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The Value of Ecosystem Services in the Commonwealth of Kentucky's Forestland

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Abstract

Assigning economic value to ecosystem services allows policy officials to evaluate and determine the services of greater importance to the general public, enabling them to develop policies to protect the resources for future use. A benefit transfer study was performed to obtain the monetary value per acre allocated to eight ecosystem services from Kentucky forestland; biological control, cultural, habitat/ refugia, pollination, recreation, soil formation, water supply, and water treatment. Using the Consumer Price Index, these values were converted into 2012 US$ per acre and multiplied by the total carbon dioxide stored in Hardwood tree stands of 50 years, per county, was calculated using date from the Forest Inventory and Analysis database from the U.S. forest service and information from the Alabama Forestry Commission. To determine the value of carbon sequestered, a sensitivity analysis was done using the values of $1, $5, $10, and $25 per ton. The ecosystem service of highest value was habitat/ refugia, and the total value of carbon at $25 per ton was over $32 billion. My results suggest that Kentucky's forest provide substantial value to the residents of Kentucky and the world in terms of ecosystem services. The valuation of ecosystem services provides information to Kentucky residents and policy makers concerning the importance of ecosystem service relative to other daily commodities. It is hoped that the results from this research will aid in the development of policies and forest management that will protect and enhance the important benefits that Kentucky's forests provide.

Key Words: Ecosystem services, carbon sequestration, Kentucky, non-market value

1. Introduction

"Ecosystem services are the benefits people obtain from ecosystems" (Ecosystems and Human Well-being: Synthesis 2005). Most ecosystem services are grouped into two forms of public goods. The first category of public goods implies that those goods/ services can be enjoyed by everyone, without hurting someone else's enjoyment/ benefit. The other form of public goods is quasi- public goods. This is the idea that if someone uses too much of a good/ service, the enjoyment/ benefit may be reduced to others (King and Mazzotta 2000).

A research study was done on the value of ecosystem services and carbon sequestration in the Commonwealth of Kentucky. The first step included extensive literature reviews relevant to the area of study. This allowed me to choose the ecosystem services I wanted to calculate a value for and to find the numbers needed to value those ecosystem services I choose. I looked through many papers but settled on two that inventoried the state of New Jersey's (Costanza 2006) and the world's ecosystem services (Costanza 1997).

2. Ecosystem Services and Their Importance

There has been much debate about the valuation of ecosystem services. Some believe that assigning economics values to ecosystem services diminishes their true worth. These people believe that one should protect ecosystems for cultural and aesthetic purposes; which does not require values. Some argue that putting a value on an ecosystem service has distributional implications because people's value for ecosystem services differ depending on their direct need/ use for the service. Those who believe in valuing ecosystem services believe so because essentially 'money talks' and it is understood by everyone.

2.1 Types Of Ecosystem Services

Ecosystem services are important to the everyday function of today's society. Ecosystem services can be divided into four main categories: supporting services, provisioning services, regulating services and cultural services. Each of these categories provides services that are important to the everyday function of the world. Supporting services are services provided by the ecosystem that supports provision of other ecosystem services (Ecosystems and Human Well-being: Synthesis 2005). The supporting services evaluated in this study were soil formation[1] and waste treatment[1]. Provisioning services are the services that give humans a direct use and can usually be bought and sold (2005). The only provisioning service evaluated in this study was water supply[2]. Regulating services are those that regulate and maintain the overall function of the ecosystem (2005). The regulating services evaluated in this study were pollination[2], biological control[1], and carbon sequestered. The final service is the cultural service, which provides some form of culture or aesthetic value (2005). The cultural services evaluated in this study were habitat/ refugee[2], recreation[1], and cultural experience[1].

2.2 Millennium Ecosystem Assessment

The Millennium Ecosystem Assessment (MEA) took place from 2001- 2005 and examined the relationship between ecosystem services and the human well-being. The purpose of the MEA report was to help set in place actions and policies in order to protect and conserve the depleting ecosystem services around the globe (Ecosystems and Human Well-being: Synthesis 2005). The MEA considered the global status of three ecosystem service categories; provisioning, regulating, and cultural. The report discussed the present issue with each ecosystem service, as well as a prediction of how each specific ecosystem will evolve, and what its status will be in the year 2050 (Ecosystems and Human Well-being: Synthesis 2005). The MEA looked at if these services were either depleted or enhanced over the given time period. The ecosystem services that were assessed came from the following biomes; marine, coastal, inland water, forest/ woodland, dryland, island, mountain, polar, cultivated and urban (Ecosystems and Human Well-being: Synthesis 2005). The report also factored in the increasing rate of population and its effect on ecosystem services; it was compared to the net primary productivity and gross domestic product (GDP) within different biomes (Ecosystems and Human Well-being: Synthesis 2005).

2.3 Current Status of Ecosystem Services

In the Millennium Ecosystem Assessment there were three main findings, these findings are listed below, in no significant order:

Over the past half a century, the human population has more quickly and significantly altered ecosystems to meet the high demands for ecosystem services such as fresh water, timber/ fuel and food; leading to a substantial decrease in diversity across the globe (Ecosystems and Human Well-being: Synthesis 2005).

Even though the changes made to these ecosystems have resulted in a higher GPD and economic stability for most countries, the continuation of degradation of ecosystem services has lead some countries into severe poverty. If these problems continue there will be minimal ecosystem benefits for future generations (Ecosystems and Human Well-being: Synthesis 2005).

The continual degradation of these ecosystem services is expected to considerably increase, resulting in a hardship to complete the eight Millennium Development Goals set by the United Nations 2000 (Ecosystems and Human Well-being: Synthesis 2005).

2.4 Human Dependence on Ecosystem Services

The concept of human dependence on ecosystem services is a major factor in why ecosystem services are continuously being exacerbated and depleted, and why it is imperative to estimate the economic value of these services. While it is necessary for the human population to have a fresh water source as well as food to consume to live, that is not the sole reason why humans relay on ecosystem services. Pursuit of over-all economic well-being byincreasing GDP, as well is a defining reason why ecosystem services have been degraded and depleted over the past decades. Some ecosystem services are considered a commodity in the global market place (Costanza 1997) and are traded in well-functioning markets and thus have established economic values. However, other ecosystem services are not typically traded in markets, but are public goods, and thus tend to be undervalued in economic decisions. The value of ecosystem services are directly correlated to a country's GPD. (Guo 2010).

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3. Why and How of Ecosystem Services Economic Valuation

The concept of Economic Value is defined as "the measure of the contribution something makes toward human wellbeing" (Moore 2011). Placing an economic value on ecosystem services can be an important or even the only way to distinguish which services are more valuable than others to the human population. Assigning an economic value to an ecosystem service allows for individuals all over the world, no matter their currency system, to understand and compare ecosystem services because each service is now represented as a commodity and has a monetary value, a language that is spoken globally.

3.1 Ways Ecosystem Services are Valued

An ecosystem service's value is dependent upon how important that service is to the public, or how much it is worth to them. There many methods used in determining an ecosystem service's value; each method allows for several techniques to be used in order to acquire the services' values. The first approach in ecosystem valuation is to use the market price of the ecosystem service. This generally consists of estimates based on the exchange, or supply and demand, for the ecosystem service (Moore 2011). This could simply be the supply and demand for timber supplies. The second approach is to put a production function value on the ecosystem good/ service. This idea is the value of a non-market resource is estimated based on its contribution to the production of some other market good (Moore 2011). This could be the value of irrigation water and its contribution to crop production. The third approach is assessing the replacement cost of the service. This is the idea of considering the cost of replacing the original ecosystem service with some form of a substitute (Moore 2011). An example of this could be replacing the water filtration service from a wetland by estimating the cost of building a wastewater treatment plant. The fourth approach of ecosystem service valuation is a revealed preference. This considers an individuals' decision in a related market to determine the value of a market or non-market service. There are four ways to do this; hedonic pricing, travel cost, defensive behavior, and damage cost (Moore 2011). Hedonic pricing is the people's WTP to be in close proximity to a service. Travel cost is the price people will pay in order to travel to a service's location, "including the imputed value of their time" (Costanza 2006). Defensive behavior is "individuals' actions to avoid possible damage", such as the purchase of bottled water reveals the a greater WTP for better water quality. Damage cost is "individuals' WTP to avoid damage from [natural events] must be higher than the cost of dealing with these damages" (Moore 2011).

The fifth approach in the valuation of an ecosystem service is the concept of stated preference (Moore 2011). For this method, one could simply asked questions to determine a person's willingness to pay (WTP) for a positive or negative change in environmental quality (Costanza 1997). An example of this might be surveying a community on how they might feel on an increase in taxes to improve water quality for the area. The sixth, and final approach is to place a value on an ecosystem service is the idea of a benefit transfer. This is a study that accepts a value or estimate from a previous study and places it in a different context (Moore 2011). This approach was used to calculate all ecosystem service values in this study except the value of carbon sequestration (which was calculated using potential market prices derived from existing carbon markets).

4. Methods

The objective of this research study was to present a valuation of the economic benefits provided by the forestland in the Commonwealth of Kentucky. The goal was to estimate the net value of the selected ecosystem services found on the forestland in the Commonwealth of Kentucky by performing a transfer value study for each of the ecosystem services selected and calculating the metric tons of carbon dioxide equivalent ($MTCO_2e$). "By estimating the economic value of environmental features not traded in the marketplace, social costs or benefits that otherwise would remain hidden or unappreciated are revealed, so that when tradeoffs between alternative land uses in [Kentucky] are evaluated, information is available to help decision makers avoid systematic biases and inefficiencies" (Costanza 2006).

The forested land in each county in the Commonwealth of Kentucky was evaluated to determine the total weight of merchantable timber, in green tons. Each county was broken up into three different site qualities; low = 50-59, medium = 60-69 and high = 70-79[3]. The quantity of acres of forestland within each site quality, per county, was retrieved from the Forest Inventory and Analysis National Program (FIA) (USDA Forest Service 2011). The total number of acres of forested land in each county was determined by adding the acres in each counties' low, medium, and high site qualities.

4.1 Ecosystem Services Values from Benefit Transfer

This research study began as transfer value, in which the monetary values allocated to the eight ecosystem services evaluated were obtained from two other studies- averaging the values present in both publications. The values for each ecosystem service per acre was obtained from *The Value of New Jersey's Ecosystem Services and Natural Capital* (Costanza 2006) and *The Value of the World's Ecosystem Services and Natural Capital* (Costanza 1997). The values obtained from the two studies were based off of peer-reviewed and non-peer reviewed literature, economic, conventional and non-conventional valuation methods and conventional preference-based non-conventional preference-based and non-preference-based values. Because all of these monetary values were in 1994 US$ per acre per year or 2004 US$ per acre per year, the values were converted to 2012 US$ per acre per year using the Consumer Price Index (Table 1). To calculate the total ecosystem service value per county, the total number of acres in the county was multiplied by the value of the ecosystem service per acre per year, in 2012 US$.

Table 1. The ecosystem services used and evaluated for the project in 2012 US$. [1]Values were obtained from The Value of the World's Ecosystem Services and Natural Capital (Costanza 1997) and were converted from 1994 US$ per hectare per year to 1994 US$ per acre per year. [2]Values were obtained from The Value of New Jersey's Ecosystem Services and Natural Capital (Costanza 2006). [3]The total 2012 US$ values are an average of the converted 1994 US$ per acre per year and 2004 US$ per acre per year.

Ecosystem Service	**1994 US$/ acre/ year**	**2004 US$/ acre/ year**	**2012 US$/ acre/ year**
Biological Control	$1.62[1]	$2.00[2]	$2.47[3]
Cultural	$0.81[1]	$1.00[2]	$1.24[3]
Habitat/ Refugia		$923.00[2]	$1,121.84
Pollination		$162.00[2]	$196.90
Recreation	$14.57[1]	$122.00[2]	$85.43[3]
Soil Formation	$4.04[1]	$5.00[2]	$6.17[3]
Waste Treatment	$35.21[1]	$163.00[2]	$54.04[3]
Water Supply		$44.00[2]	$198.11

4.2 Total Metric Tons of Carbon Dioxide Equivalent, per County

A six-step process obtained from the Alabama Forestry Commission (Carbon Sequestration) was used to calculate the amount of carbon sequestered in each county. The implementation of this six-step process provided the entire live tree, aboveground carbon dioxide equivalent in metric tons. The average age of the tree stands are 50 years and consist primarily of mixed-hardwoods.

Step 1: Step one was to calculate the total merchantable weight, in green tons, per county. The total volume of merchantable timber, for each site quality, was acquired by adding the total amount of Hardwood-Sawtimber in green tons, at 50 years, and the total amount of Hardwood-Pulpwood in green tons, at 50 years. The low, medium, and high site quality values were then summed to determine the total amount of green tons of merchantable roundwood in each county.

Step 2: Step two was to calculate the total above ground biomass, since biomass is stored not only in the roundwood but in the entire tree (leaves, roots, etc.) (Carbon Sequestration). To calculate this value, the result of step one, the total amount of merchantable roundwood in each county, was multiplied by 1.33. The number 1.33 is the total tree conversion factor for hardwoods. The product was the total amount of green weight.

Step 3: Step three was to convert the total number of green tons to the total number of dry tons. To calculate this value, the result of step two, the total amount of green tons, was multiplied by 0.529. The number 0.529 is the specific gravity conversion for the general species of hardwoods. The product was the total amount of dry weight.

Step 4: Step four was to convert the total amount of tree biomass to the carbon equivalent. To calculate this value, the result of step three, the total amount of dry tons, was multiplied by 0.5. The product was the comparable weight of the carbon sequestered.

Step 5: Step five was to convert the total amount of carbon to CO^2e. To calculate this value, the result of step four, the tons of sequestered carbon, was multiplied by 3.67. The product was the comparable weight of the CO^2e.

Step 6: The final step was to convert the total amount of short tons to the total amount of metric tons. To calculate this value, the result of step five, the CO^2e in short tons, was multiplied by 0.9072. The product was the total $MTCO^2$e.

$MTCO^2e$ = (merchantable weight) * (1.33) * (0.529) * (0.50) * (3.67) * (0.9072)

4.3 Total Metric Tons of Carbon Dioxide Equivalent, per Site Quality

In each county, the total quantity of acres was divided into three separate groups: Low Quality, Medium Quality and High Quality. To calculate the Low Quality Acres value of the $MTCO^2e$ per county, the total number of acres in the low category was multiplied by, 25.88 $MTCO^2e$. The value, 25.88 $MTCO^2e$, was obtained by averaging the calculated $MTCO^2e$ for a 60-year stand growth in one low quality acre (USDA Forest Service 2011). To calculate the Medium Quality Acres value of the $MTCO^2e$ per county, the total number of acres in the medium category was multiplied by 41.81 $MTCO^2e$. The value, 41.81 $MTCO^2e$, was obtained by averaging the calculated $MTCO^2e$ for a 60-year stand growth in one medium quality acre (USDA Forest Service 2011). To calculate the High Quality of Acres value of the $MTCO^2e$ per county, the total number of acres in the high category was multiplied by 58.67 $MTCO^2e$. The value, 58.67 $MTCO^2e$, was obtained by averaging the calculated $MTCO^2e$ for a 60-year stand growth in one high quality acre (USDA Forest Service 2011). To obtain the total $MTCO^2e$ in each county, the values of the low, medium, and high quality acres in each county were summed.

4.4 Sensitivity Analysis for the Value of Carbon

To determine the total economic value for the carbon sequestered, the total amount of $MTCO^2e$ was multiplied by a range of carbon prices reflecting recent carbon prices in existing markets. Four different carbon prices were used: $1.00 per ton, $5.00 per ton, $10.00 per ton and $25.00 per ton.

5. Results

The ecosystem service with the highest value was habitat/ refugia, totaling $5,826,155,646.64 per year from forestland in the Commonwealth of Kentucky. The ecosystem services with the lowest value turned out to be cultural experience, totaling $6,439,806.72 per year from forestland in the Commonwealth of Kentucky. The values for the ecosystem services of pollination and water supply were particularly similar and of higher value, totaling $1,022,578,987.19 per year and $1,028,862,992.14 per year from forestland in the Commonwealth of Kentucky, respectively. The values for the ecosystem services of recreation and waste treatment were relatively similar to one another, totaling $443,671,522.98 per year and $280,650,931.78 per year from forestland in the Commonwealth of Kentucky, respectively. The values for the ecosystem services of biological control and soil formation were particularly similar as well, but of lower value, totaling $12,827,679.52 per year and $32,043,231.85 per year from forestland in the Commonwealth of Kentucky (Figure 1).

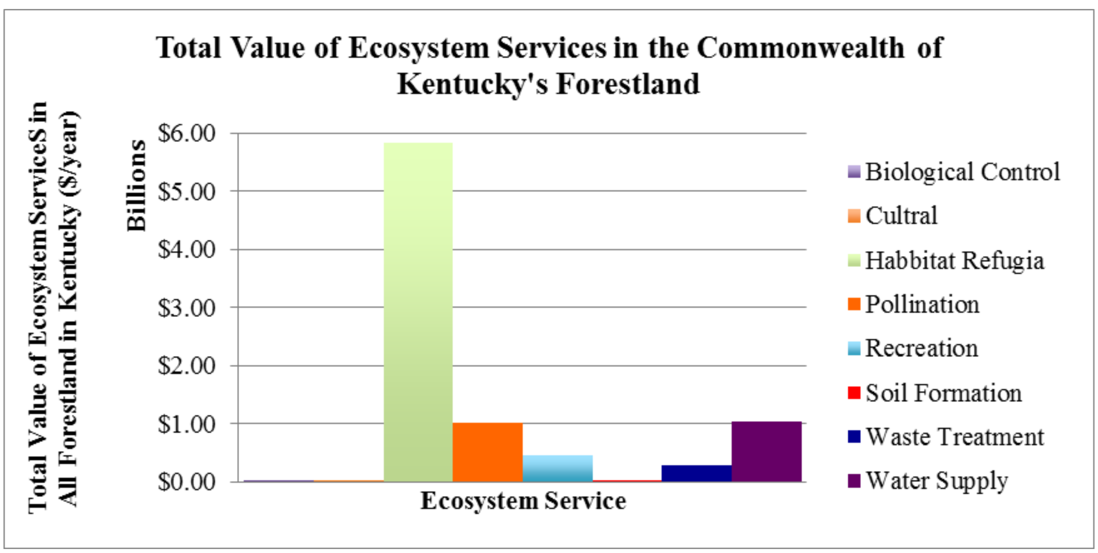

Figure 1. the total value of ecosystem services in the Commonwealth of Kentucky, in 2012 US$.

The total value of carbon sequestered in Kentucky's forest increased substantially with even modest increases in carbon price. The total $MTCO^2e$ value at $25.00 per $MTCO_2e$ was $32,917,447,098.98 per $MTCO_2e$. The total $MTCO^2e$ value at $1.00 per $MTCO_2e$ was the was $1,229,037,641.84 per $MTCO_2e$ for the Commonwealth of Kentucky. The total $MTCO^2e$ values at $5.00 per $MTCO_2e$ and $10.00 per $MTCO_2e$ were $6,602,105,884.70 per $MTCO_2e$ and $13,180,941,188.27 per $MTCO_2e$ for the Commonwealth of Kentucky, respectfully (Figure 2).

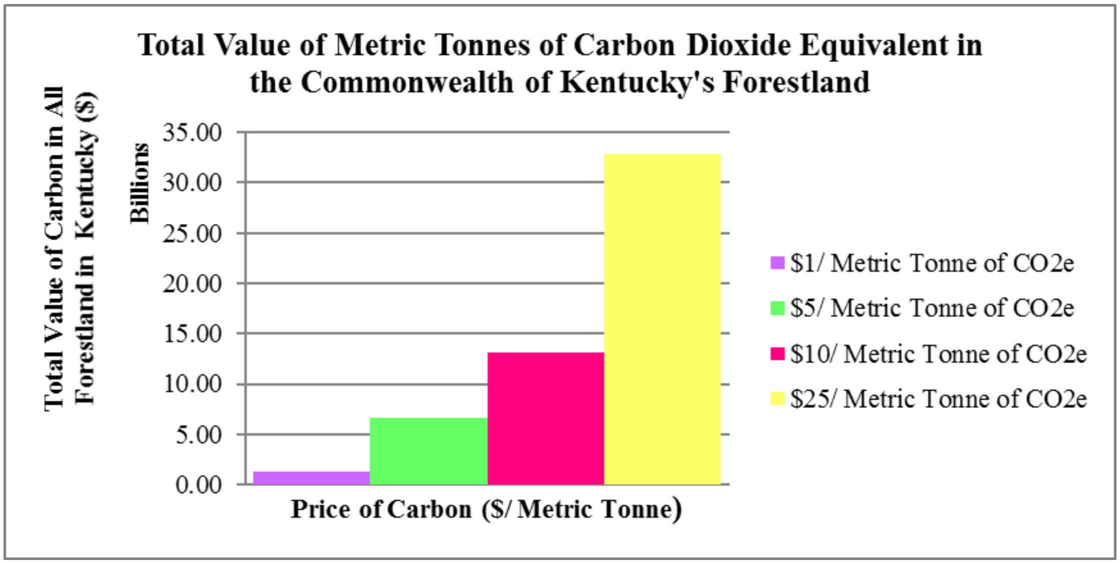

Figure 2. the total value of carbon in the Commonwealth of Kentucky at the variables of $1.00, $5.00, $10.00, and $25.00, in 2012 US$.

6. Conclusion

This research study began as a literature review in order to help become more familiar and knowledgeable on the various categories of ecosystem services. Subsequently, the amount of acres residing within each county was calculated and then assigned to the site quality indexes of low, medium, or high. The ecosystem services evaluated in this research study were converted from either 1994 or 2004 US$ into 2012 US$. The Alabama Forestry Commission was used to calculate the total amount of carbon sequestered per county. The total amount of $MTCO^2e$ was then multiplied by the number of the average 60-year stand growth in one acre for each site quality index. In conclusion, the project yielded values which provide significant merit and can assist policy leaders and forest managers on their decisions to utilize ecosystem services, and thus proliferate the benefit bestowed in the Commonwealth of Kentucky's forestland in a positive way to eventually obtain better air quality and maximum sustainable consumption for everyone.

The results of this research study prove "that ecosystem services provide an important portion of the total contribution to human welfare" (Costanza 1997) in the Commonwealth of Kentucky. It is imperative that we begin to consider these ecosystem services and the natural capital they provide throughout the decision-making processes in order to secure current and future environmental sustainability and human welfare (Costanza 1997). Determining a value for ecosystem services provides the public and decision-makers with the knowledge of the services' use and importance, relevant to other market-value commodities. This research study provides evidence that future land-use decisions should not solely be based off of the human desire for market value goods and services, but also on environmental quality and non-market value services. This study can be used for project appraisals for future land-use, in which the "ecosystem services lost must be weighed against the benefits of a specific project" (Costanza 1997).

"In response to government, business, and individual commitments to reduce carbon dioxide emissions, carbon is now a priced environmental commodity in the global marketplace" (USDA Forest Service 2013). The results from this research study support the implementation of the Voluntary Reporting of Greenhouse Gases Program, established in 1992 under the Energy and Policy Act. The calculated sequestered carbon values illustrate the economic incentive for forest landowners and managers to record and maintain their emission reductions, further advancing the carbon market. This research study can provide forest landowners and managers with the evidence and incentive to participate in carbon credits and trading; adhering to increased conservation and development of forestland cover and ecosystem services. As ecosystem services and environmental quality continue to become more stressed in the future, this research study can be used to help persuade forest landowners and managers that conservation not only enhances environmental quality, but also natural capital and personal revenue.

A limitation in this project was not considering and calculating every type of ecosystem service, and thus the total value of ecosystem services in The Commonwealth of Kentucky so most likely is an underestimate. Another limitation in this research study was the use of values from other forest regions in order to place a value on the Commonwealth of Kentucky's ecosystem services. Forests and human populations differ from region to region and the results may have been different if all the values were calculated directly from Kentucky's forest and population.

While the results to this research study provide evidence that ecosystem services and natural capital are of significant importance to human welfare in the Commonwealth of Kentucky, it also attest to the need for additional research. An extension of this study should include the implementation of contingent valuation surveys and other non-market valuation methods for ecosystem services from forestland in the Commonwealth of Kentucky instead of performing a benefit transfer analysis. For more precise results, the inclusion of all ecosystem services from forestland in the Commonwealth of Kentucky should be evaluated, as well as taking into account various forest types and locations. The execution of a valuation of ecosystem services on areas of different land use, such as reclaimed coalmines or wetlands, would assist decision makers to formulate policies and regulations that will promote natural capital and human welfare in full confidence

7. Acknowledgements

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9. Endnotes

1 Values were obtained from The Value of the World's Ecosystem Services and Natural Capital (Costanza 1997) and The Value of New Jersey's Ecosystem Services and Natural Capital (Costanza 2006) and averaged.

2 Value was obtained from The Value of New Jersey's Ecosystem Services and Natural Capital (Costanza 2006).

3 Site quality is measured by site index, which measures the height of the dominant trees in a stand and at a base age of 25, 50, or 100 years. In this study the base age was 50 years. For the low site quality, the dominant trees at age 50 years were 50- 59 feet tall. For the medium site quality, the dominant trees at age 50 years were 60- 69 feet tall. For the high site quality, the dominant trees at age 50 years were 70- 79 feet tall.