year. If the filtration plant ended up costing $200 million, then the rates for the top commercial and industrial users could increase by as much as 117%, thereby the equivalent to 2,470 to 3,140 acres per year in forestland that could be potentially conserved with funds provided by the top 10 and top 50 water users, respectively.

If all water users in the PWD, including residential clients, contributed to the fund to the point that cost of doing so was equal to the annualized cost of building and maintaining the plant, then there could potentially be enough funds to conserve up to 15,000 acres of forestland, on average, per year. At this rate, the target conservation area of 160,000 acres could feasibly be met over the next 25 years, assuming that the cost of acquiring land and establishing conservation easements remains relatively constant over time.

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[15] Data for top 50 users supplied to TNC by PWD in July 2017

Table 14. Estimated Water Costs for Top 10 Water Users in PWD (medium filtration plant cost option).

Customer Name	Customer Location	2017 Water Consumption (HCF)	2017 Water Charges ($)	Additional Water Cost w/Plant ($)*	Total Water Charges with Filtration Plant ($)
Calpine	Westbrook	447,139	$433,165	$400,894	$834,059
Sappi Fine Paper	Westbrook	306,252	$365,189	$337,982	$703,171
Texas Instruments	S. Portland	176,645	$295,221	$273,227	$568,448
ON Semiconductors	S. Portland	139,671	$155,188	$143,627	$298,815
Yarmouth Water District	Yarmouth	137,074	$162,703	$150,582	$313,285
Ecomaine	Portland	120,922	$123,383	$114,191	$237,574
Maine Medical Center	Portland	108,177	$190,914	$176,691	$367,605
B&G Foods	Portland	75,885	$81,514	$75,441	$156,955
Portland Housing Authority	Portland	57,738	$129,521	$119,872	$249,393
Oakhurst Dairy	Portland	44,192	$62,329	$57,685	$120,014
Top 10 Total		1,613,695	$1,999,127	$1,850,192	$3,849,319
Top 50 Meters Total		2,055,295	$2,546,203	$2,356,512	$4,902,715
PWD Total		8,487,249	$23,186,245	$15,009,664	$38,195,909

* assuming that customers do not adjust their water consumption as a result of increased rates.

Some local industries within the PWD are concerned about how losses in water quality could affect their operations. For example, breweries who use Portland municipal water which comes from Sebago Lake have recently been outspoken about potential impacts to clean water, if Clean Water Act (CWA) regulations are loosened. Rising Tide, Allagash, and Shipyard Brewing all argued that weakening water quality regulation could mean pollutants getting into smaller waterways in the watershed, eventually making their way to their brewing facilities[16]. Given that it takes 3-7 gallons of water to brew one gallon of beer, these breweries have a strong motivation to voice their concerns.

4.5.2 Corporate Social Responsibility and Premiums for 'Green' Products

Some consumers tend to place higher value on corporate social responsibility (CSR) and consider it to be an important factor determining their patronage (Sirakaya-Turk et al., 2014, Brown and Dacin, 1997, Mohr and Webb, 2005). According to Lindgreen and Swaen (2010), the high ranking of CSR on research agendas (Greenfield, 2004, Maignan and Ralston, 2002, Pearce and Doh, 2005) appears to be reflected in theoretical and managerial discussions that argue "not only is doing good the right thing to do, but it also leads to doing better" (Singal, 2014, Bhattacharya and Sen, 2004, Kotler and Lee, 2005). An added benefit is a staff that feels more fulfilled and has a very positive view of their employer (Raub and Blunschi, 2014). As a result, CSR has moved from ideology to reality, and many consider it necessary for organizations to define their roles in society and apply social and ethical standards to their businesses.

CSR activities designed to appeal to consumer interest in and demand for sustainability could take many forms. These include incorporating product features that are environmentally friendly (green products), minimizing waste, energy conservation, pollutant reductions, adopting socially-conscious marketing and human-resource practices, and supporting the needs of the community by donating both money and time. However, while CSR and 'green' production is growing in

[16] https://www.nrdc.org/brewers-clean-water

recognition and interest, there are still limited empirical results indicating the average consumer is actually willing to pay more for a 'greener' level of product or service (Krishnamurthy and Kriström 2016). Often, it is found that only those consumers who are already actively involved in environmentally and socially responsible practices are willing to pay more (Parsa et al. 2015). Given this brief review, we find that it cannot hurt businesses in the Sebago Lake watershed to develop and follow a CSR plan and promote their products as green because they are sourced from a protected watershed. However, we caution that it may not produce a significant premium for their product. Thus, businesses should be more concerned about the potentially large increase in costs associated with PWD having to build a filtration plant to cope with deteriorating water quality associated with lost in forest cover in the Sebago Lake watershed.

4.5.3 Ecosystem Market Potential

The carbon stored and sequestered in the Sebago Lake watershed forests is valuable, depending on the \$/CO_2 used to value it, the carbon in the forests is *worth* between \$76 million (based on the voluntary market offset price in 2016 of \$5.10/tCO2e) and \$581 million dollars (based on the social cost of carbon value of \$39/tCO2e). A reduction of forest cover in the watershed to 66% from the current 84% would cause an estimated \$130 million in damages from climate change based on the social cost of carbon using 2015 values. In order for a land owner to be paid for additional carbon sequestration services, they must eligibility criteria and be able to show that they are sequestering more carbon through forest management than they otherwise would have. This can be achieved through reforestation, avoided deforestation that was otherwise planned, or through forest management that enhance carbon stocks. The amount of carbon sequestered through enhanced forest management would be a small fraction of the 14 million tons of CO_2 stored in the Sebago Lake forest, and thus represents a small fraction of the total value of the service that can currently be monetized through offset markets.

The state of the market for forest carbon credits in the Sebago Lake watershed is primarily a voluntary market in which emitters may purchase carbon offsets through an established offset development protocol are registered through one of several carbon registries, including the American Carbon Registry, Climate Action Reserve, and Verified Carbon Standard. Prices per ton of CO_2 sequestered on the voluntary market range averaged \$5.10 per metric ton for forest management projects in 2016 (Carbon Market Watch 2017). Currently, there is relatively minimal participation of Maine forested lands in the voluntary carbon market with fewer than a dozen projects statewide due to eligibility constraints and landowner hesitation to enter into 100 year forestry agreements. At these prices and with these requirements, we estimate participation to be low. However, US and international climate change mitigation policy could change over the next 25 years and thus enhance the relative value of carbon sequestration payments, likely in the range of the social cost of carbon estimates, or even higher.

However, there is potential for some large private landowners (i.e., 5,000 acres or more) in the watershed to participate in California's carbon market, especially those landowners with active forestry management plans. For these landowners, participation in a carbon market could make sense. Note that most tracts in the Sebago Lake watershed are much smaller than those now enrolled in the California market.

Ecosystem service market initiatives in the US have grown significantly over the past 30 years (Figure 22). Most of the existing $2.8 billion per annum market encompassing close to 3,000 'initiatives' is devoted to wetlands and streams ($2.2 bil/yr), followed by watersheds ($0.4 bil/yr), and imperiled species and habitats ($0.2 bil/yr). New forest carbon markets have emerged in recent years, but with just $58 million per year in turnover, are still considered relatively small (Bennett et al. 2016).

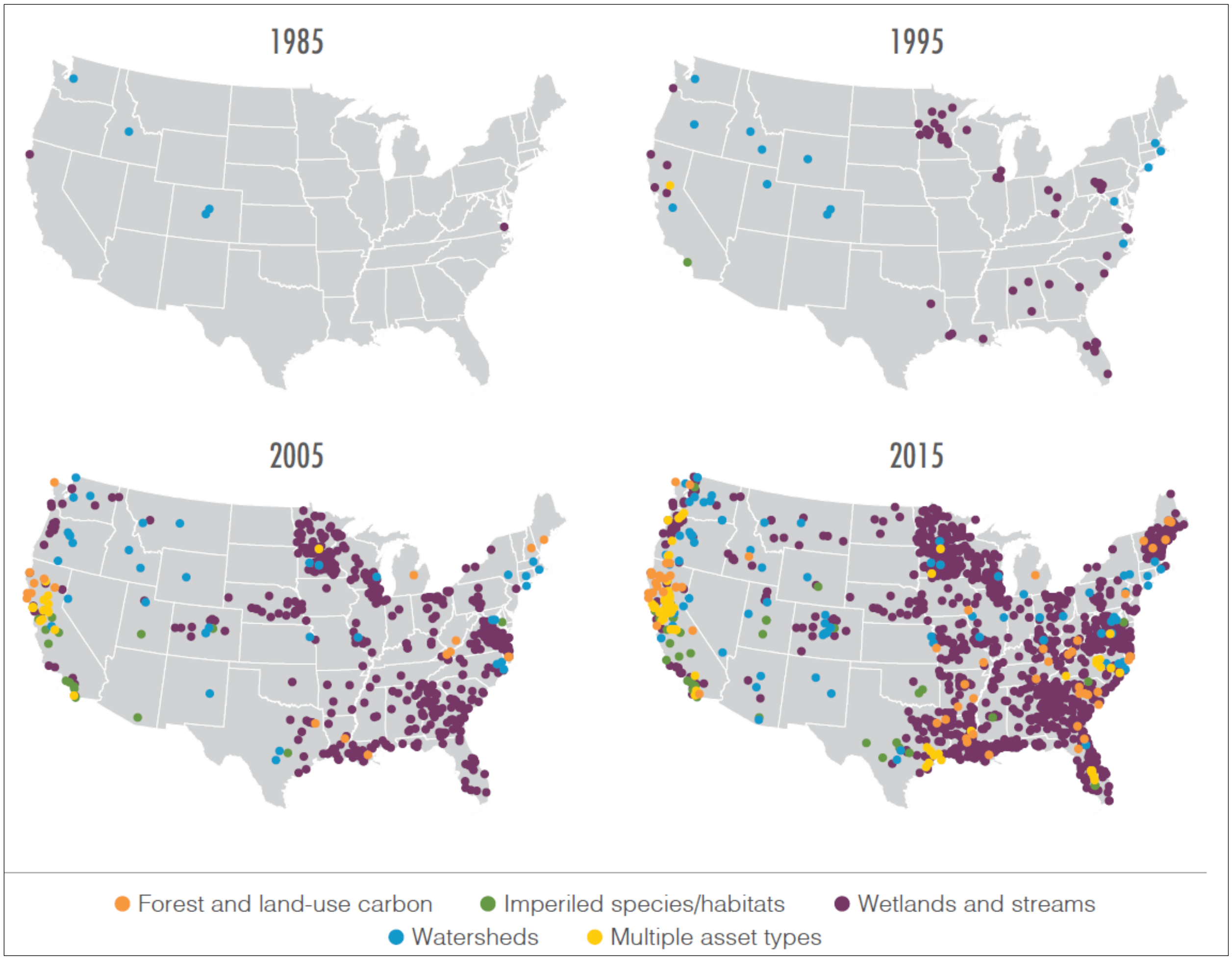

Figure 22. Growth in Ecosystem Markets Initiatives in the United States, 1985–2015 (Source: Bennett et al. 2016).

Some ecosystem markets or projects focus on more than one asset or service. For example, a landowner might sell habitat credits covering a forested area on his property and wetland credits representing restoration activities on wetland areas of the same tract. These multiple-asset initiatives currently represent only a 111 out of close to 3,000 total projects in the US (Bennett et al. 2016). However, there is strong potential for growth, especially where multiple ecosystem markets are active (e.g., Virginia, California, and Oregon) and project developers seek buyers across market types. Given the interest for the Sebago Lake watershed to preserve water quality through the conservation of forests that have strong carbon sequestration and habitat potential, the watershed is a prime candidate for hosting one of the first multi-service 'projects' in the northeast.

5 Summary

Our analysis produced the following responses to these six specific questions:

1. *At what level of forest area converted to development would the Sebago water supply be at risk of significant decreases in water quality?*

A review of recent literature indicates that the likely 'threshold' where water treatment costs start to measurably increase is when there is less than 60-90% forested area in a watershed. Our assessment found that reducing the area of forest cover in the Sebago Lake watershed from its current level of 84% down to about 76% – a pace of forest loss that is possible over the next half century given development patterns and historical rates of land use change – could lead to a noticeable increase in pollutants (nitrogen, phosphorus, sediment) that would significantly degrade lake, stream, river and wetland water quality in the watershed, particularly if that forestland were converted to various types of development. Furthermore, we anticipate that if about 10% of the current forest cover were lost, then the *entire* Sebago Lake watershed would, on average, be below state water quality standards. This would trigger the need for ameliorative water quality management throughout the watershed, rather than for a select few ponds, as is currently the case. At this level of forest loss, we estimate that nearly all lakes in the watershed could potentially become eutrophic due to nutrient enrichment (based on Trophic State Indices – TSI). However, our analysis highlights that the water quality consequences will depend strongly on where and what type of development occurs. That is, the conversion of land to urban areas with impervious surfaces poses more significant and immediate water quality risks due to elevated nutrient loading than clearing of forests for lower intensity residential development.

2. *What are the costs and benefits of protecting enough land to ensure clean water?*

We conducted an economic analysis using a range of assumptions and scenarios to estimate the potential costs and benefits of conserving forestland in the Sebago Lake watershed. These scenarios varied the cost of conserving land, the monetized value of the benefits of maintaining clean water and other ecosystem services[17] deemed important by stakeholders in the watershed that forested areas in the watershed provide, and the amount of area that could be protected. We estimate that if *all* 180,000 acres of the forest area currently not conserved were done so via a conservation easement or fee purchase, then this would yield a net benefit for the catchment even under conservative assumptions. Focusing on the amount of forestland conservation required to meet the water quality threshold (i.e., 76% forest cover for entire watershed, or about 160,000 additional acres) produces similar results. That is, we estimate that every dollar invested in forestland conservation is likely to yield between $4.80 and $8.90 in benefits, including the preservation of water quality. Additional sensitivity analysis confirmed that benefits of conservation outweighed the costs on more than 95% of the forest area. We do note however, that investing in broad forestland conservation is not costless, and that purchasing enough conservation land to meet the target of 76% forest cover in perpetuity would require about $193 million in investment.

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[17] These include provision of fuel, fiber, and freshwater, climate and water regulation, erosion control, water purification and regulation, recreation and provisioning of habitat.

3. *What is the value to beneficiaries of clean water and the associated co-benefits of land protection in the watershed?*

In addition to the provision of freshwater, forestland protection in the Sebago Lake watershed has the potential to provide other ecosystem services of interest to stakeholders in the region (see footnote 1). While not all of these values are recognized through a direct market transaction (e.g., purchasing timber), our analysis does illustrate that forestland conservation can provide non-market benefits through the form of providing recreation opportunities, preserving habitat, and mitigating climate change. We estimate that the total annual value of forest ecosystem services (FES) in the Sebago Lake watershed could range from $42-287 million per year, which equates to a value of $219-1486/ac/yr depending on the scenarios and assumptions used in the analysis. Our ‘moderate’ forest ecosystem service values scenario estimates that forests in the watershed could provide about $90 million in benefits per year, or $615/ac/yr.

4. *Is there a business case for commercial water users to invest in watershed protection to reduce future risk to their water quality?*

Yes. We estimate that if forestland continued to be at risk to development to the point that PWD would have to build a filtration plant costing about $150 million dollars, then they would increase their water rates by about 84%, on average, to offset the costs of constructing and maintaining the plant. This equates to more than $1.7 million per year in additional water charges for the top 10 consumers in the District, based on annual consumption. For the top 50 meters in the PWD, of which nearly all are connected to industrial and commercial operations, this figure increases to more than $2.1 million per annum. Thus, commercial and industrial water users in the district have a strong incentive to invest in watershed protection, such that the cost of doing so is less than the additional charges that they would face if the plant were constructed. If the top district water users used their potential cost savings for forest protection, this likely would be enough funds to invest in about 1,750-2,240 acres of forest protection per year. If all water users, including residential clients, contributed to the fund to the point that cost of doing so was equal to the annualized cost of building and maintaining the plant, then there could be enough funds to conserve up to 14,000 acres of forestland, on average, per year. At this rate, the target conservation area of 160,000 acres could feasibly be met over the next 25 years, assuming that the cost of acquiring land and establishing conservation easements remains relatively constant over time.

5. *What is the marketing value for commercial water users to invest in watershed protection?*

Our analysis, coupled with a literature review, suggests that there is minimal downside for businesses in the Sebago Lake watershed to develop a marketing plan aimed at promoting their products as ‘green’ because they are sourced from a protected watershed with high water quality. However, we caution that developing green credentials for their products may or may not result in a price premium for their product(s). Instead, businesses should be more concerned about the potentially large cost increases associated with building filtration plant(s) to cope should water quality further deteriorate in the Sebago Lake watershed.

6. ***Are there investment grade conservation opportunities in the watershed? For example, is there real potential for existing ecosystem service markets (e.g., carbon market) to use any value of co-benefits to help pay for watershed protection?***

There has been significant growth in ecosystem service market initiatives in the US over the past 30 years. There are close to 3,000 different initiatives eliciting value from ecosystem service flows. Most of the existing $2.8 billion per annum market for ecosystem services comes from wetlands and streams ($2.2 bil/yr), followed by watershed initiatives ($0.4 bil/yr), and imperiled species and habitats ($0.2 bil/yr). New forest carbon markets have emerged in recent years, but with just $58 million per year in turnover, they are still considered relatively small. This is a voluntary market in the US meaning there is more variability in the quality of these credits and a more volatile market, at least in the short term. Some ecosystem markets or projects focus on more than one asset or service too. For example, a landowner might sell both habitat credits covering a forested area nearby on his property and wetland credits representing restoration activities on wetland areas. Given the interest for the Sebago Lake watershed to preserve water quality through the conservation of forests that have strong carbon sequestration and habitat potential, the watershed is a prime candidate for hosting one of the first multi-service 'projects' in the northeast.

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Appendix 1 – InVEST model details

This section presents the key data used to model the Sebago Lake watershed in InVEST. It is not intended to be an exhaustive list of assumptions of how InVEST works, but rather a highlight of the datasets and parameters that were used to estimate the nutrient loads, sediment loads, and carbon stocks under different forest conversion scenarios. More details on how InVEST works can be found in the model user guide (InVEST, 2018).

Land Cover

Our baseline land cover classifications were taken from the 2011 National Land Cover Database generated by the Multi-Resolution Land Characteristics (MRLC) Consortium. (USGS 2011). The 2011 land cover database uses multispectral Landsat satellite at 30m pixel resolution. Land cover classifications are made based on the spectral signature of different land cover types and standardized. NLCD data can be accessed at http://www.mrlc.gov.

Table 15. NLCD land use land cover classification codes and description

LU Code	Land Use Land Cover Description
11	Open Water
21	Developed, Open Space
22	Developed, Low Intensity
23	Developed, Medium Intensity
24	Developed, High Intensity
31	Barren Land (Rock/Sand/Clay)
41	Deciduous Forest
42	Evergreen Forest
43	Mixed Forest
52	Shrub/Scrub
71	Grassland/Herbaceous
81	Pasture/Hay
82	Cultivated Crops
90	Woody Wetlands
95	Emergent Herbaceous Wetlands

The Nutrient Delivery Ratio Model

We use InVEST (v. 3.3.6, February 2016) Nutrient Delivery Ratio model to estimate nitrogen (N) and phosphorus (P) export from land to streams for each scenario. A full description of the NDR model can be found in the Natural Capital Project's InVEST User Guide. Briefly, for each 30m pixel, the model estimates the amount of nitrogen or phosphorus running off the pixel to an adjacent pixel (either by surface or subsurface flow). Based on nutrient retention coefficients and pixel path-lengths to streams (defined by a digital elevation model), the amount of nitrogen or phosphorus that is transported to a given waterway or stream is estimated. Note that initial values of nutrient loading (initial N or P inputs) are parameters that the user enters for each land use type or classification. Key data sources are listed in Table 16 while the specific parameterization for the NDR input file is listed in Table 17.

Table 16. InVEST nutrient delivery ratio (NDR) data sources

Input	Data Type	Modeled Source
Digital Elevation Model	Raster (Pixel by Pixel)	ME GIS
Land Use / Land Cover	Raster (Pixel by Pixel)	NLCD MRLC 2011 Land Cover Database for Sebago lake Watershed
Watershed Map	Shapefile	ME GIS
Table of Biophysical Parameters	Spreadsheet	User-defined based on literature and parameterization
Subsurface Critical Length	Constant	150 (for N and P)
Threshold Flow Accumulation	Constant	1000
Borselli k Parameter	Constant	2
Subsurface Max Retention	Constant	0.8

Table 17. InVEST nutrient delivery ratio (NDR) parameterization for Sebago Lake watershed model

General Parameters				Nitrogen Parameters				Phosphorus Parameters			
lucode	LULC_veg	root_depth	Kc	load_n	eff_n	crit_len_n	p_s_n	load_p	eff_p	crit_len_p	p_s_p
11	0	1	1	0.001	0.05	1	0	0.001	0.05	1	0
21	0	1	0.5626	2	0.3	10	0	5	0.05	10	0
22	0	1	0.4456	11.25	0.2	10	0	11	0.05	5	0
23	0	1	0.3124	20.5	0.1	10	0	15	0.05	5	0
24	0	1	0.1701	29.75	0.05	10	0	21	0.025	5	0
31	0	1	0.5	29.75	0.05	10	0	7.53	0.05	10	0
41	1	1000	0.9993	2.86	0.9	30	0	0.236	0.95	30	0
42	1	1000	0.9996	2.86	0.9	30	0	0.236	0.95	30	0
43	1	1000	0.9973	2.86	0.9	30	0	0.236	0.95	30	0
52	1	750	1	2.86	0.8	30	0	0.236	0.8	30	0
71	1	750	1	5.755	0.53	30	0	0.868	0.4	30	0
81	1	500	1	8.65	0.53	30	0	2.5	0.4	30	0
82	1	500	1	16.53	0.53	30	0	3.31	0.4	30	0
90	1	400	1	2.86	0.85	30	0	0.236	0.8	30	0
95	1	400	1	2.86	0.72	30	0	0.236	0.62	30	0

Sediment Delivery Ratio Model

We use InVEST (v. 3.3.6, February 2016) Sediment Delivery Ratio (SDR) model to estimate sediment export from land to streams for each scenario in tons. A full description of the SDR model can be found in the Natural Capital Project's InVEST User Guide. Briefly, for each 30m pixel, the model estimates the amount of sediment produced on each pixel, the soil loss and flow pathways of that sediment towards the stream (based on slope) and the amount of sediment that flows through each pixel (based on land cover type). Key data sources are listed in Table 18 while the specific parameterization for the NDR input file is listed in Table 19.

Table 18. InVEST sediment delivery ratio (SDR) data sources

Input	**Data Type**	**Modeled Source/Data**
Digital Elevation Model	Raster (Pixel by Pixel)	ME GIS
Land Use / Land Cover	Raster (Pixel by Pixel)	NLCD MRLC 2011 Land Cover Database for Sebago lake Watershed
Watershed Map	Shapefile	ME GIS
Table of Biophysical Parameters	Spreadsheet	User defined (shown below)
Threshold Flow Accumulation	Constant	1000
Borselli k Parameter	Constant	2
Borselli IC_0 Parameter	Constant	0.5
Max Sediment Delivery Ratio	Constant	0.8

Table 19. InVEST sediment delivery ratio (SDR) parameterization for Sebago Lake watershed model

lucode	usle_c	usle_p
11	0.001	1
21	0.15	0.5
22	0.15	0.5
23	0.15	0.5
24	0.15	0.5
31	0.3	1
41	0.01	1
42	0.01	1
43	0.01	1
52	0.15	1
71	0.01	1
81	0.3	1
82	0.3	1
90	0.001	1
95	0.001	1

Carbon Storage Model

Carbon storage on land is a function of the size of four carbon "pools:" aboveground biomass, belowground biomass, soil, and dead organic matter. The InVEST Carbon model aggregates the amount of carbon stored in these pools according to the land use maps and classifications produced by the user. Aboveground biomass is living plant tissue including trees, branches and leaves. Belowground biomass is living root systems. Soil organic matter is organic carbon stored in soils, and dead organic matter includes standing dead wood and all non-living vegetative matter. For each land-cover type, an average amount of carbon and standard deviation of carbon stored in each of these four pools is used to calculate carbon storage. Thus, carbon storage estimates are a static function of land cover classification and user-defined pool size.
The specific parameters used to estimate the amount of carbon stock for each land cover classification are listed in Table 20.

Table 20. InVEST carbon storage model parameterization for Sebago Lake watershed model

lucode	C_above_mean	C_above_sd	C_below_mean	C_below_sd	C_soil_mean	C_soil_sd	C_dead_mean	C_dead_sd
11	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0
22	23	10	5	2	39	1	13	4
23	12	5	2	1	39	2	7	2
24	4	2	1	0	43	2	2	1
31	0	0	0	0	0	0	0	0
41	106	61	12	5	72	10	34	10
42	104	53	12	5	73	10	30	9
43	105	56	12	5	72	10	32	10
52	105	54	12	5	72	12	31	10
71	4	1	11	2	99	40	0	0
81	4	1	11	2	99	40	0	0
82	2	1	5	2	72	21	0	0
90	109	56	12	6	74	12	31	10
95	3	0	11	2	124	45	0	0

Appendix 2 – Detailed Data

Table 21. Summary of monetary values for global ecosystem services per biome (2007$/ha/yr)

Summary of monetary values for each service per biome (values in Int.$/ha/year, 2007 price levels).

	Marine	Coral reefs	Coastal systems	Coastal wetlands [a]	Inland wetlands	Fresh water (rivers/ lakes)	Tropical forest	Temperate forest	Woodlands	Grasslands
Provisioning services	102	55,724	2396	2998	1659	1914	1828	671	253	1305
1 Food	93	677	2384	1111	614	106	200	299	52	1192
2 Water				1217	408	1808	27	191		60
3 Raw materials	8	21,528	12	358	425		84	181	170	53
4 Genetic resources		33,048		10			13			
5 Medicinal resources				301	99		1504			1
6 Ornamental resources		472			114				32	
Regulating services	65	171,478	25,847	171,515	17,364	187	2529	491	51	159
7 Air quality regulation							12			
8 Climate regulation	65	1188	479	65	488		2044	152	7	40
9 Disturbance moderation		16,991		5351	2986		66			
10 Regulation of water flows					5606		342			
11 Waste treatment		85		162,125	3015	187	6	7		75
12Erosion prevention		153,214	25,368	3929	2607		15	5	13	44
13 Nutrient cycling				45	1713		3	93		
14 Pollination							30		31	
15 Biological control					948		11	235		
Habitat services	5	16,210	375	17,138	2455	0	39	862	1277	1214
16 Nursery service		0	194	10,648	1287		16		1273	
17 Genetic diversity	5	16,210	180	6490	1168		23	862	3	1214
Cultural services	319	108,837	300	2193	4203	2166	867	990	7	193
18 Esthetic information		11,390			1292					167
19 Recreation	319	96,302	256	2193	2211	2166	867	989	7	26
20 Inspiration		0			700					
21 Spiritual experience			21							
22 Cognitive development		1145	22					1		
Total economic value	**491**	**352,249**	**28,917**	**193,845**	**25,682**	**4267**	**5264**	**3013**	**1588**	**2,871**

Source: de Groot et al (2012)

Table 22. Summary of monetary values for global temperate forests biome (2007 US$/ha/yr)

Temperate forests	No. of used Estimates	Mean Value (int$/ha/y)	Median Value (Int$/ha/y)	St Dev of values	Minimum Value (int$/ha/y)	Maximum Value (Int$/ha/y)
TOTAL:	**58**	**3.013**	**1.127**	**5.437**	**278**	**16.406**
PROVISIONING SERVICES	**9**	**671**	**450**	**867**	**121**	**1.593**
1 Food	2	299	299	422	0	597
2 (Fresh) water supply	3	191	121	123	118	333
3 Raw materials	4	181	31	322	2	662
4 Genetic resources						
5 Medicinal resources						
6 Ornamental resources						
REGULATING SERVICES	**13**	**491**	**367**	**584**	**105**	**1.212**
7 Influence on air quality						
8 Climate regulation	6	152	34	241	7	624
9 Moderation of extreme events						
10 Regulation of water flows						
11 Waste treatment / water purification	3	7	0	13	0	22
12 Erosion prevention	*1*	*5*	*5*		*5*	*5*
13 Nutrient cycling / maintenance of soil fertility	*1*	*93*	*93*		*93*	*93*
14 Pollination						
15 Biological control	2	235	235	330	1	469
HABITAT SERVICES	**10**	**862**	**171**	**1.342**	**51**	**3.573**
16 Lifecycle maintenance (esp. nursery service)						
17 Gene pool protection (conservation)	10	862	171	1.342	51	3.573
CULTURAL SERVICES	**26**	**990**	**139**	**2.644**	**1**	**10.028**
18 Aesthetic information						
19 Opportunities for recreation and tourism	25	989	138	2.644	1	10.027
20 Inspiration for culture, art and design						
21 Spiritual experience						
22 cognitive information (education and science)	*1*	*1*	*1*		*1*	*1*

Source: de Groot et al (2012)

Table 23. Summary of monetary values for global forest biomes (2007$/ha/yr)

Ecosystem Service	**Study Year**	**2007 $/ha/yr**		
		Tropical	*Temperate/Boreal*	*All Forest*
Gas Regulation	1997			
	2011	$12		$4
Climate Regulation	1997	$307	$122	$194
	2011	$2,044	$152	$711
Disturbance Regulation	1997	$7		$3
	2011	$66		$19
Water Regulation	1997	$8	$0.1	$3
	2011	$8	$0.1	$3
Water Supply	1997	$10		$4
	2011	$27	$191	$143
Erosion Control	1997	$337		$132
	2011	$337		$100
Soil Formation	1997	$14	$14	$14
	2011	$14	$14	$14
Nutrient Cycling	1997	$1,272		$498
	2011	$3	$93	$66
Waste Treatment	1997	$120	$120	$120
	2011	$120	$120	$120
Pollination	1997			
	2011	$30		$9
Biological Control	1997		$6	$3
	2011	$11	$235	$169
Habitat/ Refugia	1997			$0
	2011	$39	$862	$619
Food Production	1997	$45	$69	$59
	2011	$200	$299	$270
Raw Materials	1997	$435	$34	$191
	2011	$84	$181	$152
Genetic Resources	1997	$57		$22
	2011	$1,517		$448
Recreation	1997	$154	$50	$91
	2011	$867	$989	$953
Cultural	1997	$2	$3	$3
	2011	$2	$1	$1
Total ES Value	1997	**$2,769**	**$417**	**$1,338**
	2011	**$5,382**	**$3,137**	**$3,800**

Source: Costanza et al (2014); Costanza et al (1997)

Table 24. Summary of monetary values for non-provisioning services in Maine's forest biomes (2012 US$)

Forest Type	Area (ha)	Total Value ($/yr)	$/ha/yr	$/ac/yr
Adjacent to stream	122,300	$427,191,795	$3,493	$1,412
Heavy partial cut	292,473	$86,397,185	$295	$119
Light partial cut or regenerating	718,887	$552,138,467	$768	$311
Non-urban	4,823,922	$5,699,992,133	$1,182	$478
Suburban	26,922	$212,342,508	$7,887	$3,189
Urban	2,774	$64,913,291	$23,396	$9,461
total	5,987,279	$7,042,975,379	$1,176	$476

Source: Troy (2012); Services include (author's categorical naming): gas regulation, disturbance regulation, soil regulation, nutrient regulation, water supply, recreation, habitat refugium

Table 25. Summary of monetary values for non-provisioning services in Maine's forest biomes by ecosystem service type (2012$/ac/yr)

Ecosystem service and Forest Type	Adjacent to stream	Heavy partial cut	Light partial cut or regen	Non-urban	Suburban	Urban
Gas Regulation	$71	$71	$71	$71	$71	$71
Disturbance Regulation	$53	$53	$53			
Soil Regulation	$277					
Nutrient Regulation	$183		$183	$183	$183	$183
Water Supply	$469				$587	$587
Recreation	$198			$66	$691	$5,298
Habitat Refugium	$163			$52		
Pollination and Seedlings						$3,246
Aesthetic and Amenity					$1,574	
Other Cultural				$106	$89	$89
Total Value	$1,414	$124	$306	$478	$3,193	$9,472

Table 26. PWD - Grant cost of recent conservation land in Sebago Lake watershed ($/ac)

Name	Location	Type	Year	Acres	Value ($)	Val ($/ac)
Hague	Waterford	CE	2008	350	$100,000	$286
Watkins	Waterford	CE	2011	690	$750,000	$1,087
Camp Wawenock	Raymond	CE	2010	60	$1,500,000	$25,000
Tenny River	Raymond	Fee	2012	28	$226,000	$8,071
Hague Farmstead	Waterford	CE	2012	88	$71,000	$807
Perley Mills	Bridgton/Denmark	Fee	2013	800	$1,100,000	$1,375
Maple Ridge	Harrison	Fee	2013	35	$70,000	$2,000
Moon Valley	Harrison	Fee	2013	14	$58,500	$4,179
Flint Farm	Albany Township	CE	2013	156	$40,000	$256
Perley Pond/NW River	Sebago	Fee	2014	150	$160,000	$1,067
Crooked River W. Forest	Harrison/Otisfield	Fee	2014	791	$1,600,000	$2,023
Cummings Parcel	Harrison	Fee	2014	10	$35,000	$3,500
Stanley Parcel	Waterford	Fee	2015	21	$7,500	$357
Raymond Community Forest	Raymond	Fee	2014	350	$615,000	$1,757
Whitney Pond	Stoneham	Fee	2015	70	$330,000	$4,714
Proctor Pond	Albany Township	Fee	2015	54	$44,100	$817
	Total	**CE**		**1,344**	**$2,461,000**	**$1,831**
	Total	**Fee**		**2,323**	**$4,246,100**	**$1,828**
	Total	**Total**		**3,667**	**$6,707,100**	**$1,829**

Source: PWD

Table 27. PWD - Fee cost of recent conservation land in Sebago Lake watershed ($/ac)

Name	Address	Date	Cost	Size (Ac)	Cost/acre
Woodbrey (Swap)	Littlefield Road	11/16/1994	$0	3.05	$0
Esty	Eel Cove Road	3/28/1996	$62,500	0.2	$312,500
Lowell	Rear Ellenwood Rd	5/15/1996	$83,000	35	$2,371
Metcalf	Eel Cove Road	6/17/1996	$180,000	0.4	$450,000
Dunham	Richville Road	7/2/1996	$120,000	0.32	$375,000
Baribeau	Maple Street	9/17/1997	$102,000	0.45	$226,667
Rayburn	Maple Street	10/27/1997	$70,000	0.44	$159,091
Shaw/Myers (Swap)	Littlefield Road	4/30/1998	$0	0.18	$0
Cragin	Eel Cove Road	12/9/1998	$155,000	0.2	$775,000
Bean	Richville Road	10/5/1999	$62,000	1	$62,000
Dyer	Maple Street	11/15/1999	$119,000	0.6	$198,333
USA, Sec. Of HUD	Maple Street	2/4/2000	$108,000	1.3	$83,077
Town of Standish	Cottage Road	10/26/2001	$6,650	0.15	$44,333
Shaw/Mosley (Swap)	Eel Cove Road	3/17/2003	$0	7.85	$0
J&D Ent. (Hunt)	5 Richville Road	2/22/2006	$350,000	0.3	$1,166,667
Lawrence (Gorgone)	86 Eel Cove Road	3/28/2006	$430,000	0.2	$2,150,000
Lanni	281 Smith Mill Road	10/10/2007	$400,000	0.25	$1,600,000
Porter	295 Smith Mill Road	10/18/2007	$380,000	0.2	$1,900,000
Stanford	15 Dog Leg Road	6/30/2008	$380,000	0.28	$1,357,143
Total			**$3,008,150**	**52.37**	**$57,440**

Source: PWD

Table 28. TNC cost of recent conservation land in Sebago Lake watershed ($/ac)

Org	Tract	Fee or CE	Date	Acres	Purchase Price	Town	$/acre
WFLT	MNRCP Moon Valley	Fee	2013	14	$45,000	Harrison	$3,214
WFLT	MNRCP Witt Swamp	Fee	2014	111	$84,000	Norway	$757
WFLT	MNRCP Robie Meadow	Fee	2012	51	$50,000	Harrison	$980
WFLT	Crooked River Twin Bridges	Fee	2015	255	$600,000	Otisfield	$2,353
WFLT	MNRCP Crooked River Green	Fee	2015	260	$325,000	Otisfield	$1,250
WFLT	Crooked River - Fogg	Fee	2017	76	$68,000	Otisfield	$895
LELT	Saco River (Norkin)	CE	2012	210	$160,000	Denmark	$762
LELT	Crooked River - Intervale	Fee	2015	296	$495,000	Harrison	$1,672
TNC	Saco River (Russell)	CE	2012	524	$270,000	Fryeburg	$515
TNC	Saco River (Doughty)	Fee	2009	6	$3,300	Denmark	$550
	Total	**CE**		**734**	**$430,000**		**$586**
	Total	**Fee**		**1069**	**$1,670,300**		**$1,562**
	Total	**Total**		**1803**	**$2,100,300**		**$1,165**

Source: TNC

Table 29. MRS estimated land valuation for forest or 'back lot' land in Sebago Watershed municipalities ($/ac)

Municipality	County	Area in SL Watershed (ac)	Mean Forestland Tax Valuation ($/ac)
Albany Twp	Oxford	24,077	$970
Baldwin	Cumberland	1,159	$805
Bethel	Oxford	1,636	$660
Bridgton	Cumberland	27,572	$500
Casco	Cumberland	16,817	$2,000
Denmark	Oxford	2,082	$1,000
Gray	Cumberland	132	$1,641
Greenwood	Oxford	1,654	$1,000
Harrison	Cumberland	20,843	$1,000
Naples	Cumberland	19,860	$1,250
Norway	Oxford	9,801	$673
Otisfield	Oxford	16,184	$800
Poland	Androscoggin	109	$1,025
Raymond	Cumberland	15,848	$1,066
Sebago	Cumberland	16,318	$1,745
Standish	Cumberland	12,196	$2,514
Stoneham	Oxford	6,268	$847
Sweden	Oxford	6,450	$800
Waterford	Oxford	29,237	$1,500
Windham	Cumberland	2,264	$2,208
Sebago Watershed		**230,844**	**$1,202**

Source: Maine Revenue Service (2017)

Table 30. LMF and Maine NRC Program acquisition data for land conservation in Maine by county

County	Total Acres	Overall Cost / Acre	Standard Deviation	Project Count
Androscoggin	38,533	$1,028	$849	5
Aroostook	6,244	$831	$865	8
Cumberland	8,813	$5,947	$8,345	51
Franklin	28,143	$818	$646	10
Hancock	46,582	$976	$1,052	11
Kennebec	6,864	$1,388	$737	6
Knox	912	$3,710	$1,653	8
Lincoln	1,326	$2,456	$1,595	9
Oxford	9,651	$1,255	$761	10
Penobscot	6,156	$1,619	$1,440	12
Piscataquis	243,548	$755	$578	8
Sagadahoc	2,991	$3,142	$2,275	19
Somerset	64,396	$1,742	$1,870	7
Waldo	2,313	$2,394	$2,716	10
Washington	83,499	$2,128	$2,171	37
York	15,381	$3,027	$2,367	25
Total	**565,351**	**$2,076**	**$1,870**	**236**

Source: Colgan et al (2013)

Table 31. OSI cost of recent conservation land in Sebago Lake watershed ($/ac)

Property	Fair Market Value (FMV)	Purchase Price	Acres	CE/Fee	FMV/Ac	Cost/Ac	Notes
Twin Bridges	$600,000	$600,000	255	FEE	$2,353		River & road frontage
Intervale	$495,000	$495,000	296	FEE	$1,672		River & road frontage
Oak Hill	$120,000	$17,000	131	FEE	$916		
Watkins S.	$43,000	$0	56	FEE	$768		River frontage
Fogg Lot	$68,000	$62,000	74	FEE	$919		River frontage
Noyes Mt	$480,000	$350,000	296	FEE	$1,622		Just outside watershed
Totals	**$1,806,000**	**$1,524,000**	**1108**		**$1,630**	**$1,376**	

Source: Open Space Institute (OSI)

Appendix 3 – InVEST Development Intensity Sensitivity

The environmental risk scenarios estimate the impact of converting forest with varying degrees of nutrient and sediment retention on water quality in the watershed. For each scenario, a certain fraction of the watershed's forests was "cleared" (i.e., converted to development[18]), including one where there is complete conversion of forestland to development.

This approach was done in 20% parcel conversion intervals, specified as follows:

- **Env S0:** Baseline scenario with 2011 land use land cover (LULC).
- **Env S1:** 100% conversion of all forest parcels (as represented by GIS pixels) in the watershed to development (NLCD code 22 or 24)**.**
- **Env S2**: Parcels jointly representing at least 20% of the total N, P and S loading to the watershed were converted back to baseline land use/land cover. The other parcels were maintained as cleared land (NLCD code 22 or 24).
- **Env S3**: Parcels jointly representing at least 40% of the total N, P and S loading to the watershed were converted back to baseline land use/land cover. The other parcels were maintained as cleared land (NLCD code 22 or 24).
- **Env S4**: Parcels jointly representing at least 60% of the total N, P and S loading to the watershed were converted back to baseline land use/land cover. The other parcels were maintained as cleared land (NLCD code 22 or 24).
- **Env S5**: Parcels jointly representing at least 80% of the total N, P and S loading to the watershed were converted back to baseline land use/land cover. The other parcels were maintained as cleared land (NLCD code 22 or 24).

Thus, for each sequential scenario, a smaller area of forest was converted to low intensity development (Figure 23). An example of how this could vary spatially for three of the scenarios is illustrated in Figure 24.

[18] NLCD 2011 Land Cover Classification (LCC) code 22

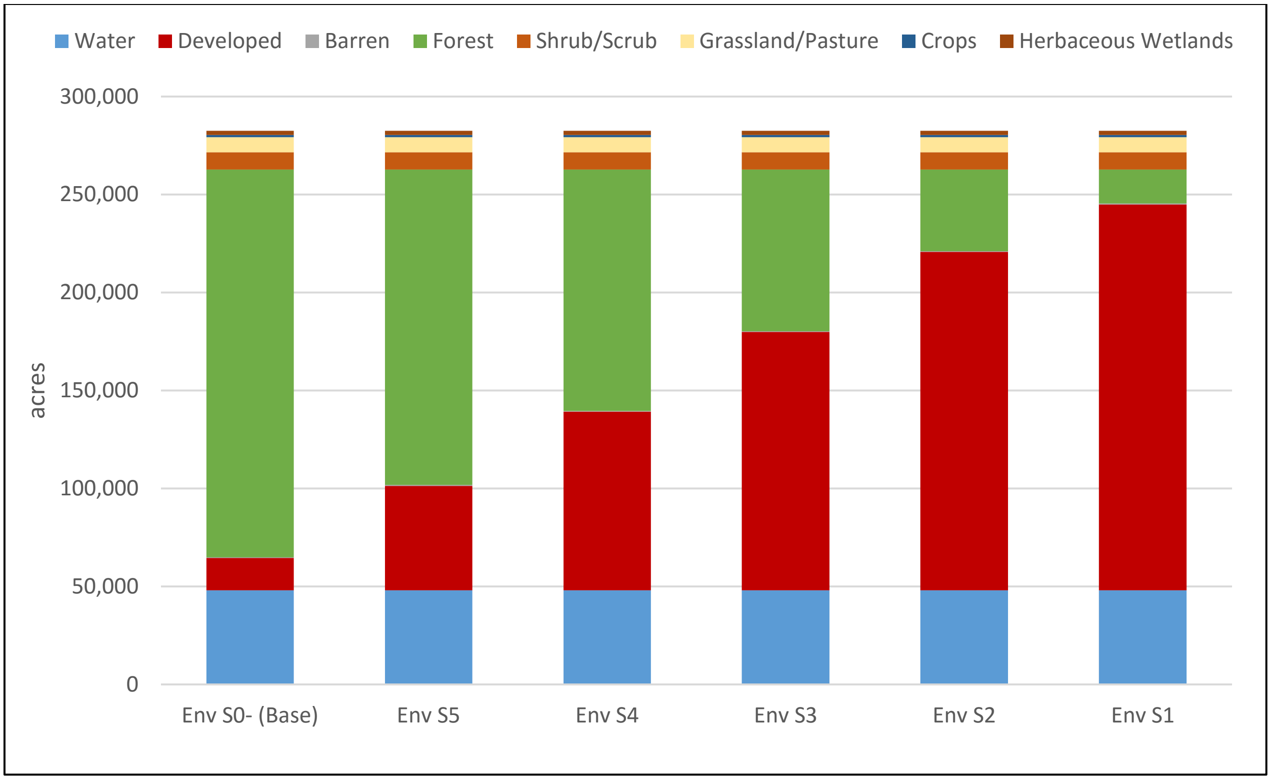

Figure 23. Sebago Lake watershed land use by Environmental Risk scenarios.

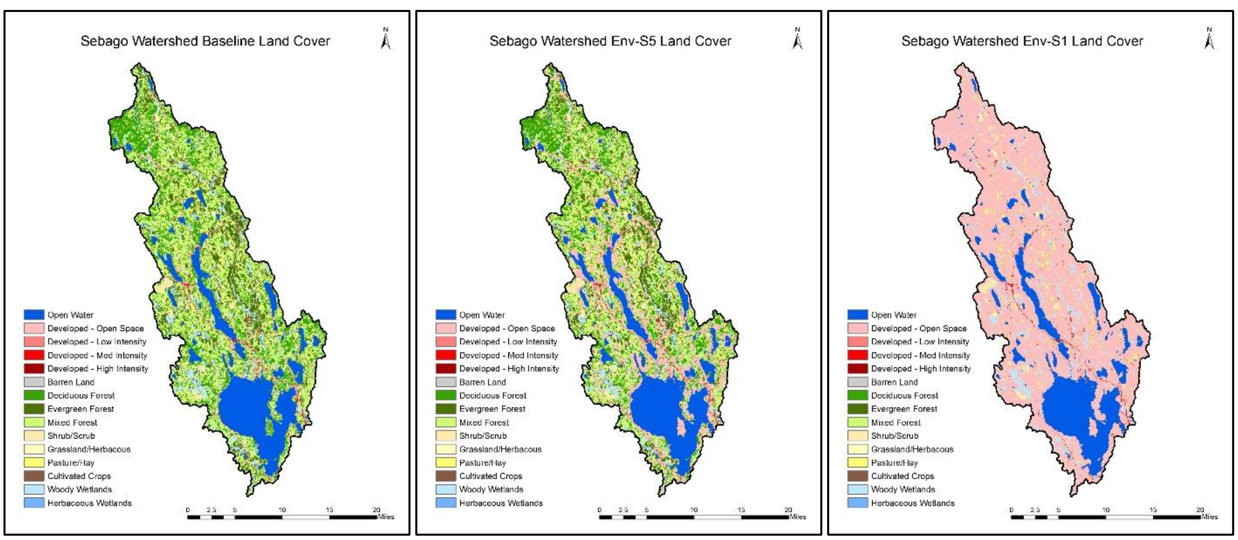

Figure 24. Land use distribution for baseline/current land cover (Env S0), gradual development based on loading severity (Env S5), and full Conversion to low intensity development (Env S1).

The main analysis for the Environmental Risk scenario assumed different levels of forests were converted to low-intensity development. However, there is also the potential that some of that land could be converted to higher-intensity development, as we assumed for the Development Risk scenarios. We thus conducted a sensitivity analysis in InVEST to estimate the potential difference in N, P, and S loads and C stocks for the two development intensity options (Figure 25).

The differences in loading estimates between the intensity assumptions are apparent, as the figure shows that N and P loadings vary by a factor of at least 2. The figure also reveals that sediment and carbon stock trajectories remain the same regardless of the development intensity classification. This is because these outputs are estimated in InVEST purely by the aggregate land cover type (i.e., "Development"), not the specific type of development that the forest is converted to (i.e., both low and high development have the same carbon stock and sediment load rates in the InVEST).

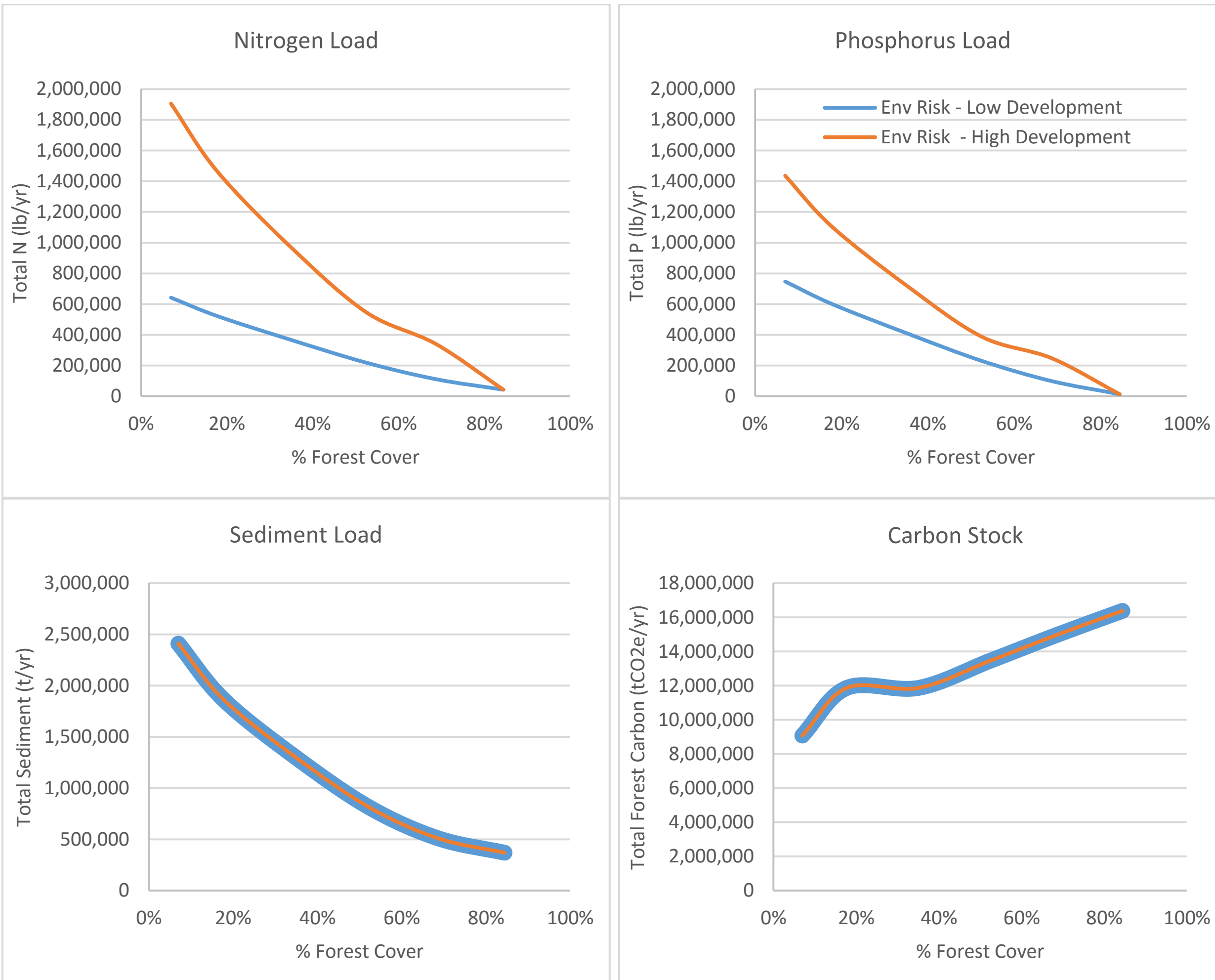

Figure 25. Sensitivity of Environmental Risk scenarios to development intensity