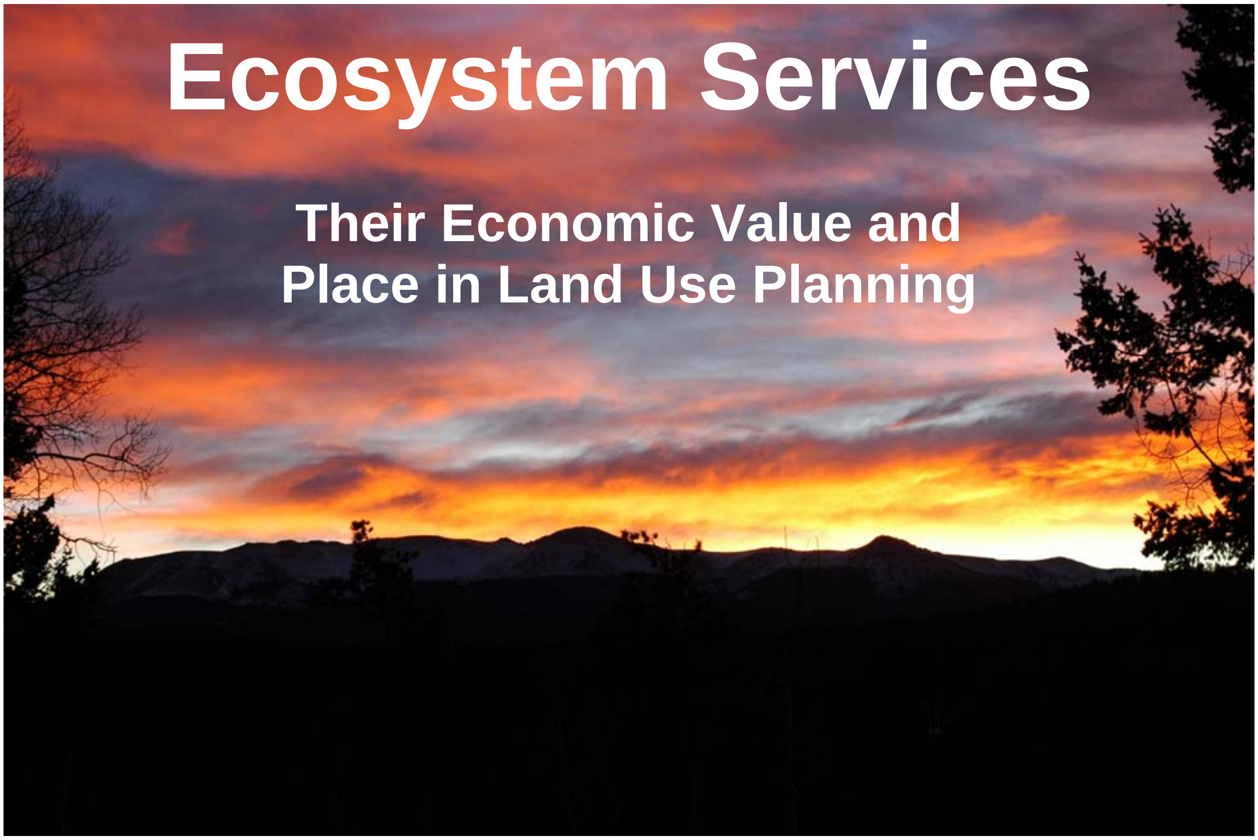



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FROM THE MOUNTAINS TO THE PRAIRIES

# Ecosystem Services:

# Their Economic Value and Place in Land Use Planning

**By**

**Tadini Bacigalupi, Ph.D.**

# Table of Contents

# Executive Summary

This study examines the economic value of ecosystem services and their place in public lands management decisions. Ecosystem services are those goods which an ecosystem provides for human use. Among the many services an ecosystem provides are fresh water, the regulation of wastes, the control of climate, the formation of soil, and protection from natural hazards. While the Forest Service describes the importance of ecosystem services, the models to evaluate the economic importance of these same services are flawed and fail to incorporate the economic value of these services.

This paper discusses the origins of the economic models used by management agencies and critiques those models. Flaws in both the assumptions and statistical bases of these models are discussed. One reason ecosystem services have not been included in these models is because the value of these ecosystem services has been difficult to establish, and therefore the loss of those services is difficult to quantify.

Many of the decisions made in land use planning are based on the economic evaluation of a proposed land use change. However the data has not been available to compare the values of an extractive industry versus the potential economic losses associated with the degradation of ecosystem services caused by that new use.

To remedy this problem, this study establishes a conservative but realistic economic value for many ecosystem services in 2008 dollars, so these economic values can be incorporated into the planning process. This study was also able to determine the total value of ecosystem services per acre per year in 2008 dollars. A single acre of land yields approximately $2208 per year in ecosystem services. When the total economic value of ecosystem services is applied to the Pike San Isabel National Forest it can be shown that the PSI contributes approximately $4.6 billion dollars of ecosystems services per year. With economic values this high, it is essential that ecosystem services be fully evaluated when land use management decisions are being made.

## Section I- Origins and critique of models

## Introduction

The Forest Service and other public agencies have long used economic analysis to make land use planning decisions. The economic value of any proposed change factors into major land use decisions. A traditional public-agency economic analysis examines familiar concerns such as resource costs, jobs created, jobs lost, plus the potential economic gain or loss for communities and the land use agency.

However, the traditional economic analysis conducted by land use agencies only considers the most visible and easy to measure economic indicators and fails to measure the very important but less visible and more difficult to quantify factors, that is, ecosystem services. Ecosystem services are defined as "the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life" (Daily 1997:3 in Alcoma 2003:55).

The traditional economic analysis made sense in an industrializing society where resource extraction was the basis of social well-being, where resources seemed unlimited and where there was little conflict between various land uses. In post-industrial society, a new economic sector has emerged and become more important than manufacturing, that is, the service sector. This sector of the economy is not based in the extraction and use of resources to provide economic well-being for the population; instead, when applied to the natural world it is based on the preservation of those very resources for ecological and recreational activities.

As society grew, changed, and became more complex new social values have been attached to public lands. Some of these values are based on recreation, solitude and quiet, and scenic views. These natural-world values are important to the citizens of society but are difficult to measure, difficult to quantify, and difficult to measure in economic terms. Yet these new values are now more important and must be considered by public land agencies when making land use decisions. Decisions that lead to the loss of these natural-world values mean an economic loss in sectors of society and therefore must be considered as part of the economic value decision-making process.

Additionally, while recreation and its associated values are difficult to measure, even more complex and important are the services that healthy ecosystems provide. Integral to the environment, these ecosystem services benefit humans in a myriad of ways and include services such as the provision of fresh water, natural hazard avoidance, climate regulation, and waste assimilation. These mostly invisible services must also be taken into consideration in land use planning. To do so they need to be economically quantified.

This study focuses on two major aspects of ecosystem services. The first examines traditional economic models, their use and their limitations; and the second examines the ecosystem services that have not been included in the traditional economic analysis of public lands, including the economic value of those services. Where those services have not been measured, the study suggests how those services could be economically quantified. To the extent possible, this study applies the economic value of ecosystems services to the Pike San Isabel National Forest and surrounding lands as a demonstration that the economic values discussed in this paper can actually be defined, measured, and used to give value to the land.

## The Historical Background: Industrialization and Economic Theory

As western society industrialized during the 18th and 19th centuries, classical and neoclassical economics emerged as the foundation for traditional economic analysis. Classical economics is based on a variety of sources from Adam Smith to Karl Marx, but there are several assumptions which underlie these diverse perspectives and provide a framework from which the economic analysis of public land use evolved.

Both Smith in *The Wealth of Nations* (1776) and Karl Marx in *Capital* (1867) essentially agreed that the value of a commodity (product) is based on the value of the labor that went into the production of that commodity. Marx believed a commodity is constructed of two things, material and labor. Therefore a wooden bowl is composed of wood, and the labor to carve the wood into a bowl. The value of the wood would be the labor involved in obtaining the wood. Therefore the value of a tree becomes the labor necessary to cut it down. In such a world, there is no incentive to preserve the tree or the forest for other uses than the wood products they provide.

Smith (1776) also implied there was an "invisible hand" in society that guided people to pursue their own self interest, but that in doing so they would unknowingly work for and promote the good of society. The crux of the invisible hand argument is that people should be free to pursue their own self interest economically, without government intervention, and that government intervention would only hinder the growth of society. Therefore whatever produces economic good for the individual is good for the larger society. And in a land of plentiful resources, this is likely true.

However, as Garret Hardin (1968) pointed out in his classic article, "The Tragedy of the Commons," when people act in their own best interest the result of selfishness is the destruction of any common resource being used by those in society. Hardin noted that when people share a common resource, in his example, ranchers putting cattle on shared rangeland, it was always in the best interest of the individual rancher to keep adding more and more cattle to the rangeland, because the profit went to the individual while the cost of the loss of grasslands was shared by all of the ranchers. Inevitably, the ranchers would keep adding more cattle to the rangeland until the land was overgrazed and was no longer able to provide pasture for anyone. The metaphor applies to all commons; if people share a commons and act in their own best interest they will always use the commons until it is no longer able to function. This would be true of air which is used to absorb the pollution of industries, or water, or the extraction of resources from public lands. Hardin's only solution was public intervention to control the use of the commons.

From the works of Smith, Ricardo, Marx, Malthus and others emerged a generalized view of the social/economic world. This view of the economic world included: "the virtue of selfishness, the benefits of limited a limited role for government, and the idea that the economic systems is independent of the natural world" (Gowdy and O'Hara, 1995:128). The work of the classical economic theorists was followed by the works of neoclassical economists who envisioned the economic world as composed of producers, consumers, resources, the productions of goods, and the relationships between money to produce goods and the cost of a product. The concepts used in the neoclassical perspective largely ignore the value of the natural world (Gowdy and O'Hara, 1995) except when it is valued for raw materials or as a pollution sink (Schnaiberg and Gould 2000 and 2008).

In the industrializing world prior to the late 20th century, most workers were engaged in manual labor for long periods of time, had little time for leisure, and therefore the use of public lands for their extractive resources was not in competition with the use of public lands for recreation or other non-extractive purposes. When Gifford Pinchot (1910, 1947) proposed the idea of conservation in 1908, he explicitly stated "conservation means development now," but with an eye to the future, so resources would be available for the use of future generations. Conservation did not mean preservation. Competition for public land resources was between big companies with specific resource needs, not between industries and the public in general and citizens' desire for a wide variety of recreational uses.

Between World War II and the present, major changes took place as the nature of work changed. Over time the service sector of the economy grew as the manufacturing sector shrank (Bureau of Labor Statistics, US Census Bureau). This led to changes where income increased for most workers, the amount of time for leisure increased, and consequently new recreational activities emerged. The population began to use the public lands for a wide variety of recreational activities which came into conflict not only with extractive industries and also led to conflict between one type of recreational activity and another.

However, resource extraction, pollution sinks, and recreation are not the only goods that the environment provides. As the 20th Century came to a close, new concepts arose as scientists, economists and many others became aware of all of the different services the ecosystem provides for humans. Recognition of this variety of services ecosystems perform emerged from the environmental movement of the 1960s and slowly became recognized as important at the end of the 20th century. The loss of critical habitat due to population growth and development led to reduced biodiversity. With climate change came the recognition that ecosystems maintain atmospheric stability. The ecosystem services previously unrecognized became visible and important. But not in land use planning. These services appeared to be difficult to measure and difficult to incorporate into traditional economic planning models.

In the early 21st century, a transition is being made from the classical and neoclassical economic analysis that valued the environment for primarily extractive uses to a broader perspective that gives economic value to the myriad of other services that are being provided by the ecosystem. This change, however, is slow partly because a common system for economically valuing ecosystem services has not emerged. Numerous studies have been conducted that give economic value to ecosystem services, but the studies have used a variety of methodologies and obtained differing results.

This study, after examining problems with the economic model currently being used in public lands planning, then develops a system to give a specific value to an array of ecosystem services by integrating results from the studies that have been previously conducted.

## Economic Analysis Models

Neoclassical economics focuses on producers, consumers, resources costs, the productions of goods, and the relationships between money to produce goods, and the cost of a product. When these concepts are assumed to be the key ingredients in the economic analysis of public lands use, the models that emerged were entirely consistent with the assumptions of the neoclassical model.

In1978 the Forest Service first developed the basic FORPLAN -- now IMPLAN ™ -- model for the purpose of evaluating the economic impacts of changes in land use management. The model is a basic input/output computer model in which specific information is put in the model, and results are obtained through the use of a variety of formulas. The model is designed to ascertain the number of dollars, jobs, and other positive "goods" that will be generated by changes in land use, an upcoming event, or a new industry being introduced into a community. The IMPLAN model, with its brother SAM ™ (social accounting matrix) has since been widely adopted by other federal agencies and many economists as the accepted model to assess the economic impacts of any change in a variety of public sectors from new forms of agriculture to the placement of public buildings or services in specific areas. IMPLAN and SAM are now privately owned computer models obtained through the Minnesota Implan Group (www.mig.com). MIG also sells a variety of databases with economic and social information that ranges from the local to the national level.

To understand how IMPLAN works this paper will examine the economic impacts of a new land use, a gold mine on public lands which employs 100 miners. The mine will generate X number of jobs, produce Y number of dollars for the industry and for workers, and result in Z amount of spending on consumer goods by workers. While this is a simple example, IMPLAN is much more complex, and includes many more variables, all of which can be measured in economic terms, i.e. dollars, and jobs. Therefore this simple example can also be expanded to include the amount of materials the gold mine must purchase from other industries in order to produce the gold. This could include mining equipment, electricity to run machinery in the mine, and many others. In this way the gold mine stimulates the industries whose products it uses. Likewise the mine also stimulates a variety of industries because of its existence. The gold mine brings workers into an area which creates new service sector jobs, such as shopkeepers, new teachers for workers' children, as well as stimulating the local government through taxes on the gold mine, real estate taxes on workers new homes, and sales taxes on goods that workers purchase in the local area. Therefore, the gold mine has many positive economic impacts, impacts that go on prior to any gold actually being mined, and positive impacts that result from the gold production.

To estimate the economic effect of the gold mine on the local economy, information from previous studies is needed. Over time a variety of complex databases have been constructed that are readily available to economists to feed data into the IMPLAN model. These databases contain "multipliers" which the economist can use to estimate the effect of the gold mine in the number of jobs or dollars that will be generated.

Table 1, next page, shows how these multipliers work. There are three types of effects that the gold mine can produce: direct, indirect, and induced. Direct effects are those within the industry itself, 100 jobs and from those jobs $5 million dollars in payroll ($50,000 per worker). Indirect effects are jobs created from supplying the gold mine. The hypothetical multiplier for this example is 1.3, that is, 1.3 jobs are needed to support every 1 miner and the multiplier for income, because these jobs are more skilled than mining is, is 1.5. The true multipliers would be found in an IMPLAN database. If our average miner makes $50,000, the workers who support the miner make $75,000. Induced jobs are those that are created from the miners' spending or consumption. This includes service-sector jobs such as sales clerks, school teachers, county government staff and workers, and professionals who serve the community. In this hypothetical example it assumed that it takes 2 people in the service sector to support each miner, but these jobs overall are also assumed to pay less than the miner's $50,000 so the multiplier for income is 0.75. Therefore, the average service worker makes $37,500.

**Table 1: IMPLAN As Applied To a Gold Mine**

| New Gold Mine | Direct effects | Indirect | Induced | Total |
|---|---|---|---|---|
| Jobs | 100 | 130 | 200 | 430 |
| Dollars | $5,000,000 | $9,750,000 | $7,500,000 | $22,250,000 |

From this simple example it can be seen that the new gold mine produces a total of 430 jobs and a total payroll of $22,250,000. This is IMPLAN in its simplest form. Numerous layers of information can be added too provide a much more complex picture of economic impacts for planners. For example, the direct and indirect jobs can be broken down into specific categories and specific income amounts for each category. Or, more than one industry can be added to the model to show the relationships between various industries as they expand and contract, and compete for workers and materials.

## Problems with IMPLAN

While IMPLAN works as it was intended, it has a number of flaws which need to be examined. These problems are especially pernicious for the environmental community. The problems are found in IMPLAN's assumptions, its statistical modeling, and the nature of the inputs allowed in the model.

### IMPLAN Assumptions

There are four interrelated assumptions that are built into the IMPLAN model which lead to problems with the results the model provides.

#### 1) Constant Technology Assumption

IMPLAN assumes that technology remains the same in an industry. This assumption is valid for IMPLAN because the predictions IMPLAN makes are based on the here and now. IMPLAN does not forecast what will go on in the future, but instead shows what is happening in the present. The gold mine produces 430 jobs and has an economic impact of $22,250,000. If mining technology changes at some point in the future, it will change the multipliers, and that will change the number of jobs and dollars produced. However, industries are not static and new technologies are constantly being introduced, therefore there will always be some inaccuracy in IMPLAN results.

#### 2) No Supply Constraints

Again because IMPLAN is giving results in the present, it does not take into consideration changes in the supply of the resource. But in reality mines and varieties of other industries use up their available resource. When that occurs, the economic benefit of the mine diminishes and perhaps disappears. All of the abandoned mines from 1800s are evidence of this. Conservation of the resource is not considered in the IMPLAN model.

### 3) No Labor Constraints

It is assumed that labor will always be available to run the industry, and that the same amount of labor will always be available. Labor will indeed always be available during times of economic hardship, but during times of economic wellbeing, laborers may choose other occupations in other locations. Farming, as an example, has suffered as children leave the rural life and find steady and higher paying jobs in the urban environment. When there is competition between varieties of industries for labor, the labor market fluctuates and labor may not be available and the price of labor may vary. These considerations are not and cannot be included in the IMPLAN model.

### 4) Present Time Orientation

While the literature clearly states that IMPLAN is producing results about the present, it is frequently misinterpreted as a predictor of the future. Planners and others make the assumption that the economic results found in the present will continue into the future. This in essence is the continuation of the constant technology, continuous supply, and constant labor assumptions. However, the social world is dynamic, and IMPLAN isn't. IMPLAN is only accurate in the very short term.

## Statistical Problems with IMPLAN

### 1) IMPLAN Is a Linear Model

Linear statistical models are models for predicting the future based on information found in the past and present. For example, if research shows the following information regarding the production of gold (as in the table below), then it is easy to predict that 12 workers will produce 24 ounces of gold.

| Number of workers | Ounces of gold produced |
|---|---|
| 2 | 4 |
| 4 | 8 |
| 8 | 16 |
| 16 | 32 |

If the mine owner wants to produce a specific amount of gold, all the owner needs to do is determine the number of workers it will take to do so.

IMPLAN is a linear model and therefore suffers the limitations of all linear models. First, while they are excellent for describing the present and relatively accurate in describing the very short term future, they quickly lose their ability to predict as the distance into the future increases. In this example, the owner of the mine knows quite accurately how many workers will or should be employed tomorrow, but next week the producing vein may diminish and instead of taking 2 workers to produce 4 ounces of gold, it may take 8 workers to produce those same 4 ounces. Unforeseen variables can continuously undermine linear models.

Second, because IMPLAN is a linear model, it does not include feedback loops, and the results of multiple iterations. In linear models the impacts of the first set of multipliers are considered the final product, in this case the final economic effect. However, because of the linear nature of the model the first set of results are not fed back into the model to determine the long term effect of some change in public lands use.

The feedback effects in the gold mine example take place over multiple years and include reductions in jobs related to recreation and tourism and ultimately people leaving the town because there is no longer a clean water supply. While the mine is still in operation, the negative feedback in the system leads to fewer available laborers to work in the mine, which then leads to fewer ounces of gold produced, and a downward spiral ensues. Instead of the mine being a positive economic force within the community, over time, it becomes a negative one.

**2) Negative Multipliers Are Rarely Used In IMPLAN**

It has generally been assumed that the multipliers in IMPLAN are positive numbers. This assumption of multipliers being positive is based on the previous assumptions of constant supply of the resource, constant availability of labor, and constant technology. The use of positive numbers makes sense when analyzing one specific event or industry. It even works well for analyzing several mutually supportive industries or events. Where the problems occur is when industries or events are in competition. In the case of the gold mine, it may lead not only to an increase in the number of jobs as discussed above, but it may also lead to the reduction of jobs in recreation, a loss of tourists, and degradation of the nearby town's water supply through pollution.

While some of these issues can be handled by multipliers between 0 and 1.00, negative multipliers come-into play when a resource takes on a negative value. Positive multipliers do not allow for the possibility of a truly negative outcome. For example, if the value of the land surrounding the gold mine loses value each year from the effects of the industry in a previously pristine area, a multiplier of .98 could be used. Therefore if the land surrounding the mine was worth $10,000 per acre, then after one year of production the surrounding land would be worth $9,800 and the next year it would be worth .98 x $9,800 or $9,604. Over a long period of time the value of the land would near but never reach $0.

As the example continues, the gold plays out, company has goes bankrupt, pollution from the mine tailings is no longer contained, and the trust fund for land reclamation is not large enough. The tailings pollute the land and water downstream of the mine. The value of the adjoining land is not just $0 because the land is polluted, but instead, is less than $0 because the land must be reclaimed, just as the mine land must. The land becomes a superfund site. This is the scenario that played out in Summitville, Colorado.

In another example, negative multipliers were used to show the impact of commercial fishing where greater and greater expenditures on fish production led to resource reduction, which lead to more competition for fewer fish, which without government intervention, lead to resource extinction and industry economic collapse (Jin et. al. 2003).

Finally, without negative multipliers, opportunities forgone are not included in the economic analysis of land use change. When a use like a gold mine is permitted, other opportunities are excluded such as hiking, hunting, fishing, OHV use, and birding. Each of these excluded uses may be in need of a negative multiplier in terms of both jobs and income for the community.

### 3) Inputs Are Limited

To create the multipliers that are used in the IMPLAN model huge amounts of information must be gathered from the Census Bureau, the Bureau of Labor Statistics, Health and Human Services, the Department of Education and so on. This information is gathered on national, regional, state, city, county and local levels and placed into data bases made available to IMPLAN users. For obvious reasons, this is a time consuming effort and the statistics that are available through government agencies will always be somewhat out of date. Census data is usually available about a year to a year and a half after it was collected. Other statistics are often not available as quickly. In other words there will always be an information lag, and a certain amount of inaccuracy built into the multipliers when government statistics are used.

On top of that, multipliers are limited to the data which is available. Unfortunately, some very important data is not available or even collected. Information for traditional economic analysis is readily available, but the impacts of an economic change are not always economic. Information is not readily available on such impacts as resource depletion, the loss of ecosystem services, and the stress on educational systems and social services. Yet, all are significant impacts that must be included in an economic analysis.

### 4) Potential Inputs Are Ignored

While many inputs are not readily available, others are ignored because they are not just difficult to obtain, but in many cases are even difficult to define. Yet these inputs do exist. When analyzing the gold mine variables such as diminished beauty, loss of habitat or biodiversity due to pollution, loss of quiet, carbon sequestering, and variables that may be important to local residents, visitors and members of the larger society alike are not included in IMPLAN analysis.

## Conclusion

While IMPLAN and its descendants give very accurate pictures of the present and are useful tools for planning purposes, these economic models have limitations that must be taken into consideration when their results are analyzed. Simply discounting the problems with IMPLAN’s assumptions, as is frequently seen in the literature, does not overcome those very real limitations. It merely suggests that we ignore them, and that is not a good solution to the very real problems with the IMPLAN model.

# IMPLAN Bibliography


Alward, Gregory. "Introduction to the Implan V2.0 Modeling System. Minnesota IMPLAN Group (MIG), Inc. Retrieved 8/13/2009. www.doleta.gov/regions/reg05/Documents/WIDRE/IMPLAN.pdf

Baker, Rose and David Passmore. 2007. "Economic Impact Analysis with IMPLAN." Penn State University. Retrieved 8/13/2009. www.slideshare.net/davidpassmore/economic-impact-analysis-with-implan

Beacon Hill Institute. 2004. "The Economic Impact of the Democratic National Convention on the Boston Economy: The Final Tally." Suffolk University. Retrieved 8/19/ 2009. www.beaconhill.org/BHIFaxSheetDNCFinal08094.pdf

Broomhall, David. 1993. "The Use of Multipliers in Economic Impact Estimates." *Agricultural Economics.* Cooperative Extension Service: Purdue University. Retrieved 8/16/2009. www.ces.purdue.edu/extmedia/EC/EC-686.html

Department of Community Development and Applied Economics. 2009. "IMPLAN Methodology for the Study of the Impact of Tourism on the Vermont Economy." University of Vermont. Retrieved 8/13/2009. www.uvm.edu/~snrvtdc/publications/implan_method.pdf

Gret-Regamey and Susanne Kytzia. 2007. "Integrating the Valuation of Ecosystem Services into the Input-Output Economics of the Alpine Region." *Ecological Economics*. 63: 786-798

Jin, Di, Porter Hoagland, Tracey Morin Dalton. 2003. "Linking Economic and Ecological Models for a Marine Ecosystem. *Ecological Economics.* 46: 367-385.

Hughes, David W. 2003. "Policy Uses of Economic Multiplier and Impact Analysis." *Choices: The Magazine of Food, Farm, and Resource Issues. 2nd Quarter. Retrieved 8/19/2009.* www.choicesmagazine.org/2003-2/2003-2-06.htm

Hodges, Alan W. 2007. "Understanding and Using Economic Multipliers (PowerPoint)." Presented to USDA Economists Group. Retrieved 8/13/2009. http://ideas.repec.org/p/ags/usdags/43793.html

Morton, P. 1999. "The Economic Benefits of Wilderness: Theory and Practice." *University of Denver Law Review.* 76:2:462-518.

Minnesota IMPLAN Group, Inc. 2002. "Elements of the Social Accounting Matrix." MIG IMPLAN Technical Report TR-98002

Mundy, Karen and Wayne Purcell. 2004. "Measuring the 'Ripple Effect': Economic Multipliers." *Horizons.* V16:4:1-3. Retrieved 8/19/2009. www.reap.vt.edu/publications/horizons/hor%2016-4.pdf

# Section II- Establishing economic value for ecosystem services

## Ecosystem Services

## Introduction

The literature is replete with discussions of ecosystem services that are not accounted for when economic analyses are conducted. The main reason these services are not taken into account is that their economic value is difficult to calculate and no common methodology has emerged as the standard for determining the economic value of these services (see Hannon 2001; Boyd and Banzhaf 2007). Additionally, while the literature has identified a large variety of ecosystem services, a common model or organizational structure for these services has only recently emerged (see Brown et. al. 2007; Hassan et. al. 2005).

Studies to establish the value of ecosystem services have also been plagued by other problems including the use of different scales of size (30 sq. meters to large landscapes), different methodologies for establishing values, and studies from different countries. Also, the studies have been conducted at different times so establishing common dollar amounts has been difficult.

In this section the common models will be discussed, methodologies for establishing economic values will be reviewed, and the methods used for establishing the values of ecosystem services in this study will be discussed. This information will then be used to create a set of economic values for many ecosystem services.

### Models

Two definitions give a picture of the scope of ecosystem services. Ecosystem services "…are the benefits people obtain from ecosystems" (Hassan et. al. 2005: 27), and "Ecosystem services are the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life" (Brown et. al. 2007: 330). The definitions are straight forward, however establishing all of the services that fit within the definitions has been more difficult.

A variety of models have emerged since the 1980s as a way to classify ecosystem services (see Costanza et. al. 1997; Morton 1999; Alcamo et. al. 2003; Pagiola et. al. 2004; Brown et. al. 2007). While these models were different, over time the major ecosystem services were delineated and expanded to include a set of services that have now been arranged in two commonly accepted models.

The first model for organizing ecosystem services is the Millenium Ecosystem Assessment (MA) working group model (Alcamo et. al. 2003; Hassan et. al. 2005). This model divides ecosystem services into four categories: Provisioning Services, Regulating Services, Cultural Services and Supporting Services. Provisioning services provide resources for human use including food, clothing, medicines, or raw materials. Regulating services are the services the ecosystem provides through climate regulation, water purification, or erosion control. Cultural services range from spiritual and artistic to education and recreation. Finally, supporting services "are all those that are necessary for the production of all other ecosystem services" (Alcamo et. al. 2003: 59) and include soil formation, nutrient cycling, oxygen production and biodiversity. Supporting services generally take place over a long period of time but are services that are vital to a functioning ecosystem.

The second model (Pagiola et. al. 2004) takes the Total Economic Value (TEV) approach and divides ecosystem services into four basic categories: Direct Use, Indirect Use, Option value, and Non-Use or existence value. Direct use services are those “goods and services directly used by human beings” (p. 9) and include everything from resource extraction and agriculture to recreation. Indirect Use services are benefits from the ecosystem that are off-site and could include the generation of knowledge, increased property values, or the attraction of new businesses. Option values result from protection of the ecosystem for future human use such as food production, recreation, and freshwater. Finally, Non-Use or existence value is the value to humans that comes from just knowing that an ecosystem still exists “even if [those people] never expect” to see or use it (Pagiola et. al. 2004:10).

Examination of both models shows categories can overlap. This potential overlap is important as it must be accounted for when calculating the total economic value of ecosystem services at a specific location. Direct use services could easily include categories that are found in Provisioning or Cultural uses. Indirect use includes ecosystem services that could easily include Regulating services. Because Option value is such a broad category, it includes virtually all other ecosystem services that are preserved for future generations. Non-use categories are philosophical and Cultural in nature and are among most difficult when it comes to determining their economic value.

Combining the two models, MA and TEV, provides the best conceptual framework for organizing ecosystem services without creating too many overlapping categories. Table 2 (next page) first uses the MA model to classify a variety of ecosystem services and then uses the TEV model to include ecosystem services that do not fit as easily into the MA model.

**Table 2: Ecosystem Services Organized by MA and TEV Model Categories**

| Provisioning | Regulating | Cultural | Supporting |
|---|---|---|---|
| Food(1)[1] | Air Quality(1) | Spiritual and Religious(1) | Soil Formation(1) |
| Fiber (1) | Climate Regulation(1) | Aesthetic values(1) | Photosynthesis(1) |
| Genetic resources(1) | Water Regulation(1) | Inspiration(1) | Oxygen production |
| Medicines(1) | Erosion Control(1) | Knowledge Systems(1) | Primary Production(1) |
| Fresh Water(1) | Disease Regulation(1) | Education(1) | Nutrient Cycling(1) |
| Fuel (2) | Pest Regulation(1) | Sense of Place(1) | Water Cycling(1) |
| Ornamental resources(2) | Natural Hazard(1) | Cultural Heritage(1) | Provisioning of habitat(2) |
| Raw materials(4) | Water Purification(2) | Solitude/quiet | Biodiversity(3) |
| Pollination(1) | Waste Control(2) | Adventure/excitement | Habitat (refugia) (4) |
| | | | |
| **Additional Ecosystem Services Organized by TEV Model Categories** | | | |
| **Direct Use** | **Indirect Use** | **Option** | **Non-Use** |
| Recreation (1) | Science, knowledge(3) | Option value(3) | Intrinsic value(3) |
| Commercial use(3) | Community change(3) | Recreation | Bequest value(3) |
| Hunting | Population(3) | Biodiversity | Existence value(3) |
| Fishing | Income(3) | Habitat | |
| Guiding | Property values(3) | Endangered species | |
| Viewing wildlife(5) | Taxes(3) | Etc., | |
| Horseback Riding | Employment(3) | | |
| Off Highway Vehicle use | Quality of life | | |
| | Business attraction | | |

(1) Hassan et. al. 2005: 7-10, (2) Alcamo et. al. 2003: 56-59, (3) Morton 1999: 3, (4) Castanza et. al. 1997: 254, (5) Brown et. al. 2007: 341

Table 2 shows the difficulty of separating multiple ecosystem goods and services into mutually exclusive categories. Recreation which falls under cultural services also falls under direct use. Additionally, Table 2 is not exhaustive. Other categories could still be added. The services in Table 2 were chosen because they are the most commonly discussed ecosystem services found in the literature.

## Methods Used For Determining Economic Value of Ecosystem Services

The methods used to determine the value of ecosystem services are varied and to date no common methodology has been accepted by all economists. Because of the lack of a standard methodology, studies of the same ecosystem service return different economic values for that service. Therefore, when multiple studies are used the result is a range of values for each ecosystem service. Ingraham and Foster (2008) resolved this problem by taking an average of the values found in the studies they used in order to calculate the economic value of ecosystem services in the U.S. National Wildlife Refuge System. This is a statistically valid approach and is used in this study.

[1] Numbers in parentheses indicate the source for this service. Sources are found below this table.

The most frequently used methods (see Hassan et. al. 2005; Brown et. al. 2007; Pagiola et. al. 2004, Eppink and van den Bergh 2007) to determine the values of an ecosystem service are:

- Contingent valuation (WTP – willingness to pay; WTA – willingness to accept)
- Changes in productivity
- Replacement of Services
- Cost of Illness; Cost of Human Capital
- Hedonic Analysis
- Travel Cost
- Benefits Transfer

**Contingent Valuation**. Contingent valuation asks consumers how much they are willing to pay (WTP) in order to obtain or maintain an environmental service. Willingness to accept (WTA) instead asks how much compensation consumers expect in order to give up that service. Example: How much are you willing to pay for recreational use of public lands, or be compensated for not being able to use those lands? In studies of this nature people are generally willing to pay less, but want to be paid more for an ecosystem service that they are asked to give up. Contingent Valuation is used primarily when numerical calculations cannot be performed using scientific information to ascertain the value of an ecosystem service. However, the reliability of WTP surveys is questionable as respondents' answers are dependent on the state of the economy and the specific wording of the question. Finally, because respondents are only asked what they would be willing to pay but are not actually asked to pay, their answers should be treated with caution.

**Changes in Productivity.** This method follows the impacts from a change in ecosystem service usage. Example: A reduction in timber allocations may lead to an increase in the price of homes, or the number of homes that could be built. Pollution of a river could lead to increases in the price of clean water.

**Replacement of Services.** This evaluation technique estimates through market analysis the amount necessary to replace the specific service. Example: What are the costs associated with replacing lumber from forests with metal, cement, plastics, or other building products?

**Cost of Illness or Cost of Human Capital.** Changes in ecosystems can impair human health and therefore lead to changes in the ability to work. Human capital is often thought of not only as the ability to do useful work but also to do skilled work. Example: If mercury pollution leads to illness, it not only affects physical ability, but also cognitive ability and a corresponding loss in labor production.

**Hedonic Analysis**. Hedonic analysis determines the effect of being near an ecological good in terms of the economic cost associated with being in proximity to that good. Example: The price of homes near open lands, wilderness areas, or scenic views is compared to the price of similar homes where these amenities are not available.

**Travel Cost.** This method measures the real cost of an ecosystem service by measuring the travel cost, lodging, and equipment necessary for a trip to a specific destination.

**Benefits Transfer**. The value of an ecological amenity that has been studied in one area is transferred or assumed to be similar to that in another area. Obvious adjustments are made based on the fact that no two areas are exactly the same.

**Total Economic Value**

A number of studies have attempted to determine the total economic value of ecosystem services in the world or in a specific location. However, this cannot be done by simply adding together the value of all of the different ecosystem services present on that particular piece of land. This is because some ecosystem services are mutually exclusive, that is, they stand alone and do not overlap with any others. Other services, however, do have values that overlap, that is they contribute to or are a part of another ecosystem service. For example, a piece of open land could have values for recreation, hunting, wildlife viewing, solitude, art, and cultural heritage. If the value per acre for recreation was $10; hunting $12, wildlife viewing $5, solitude $3, art $1, and cultural heritage $2, the addition of these values results in a total ecosystem service value of $33 per acre. However, hunting is recreation as is wildlife viewing. To obtain solitude may involve hiking. Something that a person might want to paint or photograph, perhaps an old mine, is part of America's cultural heritage. Because of these types of overlap ecosystem service values are not simply additive

This study will assess total economic value through the grouping of ecosystem services into major categories which have little or no overlap in order to overcome this problem.

## Methodology Used To Determine Ecosystem Service Values In This Study

The first goal of this study was to establish a specific value for each ecosystem service in 2008 United States Dollars (USD). A second goal was to make sure the value of an ecosystem service was not overestimated. For this reason the following methodology was established.

First, peer reviewed sources were used in order to get a set of values for each ecosystem service. Because the studies were done in a variety of countries, on a variety of scales, using a variety of monetary units, the following steps were taken to create a common set of economic values for each ecosystem service.

If a study was conducted in a foreign country and the currency amounts were expressed in currency per hectare, the amount was first converted from hectares to acres. Then the exchange rate for the year the study was conducted was used to change foreign currency per acre into dollars per acre. If the date of the study was not presented in the paper, it was assumed the study was conducted the year before the paper was accepted for publication. Finally, dollar amounts were transformed into high and low 2008 USD. High and Low values were calculated because there are many indices that can be used to convert dollars from previous years into present dollars, and the results can be very different. (Appendix C describes the dollar conversion methodologies in greater detail.) Studies conducted in the United States only needed to be converted into 2008 USD.

After ecosystem service values were obtained from several studies, the mean (average) for the high value and the mean for the low value of the service were calculated. To get a single summary score to represent an ecosystem service, the high and low means were averaged. However, if the economic values were highly skewed, meaning one score was exceptionally high while all the others were rather low then the median, which is the middle score, was used in place of the mean. The advantage of the median in a skewed distribution is that the effect of an extreme score is eliminated or reduced. Appendix C shows the difference between the use of the mean or median. A reliability of each summary economic value was evaluated and can be found in Appendix D.

The methodology described above establishes the most conservative yet realistic estimate for the value of an ecosystem service. The specific values obtained from each study used as well as the use of the mean or median is found in Appendix A.

Table 3 from Appendix A (below) demonstrates how studies were compiled to determine the value of an ecosystem service. High and low economic values were calculated for each study. In this table, the median was used because the study by Ingraham and DeGroot skewed the distribution. Finally the two medians ($5.45 and $148.00) were averaged to obtain the summary value of $76.73 per acre per year for general habitat.

**Table 3: Habitat (refugia)**

| Lead Author | Type of study | Low 2008 USD AC/YR | High 2008 USD AC/YR |
|---|---|---:|---:|
| Ingraham | US Wildlife Reserve | $220.00 | $239.00 |
| DeGroot | General | $1.55 | $1066.72 |
| Chen | Wetlands | $14.52 | $148.00 |
| Curtis | Forest | $5.45 | $6.32 |
| Troy | Forest | $4.35 | $4.72 |
| **Median** | | $5.45 | $148.00 |

Habitat (refugia): $76.73 per ac/yr

The summary values for each ecosystem services on a per acre and willingness to pay basis are found in the tables that follow. The total economic value of ecosystem services on a per acre per year basis is also calculated and then applied to the Pike San Isabel National Forest.

## Summary: Economic Values for Ecosystem Services

Table 4 presents the economic value for each ecosystem service in 2008 USD. The results are presented on a per acre per year basis and where available on a willingness to pay (WTP) pay basis. The information is presented under the larger categories of the MA and TEV models and subcategories have been combined in order to eliminate overlapping categories. It is therefore possible to calculate a total economic value of the ecosystem services on a per acre per year basis. Total economic values are shown by MA and TEV category in Table 5. Table 6 shows the total economic value of the ecosystem services when applied to the Pike San Isabel National Forest. Because WTP studies are based on survey results, and these results are easily biased by how the question was written and by the state of the economy when the survey was conducted, WTP results should be interpreted with caution. Therefore, a creating a total economic value table for ecosystem services is not prudent.

**Table 4: Summary of Ecosystem Services and Economic Values**

| **Ecosystem Service** | **2008 USD** |
|---|---|
| **Provisioning** | |
| Food and Fiber | $2.91 per ac/yr |
| Genetic Resources | $22.82 per ac/yr |
| Wetlands Genetic Resources WTP | $9.89 per household per year |
| Raw Materials | $20.59 per ac/yr |
| Ornamental Resources | $25.47 per ac/yr |
| WTP | $7.28 per household per year |
| Pollination | $36.69 per ac/yr |
| **Sub-total** | **$108.48 per ac/yr** |
| | |
| **Regulating** | |
| Water Supply, Cycling, Purification | $43.78 per ac/yr |
| WTP to restore Water Supply, Cycling, Purification | $73.34 per household per year[2] |
| Air Quality, Clean Air, O2 Production | $73.72 per ac/yr |
| Climate Regulation, Carbon Sequestering | $64.64 per ac/yr |
| Water Regulation, Erosion Control, Natural Hazard control | $88.52 per ac/yr |
| WTP | $73.34 per household per year |
| Disease Regulation | $4.18 per ac/yr |
| Pest Regulation | $23.18 per ac/yr |
| Waste Control | $533.02 per ac/yr |
| WTP | $73.34 per household per year |
| **Sub-total** | **$831.04 per ac/yr** |
| | |

[2] Loomis asked respondents how much they were willing to pay to restore 5 ecosystem services. Because the services were not weighted, it was assumed that the respondents weighted the services equally which accounts for the five services showing up as equal in this study.

| **Supporting Services** | **2008 USD** |
|---|---|
| Soil Formation | $3.80 per ac/yr |
| Nutrient Cycling | $1027.30 per ac/yr |
| Provisioning Habitat | $105.09 per ac/yr |
| Biodiversity | $6.57 per ac/yr |
| WTP for preservation of biodiversity | $24.10 per household per year |
| Healthy Ecosystem | $7.32 per ac/yr |
| WTP preservation of healthy ecosystems | $82.59 per household per year |
| Habitat (refugia) | $76.73 per ac/yr |
| WTP to preserve habitat for wildlife | $37.85 per household per year |
| **Sub-total** | **$1226.81 per ac/yr** |
| | |
| **Cultural Services** | |
| Religious/spiritual, aesthetic, inspiration | $8.70 per ac/yr |
| WTP | $12.40 per year per household |
| Cultural Heritage, Sense of Place | $9.47 per household per year |
| **Sub-total** | **$14.08 per ac/yr** |
| | |
| **Direct Use** | |
| Recreation | $26.68 per ac/yr |
| WTP | $8.81 per household per year |
| | |
| See Appendix B for Specific Recreation values for Pike San Isabel National Forest | |
| **Sub-total** | **$26.68 per ac/yr** |
| | |
| **Option value** | |
| Value to Future Generations WTP | $13.22 WTP per household per year |
| | |
| **Non-Use Values** | |
| Bequest | $10.68 WTP per household per year |
| Existence | $10.77 WTP per household per year. |
| Non-Use not specified | $1.12 per ac/yr |
| WTP Non-Use | $9.98 per household per year |
| **Sub-total** | **$1.12 per ac/yr** |
| | |

**Table 5: Summary by Category of Non-Overlapping Ecosystem Services by Category**

| Major Category | Total $ per Acre 2008 USD |
|---|---|
| Provisioning | $108.48 |
| Regulating | $831.04 |
| Supporting | $1226.81 |
| Cultural | $8.70 |
| Direct Use | $26.68 |
| Non-Use | $1.12 |
| Indirect Use; Off-site | --- |
| **Total** | **$2202.83** |
| Option Value = Total[3] | |

**Table 6: Total Economic Value of Ecosystem Services for Pike San Isabel National Forest (2.1 Million Acres not barren rock)[4]**

| Major Category | Total $ per Acre 2008 USD | Pike San Isabel 2008 USD |
|---|---|---|
| Provisioning | $108.48 | $227,808,000 |
| Regulating | $831.04 | $1,745,184,000 |
| Supporting | $1226.81 | $2,576,301,000 |
| Cultural | $8.70 | $18,270,000 |
| Direct Use | $26.68 | $56,028,000 |
| Non-Use | $1.12 | $2,352,000 |
| Indirect Use; Off-site | --- | |
| **Total** | **$2202.83** | **$4,625,943,000** |
| Option Value = Total[3] | | |

## Indirect Use, Off-site values

A great deal of literature is available regarding the importance of Indirect/Off-site use values. However, very little literature is available regarding the economic value of these services or even how these services could be measured. In Table 7 (next page) suggestions are made for determining the economic value of these Indirect Use benefits.

[3] Option value is equal to the total value as future generations would get the at least the same value from ecosystem services as the present generation if all of these services were available to in the future. It could be argued the amount should be discounted, but it is equally valid to suggest that the value should be inflated as the supply of land available to provide ecosystem services is likely to be reduced in the future. However, as option value is not added into the total ecosystem service value, the question is probably moot.

[4] It should be noted, however, that even barren rock contributes to some ecosystem services such as water supply.

**Table 7: Indirect Use, Off-site values and possible methods of measurement**

| **Indirect Use, Off-site values** | **Suggestions for Measurement** |
|---|---|
| Science and knowledge | While professional publications have little economic value, they are indicators of the knowledge being generated by studies of ecosystems and the services they provide. To the extent the accumulation of knowledge leads to social change or produces economic benefits may allow for the determination of the value of this ecosystem service. |
| Population change | Description of population increase, decrease and resulting community income changes. This variable would likely be combined with Employment changes. |
| Income | Income from business related to ecosystem services that are not based on direct use can be calculated. |
| Property Values | Available literature using hedonic analysis suggests proximity to open lands increases property values 8% to 13%. |
| Taxes | Increases and decreases in available tax revenue based on changes in ecosystem services can be ascertained. |
| Employment | Changes in employment based on changes to ecosystem services can be established. The value of labor is readily available through the Bureau of Labor Statistics. |
| Quality of Life | Changes in citizens' quality of life based on changes in ecosystem services can be determined. Quality of Life surveys are frequently conducted and can be correlated against the ecosystem service values found in Table 4. |
| Business Attraction | A survey of businesses and chambers of commerce can be conducted to determine the percent of a decision to be located in an area because of the existent ecosystem services. This percent could then be multiplied by the value of the businesses that relocate to an area. |
| Education | Number of schools and students who use the specific location to study ecosystems and ecosystem services can be found. Travel costs can then be calculated to obtain a value for this ecosystem service. |

## Conclusion and Recommendations

In the past, ecosystem services were left out of the economic analyses when land use planning was conducted. There are likely two reasons for this, first, the economic models used were based on neoclassical economic assumptions that gave little value to the environment and the services it provides; and second, ecosystems services were difficult to quantify economically. Over the last thirty years both of these reasons have been challenged and are no longer valid. Numerous studies point to the importance of ecosystem services for human survival and numerous studies have also been conducted to economically quantify the value of these services.

This study has analyzed the problems inherent in the present economic models and has established conservative economic values for a wide range of ecosystem services. These economic values have been applied to the Pike San Isabel National Forest as a demonstration that the value of these services can be established and therefore incorporated into the land use planning process. It is no longer possible or prudent to ignore the enormous benefits ecosystems provide for humans.

The following conclusions can be reached from the material presented in this paper.

1. Traditional economic models used in land use planning are flawed and therefore their results should be interpreted with great caution.
2. The economic value of ecosystem services has been ignored in the land use planning process.
3. Ecosystem services do have economic value.
4. The economic value of ecosystem services can be measured and is available in the professional literature (Appendix A).
5. The total economic value of ecosystem services is substantial (Tables 5 and 6)

Recommendations:

1. Land use agencies must create new economic models.
2. These models must deal with the flawed assumptions and statistical problems inherent in input/output models.
3. The new models must also include the economic value of ecosystem services.
4. Recursive models are necessary to assess the long term impact of land use change. Models that simply reflect the present, fail to anticipate the long term consequences of land use decisions.
5. Appropriate negative multipliers must be established and used when they will accurately reflect the long term impacts of land use change.
6. Models that can result in economic values that are less than $0 are necessary in order to show the possible impacts of land use change on ecosystem services and therefore show the true costs of losing and replacing those services.

The importance of these recommendations cannot be underestimated. Unless the changes outlined above are incorporated in the land use planning process, economic analyses conducted in the future will continue to be inaccurate. These recommendations are not only academically important, they are critical to the decision making process because if ecosystem services are ignored, human survival is compromised.

## References


Alcamo, Joseph et. al. 2003. *Ecosystems and Human Well-being: A Framework for Assessment.* Island Press.

Alward, Gregory. "Introduction to the Implan V2.0 Modeling System. Minnesota IMPLAN Group (MIG), Inc. Retrieved 8/13/2009. www.doleta.gov/regions/reg05/Documents/WIDRE/IMPLAN.pdf

Anielski, Mark and Sara Wilson. 2005. *Counting Canada's Natural Capital: Assessing the Real Value of Canada's Boreal Ecosystems.* Pembina Institute.

Ashworth, Lorena, Mauricio Quesada, Alejandro Casas, Ramiro Aguilar and Ken Oyama. 2009. "Pollinator-dependent Food Production in Mexico." *Biological Conservation.* 142: 1050-1057.

Beacon Hill Institute. 2004. "The Economic Impact of the Democratic National Convention on the Boston Economy: The Final Tally." Suffolk University. Retrieved 8/19/ 2009. www.beaconhill.org/BHIFaxSheetDNCFinal08094.pdf

Becker, Nir and Shirra Freeman. 2009 (In Press). "The Economic Value of Old Growth Trees in Israel." *Forest Policy and Economics.*

Berger Group, Lewis. 2009. *Economic Contribution of Off-Highway Vehicle Recreation in Colorado: Executive Summary.* Colorado Off-Highway Vehicle Coalition.

Broomhall, David. 1993. "The Use of Multipliers in Economic Impact Estimates." *Agricultural Economics.* Cooperative Extension Service: Purdue University. Retrieved 8/16/2009. www.ces.purdue.edu/extmedia/EC/EC-686.html

Brown, Thomas C., John C. Bergstrom and John B. Loomis. 2007. "Defining, Valuing, and Providing Ecosystem Goods and Services." *Natural Resources Journal.* 47:329-376.

Boyd, James and Spencer Banzhaf. 2007. "What are Ecosystem Services? The Need for Standardized Environmental Accounting Units." *Ecological Economics.* 63: 616-626

Chen, Z.M., G.Q. Chen, B. Chen, J.B. Zhou, Z.F. Yang, and Y. Zhou. 2009. "New Ecosystem Services Value of Wetland: Environmental Economic Account." *Communication in Nonlinear Science and Numerical Simulation.* 14:2837-2843.

Costanza, Robert, Ralph d'Arge, Rudolf de Groot, Stephen Farberk, Monica Grasso, Bruce Hannon, Karin Limburg, Shahid Naeem, Robert V. O'Neill, Jose Paruelo, Robert G. Raskin, Paul Sutton and Marjan van den Belt. 1997. "The Value of the World's Ecosystem Services and Natural Capital." *Nature.* 387: 253-260.

Curtis, Ian A. 2004. “Valuing Ecosystem Goods and Services: A New Approach Using a Surrogate market and the Combination of Multiple Criteria Analysis and a Delphi Panel to Assign Weights to the Attributes.” *Ecological Economics.* 50:163-194.

De Groot, Rudolf S. Matthew A. Wilson and Roelof M.J. Boumans. 2002. “A Typology for the Classification, Description and Valuation of Ecosystem Functions, Goods and Services.” *Ecological Economics.* 41: 393-408.

Department of Community Development and Applied Economics. 2009. “IMPLAN Methodology for the Study of the Impact of Tourism on the Vermont Economy.” University of Vermont. Retrieved 8/13/2009. www.uvm.edu/~snrvtdc/publications/implan_method.pdf

Eppink, Florian and Jeroen van den Bergh. 2007. “Ecological Theories and Indicators In Economic Models of biodiversity loss and conservation: A Critical Review.” *Ecological Economics* 61: 284-293.

Gallai, Nicola, Jean-Michel Salles, and Bernard E. Vaissiere. 2009. “Economic Valuation of the Vulnerability of World Agriculture Confronted With Pollinator Decline.” *Ecological Economics.* 68: 810-821.

Gould, Kenneth A., David N. Pellow, and Allan Schnaiberg. 2008. *The Treadmill of Production: Injustice and Unsustainability in the Global Economy*. Boulder: Paradigm Pub.

Gowdy, John and Sabine O’Hara. 1995. *Economic Theory for Environmentalists.* Boca Raton: St Lucie Press.

Gret-Regamey and Susanne Kytzia. 2007. “Integrating the Valuation of Ecosystem Services into the Input-Output Economics of the Alpine Region.” *Ecological Economics*. 63: 786-798

Guo, Zhongwie, Xiangming Xiao, Yaling Gan, and Yuejun Zheng. 2001. “Ecosystem Functions, Services and Their Values – A Case Study in Xingshan County of China.” *Ecological Economics.* 38: 141-154.

Ingraham, Molly W. and Shonda Gilliland Foster. 2008. “The Value of Ecosystem Services provided by the U.S. National Wildlife Refuge System in the Contiguous U.S.” *Ecological Economics.* 67:608-618.

Jenerette, G. Darrel, Wendy A. Marussich, and Joshua P. Newell. 2006. “Linking Ecological Footprints with Ecosystem Valuation in the Provisioning of Urban Fresh Water.” *Ecological Economics.* 59:38-47.

Jim, C.Y. and Wendy Y Chen. 2009. “Ecosystem services and Valuation of Urban Forests in China.” *Cities.* 26:187-194.

Jin, Di, Porter Hoagland, Tracey Morin Dalton. 2003. "Linking Economic and Ecological Models for a Marine Ecosystem. *Ecological Economics.* 46: 367-385.

Hannon, Bruce. 2001. "Ecological Pricing and Economic Efficiency." *Ecological Economics.* 36: 19-30

Hardin, Garrett. 1968. "Tragedy of the Commons." *Science.* 162(1968):1243-1248

Hassan, Robert M., R J Scholes, Neville Ash (eds). 2005. *Ecosystems and Human Well-being: Current State and Trends: Findings of the Condition and Trends Working Group of the Millennium Ecosystem Assessment.* Island Press.

Hodges, Alan W. 2007. "Understanding and Using Economic Multipliers (PowerPoint)." Presented to USDA Economists Group. Retrieved 8/13/2009. http://ideas.repec.org/p/ags/usdags/43793.html

Hughes, David W. 2003. "Policy Uses of Economic Multiplier and Impact Analysis." *Choices: The Magazine of Food, Farm, and Resource Issues. 2nd Quarter. Retrieved 8/19/2009.* www.choicesmagazine.org/2003-2/2003-2-06.htm

Lindberg, Kreg and John Loomis. 2009. *Economic Impact Decision Support System (DSS). Version 2.0.* Central Oregon Recreation Services.

Loomis, John, Paula Kent, Liz Strange, Kurt Fausch, and Alan Covich. 2000. " Measuring the Total Economic Value of Restoring Ecosystem Services in an Impaired River Basin: Results From a Contingent Valuation Survey." *Ecological Economics.* 33:103-117.

Marx, Karl. [1867]/ 1967. *Capital: A Critique of Political Economy.* Vol 1 New York: International Publishers

Matero, Jukka and Olli Saastamoinen. 2007. "In Search of Marginal Environmental Valuations – Ecosystem Services in Finnish Forest Accounting." *Ecological Economics.* 61:101-114.

Mertz, Tawna. 1999. *Pollination Services: No Food Without Them.* Rand Corporation. Retrieved 8/16/2009. www.rand.org/scitech/stpi/ourfuture/NatureServices/sec1_pollinators.html

Morton, P. 1999. "The Economic Benefits of Wilderness: Theory and Practice." *University of Denver Law Review.* 76:2:462-518.

Mundy, Karen and Wayne Purcell. 2004. "Measuring the 'Ripple Effect': Economic Multipliers." *Horizons.* V16:4:1-3. Retrieved 8/19/2009. www.reap.vt.edu/publications/horizons/hor%2016-4.pdf

Nijkamp, Peter, Gabriella Vindigni, and Paulo A.L.D. Nunes. 2008. "Economic Valuation of Biodiversity: A Comparative Study." *Ecological Economics.* 67:217-231.

Nunes, Paulo A.L.D. and Jeroen C.J.M. van den Bergh. 2001. "Economic Valuation of Biodiversity: Sense of Nonsense?" *Ecological Economics.* 39:203-222.

Pagiola, Stefano, Konrad von Ritter and Joshua Bishop. 2004. *How Much is an Ecosystem Worth? Assessing the Economic Value of Conservation.* Paper# 30893. The World Bank.

Patterson, Trista M. and Dana L. Coelho. 2009. "Ecosystem Services: Foundations, Opportunities, and Challenges for the Forest Products Sector." *Forest Ecology and Management.* 257:1637-1646.

Pejchar, Liba and Harold A. Mooney. 2009. "Invasive Species, Ecosystem Services and Human Well-being." *Trends in Ecology and Evolution.* 24:9:497-504.

Pinchot, Gifford. [1910,1947] in Roderick Frazier Nash. 1990. *American Environmentalism: Readings in Conservation History.* New York: McGraw-Hill. Pp73-79.

Ruijgrok, E.C.M. 2006. "The Three Economic Values of Cultural Heritage: A Case Study in the Netherlands." *Journal of Cultural Heritage.* 7:206-213.

Sattout, E.J., S.N. Talhouk, and P.D.S. Caligari. 2007. "Economic Value of Cedar Relics in Lebanon: An application of Contingent Valuation Method for Conservation." *Ecological Economics.* 61:315-322.

Schaniberg, A and K.A. Gould. 2000. *Environment and Society: The Enduring Conflict.* West Caldwell, NJ: Blackburn Press.

Smith, Adam. [1776]/1937. *The Wealth of Nations.* New York: Modern Library

Troy, Austin and Matthew A. Wilson. 2006. "Mapping Ecosystem Services: Practical Challenges and Opportunities in Linking GIS and Value Transfer." *Ecological Economics.* 60:435-449.

Vejre, Henrik, Frank Sondergaard Jensen and Bo Jellesmark Thorsen. 2009 (In Press). "Demonstrating the Importance of Intangible Ecosystem Services From Peri-urban Landscapes." *Ecological Complexity.*

Zhongmin, Xu, Cheng Goudong, Zhang Zhiqiang, Su Zhiyong, and John Loomis. 2003. "Applying Contingent Valuation in China to Measure the Total Economic Value of Restoring Ecosystem Services in Ejina Region." *Ecological Economics.* 44:345-358.

# Appendix A

## High and low dollar amounts for ecosystem services

Each table in Appendix A shows the high and low dollar amounts for each ecosystem service. The calculation of the high and low amounts is explained in the Methodology Section of this study (page 16) and in Appendix C. The mean or median high and low values are averaged to obtain the dollar amount shown below each table. This is the dollar amount used to represent each ecosystem service found in Table 4 (page 18).

## Provisioning Services

**Food and Fiber**
Food and Fiber includes the vast range of food products derived from plants, animals, and microbes, as well as materials such as wood, jute, hemp, silk, and many other products derived from ecosystems. (Alcoma 2003:56-60) Food production: That portion of gross primary production extractable as food. Production of fish, game, crops, nuts, fruits by hunting, gathering, subsistence farming or fishing. (Costanza 1997:254)

| Lead Author | Type of study | Low 2008 USD AC/YR | High 2008 USD AC/YR |
|---|---|---|---|
| | | | |
| DeGroot | General[5] | 3.11 | 1933.82 |
| Satout | Forest | 1.44 | 1.56 |
| Anielski | Forest | .25 | .29 |
| Chen | Wetlands | 16.60 | 371.41 |
| Curtis | Forests | 1.42 | 1.76 |
| Matero | Forests | 4.65 | 5.31 |
| **Median** | | 2.28 | 3.54 |

***Food and Fiber = $ 2.91 per ac/yr***

**Genetic Resources**
Genetic resources include the genes and genetic information used for animal and plant breeding and biotechnology. (Alcoma 2003:56-60). Genetic resources: sources of unique biological materials and products. Medicine, products for materials science, genes for resistance to plant pathogens and crop pests, ornamental species (pets and horticultural varieties of plants). (Costanza 1997:254)

[5] General refers to non-specified types of land

| Lead Author | Type of study | Low 2008 USD AC/YR | High 2008 USD AC/YR |
|---|---|---|---|
| DeGroot | General | 3.11 | 78.45 |
| Curtis | Forest | 4.32 | 5.36 |
| **Mean** | | 3.72 | 41.91 |
| Anielski | Wetlands | 9.19 | 10.59 |

***Genetic Resources: $22.82 per ac/yr***
***WTP Wetlands Genetic Resources: $9.89 per household per year***

**Raw Materials**
Raw materials are that portion of gross primary production extractable as raw materials. [This] includes the production of lumber, fuel or fodder. (Costanza 1997:254) *Fuel:* wood, dung, and other biological materials serve as sources of energy. (Alcoma 2003:56-60)

| Lead Author | Type of study | Low 2008 USD AC/YR | High 2008 USD AC/YR |
|---|---|---|---|
| DeGroot | General | 3.11 | 710.21 |
| Guo | Forest | 28.16 | 38.06 |
| Curtis | Forest | 1.72 | 2.13 |
| **Median** | | 3.11 | 38.06 |

***Raw Materials: $20.59 per ac/yr***

**Ornamental Resources**
Ornamental resources include animal products, such as skins and shells, and flowers are used as ornaments, although the value of these resources is often culturally determined. (Alcoma 2003:56-60) Ornamental: variety of biota in natural ecosystems with feathers, ivory, orchids, butterflies, aquarium resources (potential) ornamental use fish, shells, etc. (DeGroot 2002:396)

| Lead Author | Type of study | Low 2008 USD AC/YR | High 2008 USD AC/YR |
|---|---|---|---|
| DeGroot | General | 1.55 | 101.56 |
| Matero | Forest | .14 | .17 |
| **Mean** | | .07 | 50.87 |
| | | WTP | WTP |
| Satout | Forest | 6.82 | 7.73 |

***Ornamental Resources: $25.47 per ac/yr***
***WTP Ornamental Resources: $7.28 per household per year***

**Pollination**
Pollination includes ecosystem changes that affect the distribution, abundance, and effectiveness of pollinators. (Alcoma 2003:56-60) Pollination [is the] movement of floral gametes [and] the provisioning of pollinators for the reproduction of plant populations. (Costanza 1997:254)

| Lead Author | Type of study | Low 2008 USD AC/YR | High 2008 USD AC/YR |
|---|---|---:|---:|
| DeGroot | General | 7.26 | 17.51 |
| Mertz | General | 223.00 | 276.00 |
| Curtis | Forest | 2.13 | 2.64 |
| Ashworth | General | 1408.91 | 1408.91 |
| Gallai | General | 37.85 | 39.95 |
| Pejchar | General | 34.48 | 34.48 |
| **Median** | | 36.17 | 37.22 |

***Pollination: $36.69 per ac/yr***

## Regulating Services

**Fresh Water, Water Purification, Water Cycling**
Fresh water is an example of linkages between categories — in this case, between provisioning and regulating services. (Alcoma 2003:56-60) Water regulation: the timing and magnitude of runoff, flooding, and aquifer recharge can be strongly influenced by changes in land cover, including, in particular, alterations that change the water storage potential of the system, such as the conversion of wetlands or the replacement of forests with croplands or croplands with urban areas. (Alcoma 2003:56-60) Water purification and waste treatment: ecosystems can be a source of impurities in fresh water but also can help to filter out and decompose organic wastes introduced into inland waters and coastal and marine ecosystems. (Alcoma 2003:56-60). Water supply: Storage and retention of water: provisioning of water by watersheds, reservoirs and aquifers. (Costanza 1997:254)

| Lead Author | Type of study | Low 2008 USD AC/YR | High 2008 USD AC/YR |
| --- | --- | --- | --- |
| Ingraham | US Wildlife Reserves | 2446.00 | 2655.00 |
| DeGroot | General | 1.55 | 5323.08 |
| Guo | Forest water supply | 2.09 | 2.82 |
| | Water cycling | 46.36 | 61.31 |
| Anielski | Forest water supply | .05 | .06 |
| Sedell in Patterson | Forest water supply | 23.97 | 57.59 |
| Chen | Wetlands | 85.90 | 31000.00 |
| Jenerette | Water sheds | 390.00 | 410.00 |
| Curtis | Forests | 2.54 | 3.16 |
| Troy | Forest | 65.95 | 6.46 |
| | Grasslands | 1.60 | 1.74 |
| **Median** | | 29.97 | 57.59 |
| | | WTP | WTP |
| Loomis | WTP to restore ecosystem service | 64.01 | 82.66 |

***Water Supply, Cycling, Purification: $43.78 per ac/yr***
***WTP to restore Water Supply, Cycling, Purification: $73.34 per household per year***

**Clean Air, $O_2$ production, Air Quality**
Air quality maintenance: ecosystems both contribute chemicals to and extract chemicals from the atmosphere, influencing many aspects of air quality. (Alcoma 2003:56-60) Gas regulation: regulation of atmospheric chemical composition. $CO_2/O_2$ balance,$O_3$ for UVB protection, and $SO_x$ levels. (Costanza 1997:254)

| Lead Author | Type of study | Low 2008 USD AC/YR | High 2008 USD AC/YR |
| --- | --- | --- | --- |
| DeGroot | General (gas reg) | 3.63 | 185.61 |
| Guo | Forest ($O_2$ prod) | 24.58 | 33.22 |
| Chen | Wetlands (gas reg) | 19.92 | 64.74 |
| Curtis | Forest ($O_2$ prod) | 4.08 | 5.07 |
| Jim | Forest ($O_2$ prod) | | 2070.00[6] |
| | Air quality | | 253.50 |
| **Median** | | 22.25 | 125.18 |

***Air Quality, Clean Air, $O_2$ Production: $73.72 per ac/yr***

[6] The values given by Jim et. al, 2009 was placed in either the high or low column according to whether the values were more in line with high or low values. There was not a range of values because the study was conducted using 2008 USD.

**Climate regulation, Carbon Sequestering**
Climate regulation: ecosystems influence climate both locally and globally. For example, at a local scale, changes in land cover can affect both temperature and precipitation. At the global scale, ecosystems play an important role in climate by either sequestering or emitting greenhouse Gases (Alcoma 2003:56-60). Climate regulation: regulation of global temperature, precipitation, and other biologically mediated climatic processes at global or local levels. Greenhouse gas regulation: DMS [dimethylsulphide from plankton] production affecting cloud formation. (Costanza 1997:254)

| Lead Author | Type of study | Low 2008 USD AC/YR | High 2008 USD AC/YR |
|---|---|---:|---:|
| Ingraham | US Wildlife Reserve | 1525.00 | 1656.00 |
| DeGroot | General | 45.60 | 156.19 |
| Guo | Forest | 162.30 | 219.35 |
| Anielski | Forest | 5.74 | 6.61 |
| Lighety in Patterson | Forest | 2.60 | 2.74 |
| Curtis | Forest | 4.02 | 4.99 |
| Troy | Forest | 605.00 | 657.00 |
| | Grassland | 3.74 | 4.08 |
| Matero | Forest | 43.63 | 51.85 |
| | Peat | 6.86 | 8.15 |
| Jim | Forest (climate reg.) | | 9151.00 |
| | Carbon sequestering | | 21154.00 |
| **Median** | | 25.25 | 104.02 |

*Climate Regulation, Carbon Sequestering: $64.64 per ac/yr*[7]

**Water Regulation, Erosion Control, Natural Hazard Control**
Erosion control: vegetative cover plays an important role in soil retention and the prevention of landslides. *Storm protection:* the presence of coastal ecosystems such as mangroves and coral reefs can dramatically reduce the damage caused by hurricanes or large waves. (Alcoma 2003:56-60) Water regulation: regulation of hydrological flows. Provisioning of water for agricultural (such as irrigation) or industrial (such as milling) processes or transportation. Disturbance regulation: capacitance, damping and integrity of ecosystem response to environmental fluctuations. Storm protection, flood control, drought recovery and other aspects of habitat response to environmental variability mainly controlled by vegetation structure. Erosion control and sediment retention: retention of soil within an ecosystem. Prevention of loss of soil by wind, runoff, or other removal processes, storage of stilt in lakes and wetlands. Costanza 1997:254)

[7] Loomis asked respondents how much they were willing to pay in new taxes to restore 5 ecosystem services. Because the services were not weighted, it was assumed that the respondents weighted the services equally which accounts for the 5 services showing up as equal in this paper.

| Lead Author | Type of study | Low 2008 USD AC/YR | High 2008 USD AC/YR |
|---|---|---|---|
| Ingraham | US Wildlife Reserve | 2244.00 | 2436.00 |
| DeGroot | Water regulation | 1.04 | 3813.70 |
| | Disturbance regulation | 1.04 | 5070.73 |
| | Soil Retention | 15.03 | 171.60 |
| Guo | Water flow reg | 34.76 | 46.98 |
| | Natural hazard | 1.69 | 2.28 |
| Chen | Water reg wetlands | 103.33 | 2217.65 |
| Curtis | Water flow and reg | 4.97 | 6.17 |
| Troy | Grassland | .54 | .58 |
| Jim | Forest | 5.83 | |
| **Median** | | 5.40 | 171.60 |
| | | WTP | WTP |
| Loomis | South Platte flat lands | 64.01 | 82.66 |

***Water Regulation, Erosion Control, Natural Hazard control: $88.52 per ac/yr***
***WTP for these services: $73.34 per household per year***

**Disease Regulation**
Regulation of human diseases: changes in ecosystems can directly change the abundance of human pathogens, such as cholera, and can alter the abundance of disease vectors, such as mosquitoes (Alcoma 2003:56-60)

| Lead Author | Type of study | Low 2008 USD AC/YR | High 2008 USD AC/YR |
|---|---|---|---|
| Curtis | Forests | 3.73 | 4.63 |

***Disease Regulation: $4.18 per ac/yr***

**Pest Regulation**
Biological control: ecosystem changes affect the prevalence of crop and livestock pests and diseases (Alcoma 2003:56-60)

| Lead Author | Type of study | Low 2008 USD AC/YR | High 2008 USD AC/YR |
|---|---|---|---|
| DeGroot | General | 1.04 | 54.63 |
| Anielski | Forest | 17.74 | 19.30 |
| **Mean** | | 9.39 | 36.97 |

***Pest Regulation: $23.18 per ac/yr***

**Waste Control**
Waste treatment: recovery of mobile nutrients and removal or breakdown of excess or xenic nutrients and compounds. Waste treatment, pollution control, detoxification.(Costanza 1997:254)

| Lead Author | Type of study | Low 2008 USD AC/YR | High 2008 USD AC/YR |
|---|---|---|---|
| Ingraham | US Wildlife Reserves | 1853.50[8] | 2009.50 |
| DeGroot | General | 30.03 | 4689.91 |
| Chen | Wetlands | 2034.00 | 54755.00 |
| Curtis | Forests | 3.02 | 3.75 |
| Troy | Grasslands | 46.29 | 50.24 |
| Matero | Forests | 4.67 | 5.56 |
| **Median** | | 36.16 | 1029.87 |
| | | WTP | WTP |
| Loomis | South Platte flat lands | 64.01 | 82.66 |

***Waste Control: $533.02 per ac/yr***
***WTP for waste control: $73.34 per household per year***

## Supporting Services

**Soil Formation**
Soil formation and formation processes: weathering of rock and the accumulation of organic material. (Costanza 1997:254)

| Lead Author | Type of study | Low 2008 USD AC/YR | High 2008 USD AC/YR |
|---|---|---|---|
| DeGroot | General | .52 | 7.00 |
| Guo | Forest | 112.62 | 152.21 |
| Curtis | Forest | .59 | .73 |
| **Median** | | .59 | 7.00 |

***Soil Formation: 3.80 per ac/yr***

**Nutrient Cycling**
Nutrient cycling: storage, internal cycling, processing and acquisition of nutrients. Nitrogen fixation: nitrogen, phosphorus and other elemental or nutrient cycles. (Costanza 1997:254)

[8] Ingraham combined waste treatment and nutrient cycling, therefore the values were divided equally between the two categories.

| Lead Author | Type of study | Low 2008 USD AC/YR | High 2008 USD AC/YR |
|---|---|---|---|
| DeGroot | General | 45.09 | 14,788.54 |
| Ingraham | US Refuge System | 1853.50 | 2009.50 |
| Curtis | Forest | 2.31 | 2.86 |
| **Median** | | 45.09 | 2009.50 |

***Nutrient Cycling: $1027.30 per ac/yr***

**Provisioning Habitat**
Nursery function. Suitable reproduction [of] habitat [for] hunting, gathering of fish, game, fruits, Production Functions Provision of natural resources etc. [for] small-scale subsistence farming and aquaculture (DeGroot 2002:396)

| Lead Author | Type of study | Low 2008 USD AC/YR | High 2008 USD AC/YR |
|---|---|---|---|
| DeGroot | General | 73.59 | 136.58 |

***Provisioning Habitat: $105.09 per ac/yr***

**Biodiversity**
The United Nations Convention on Biological Diversity (UNEP, 1992) defines [biodiversity] as '… the variability among living organisms from all sources, including terrestrial, marine and the ecological complexes of which they are part…' (art. 2, page 5). (Nunes 2001: 204)

| Lead Author | Type of study | Low 2008 USD AC/YR | High 2008 USD AC/YR |
|---|---|---|---|
| Curtis | Forest | 5.86 | 7.27 |
| | | WTP | WTP |
| Satout | Forest | 10.26 | 11.18 |
| Nunes | General | 6.10 | 281.30 |
| Nijkamp | General | 36.89 | 37.94 |
| **Median** | | 10.26 | 37.94 |

***Biodiversity: $6.57 per ac/yr***
***WTP for preservation of biodiversity: $24.10 per household per year***

**Healthy Ecosystem**
Biological control: Trophic-dynamic regulations of populations. Keystone predator control of prey species, reduction of herbivory by top predators. (Costanza 1997:254)

| Lead Author | Type of study | Low 2008 USD AC/YR | High 2008 USD AC/YR |
|---|---|---|---|
| Curtis | Forest | 3.25 | 4.07 |
| Lead Author | Type of study | WTP | WTP |
| Nunes | Terrestrial | 34.94 | 146.45 |
| | Wetlands | 9.76 | 139.20 |
| **Mean** | | 22.35 | 142.83 |

***Healthy Ecosystem: $7.32 per ac/yr***
***WTP preservation of healthy ecosystems: $82.59 per household per year***

**Habitat (refugia)**
Refugia: habitat for resident and transient populations. Nurseries, habitat for migratory species, regional habitats for locally harvested species, or overwintering grounds. (Costanza 1997:254)

| Lead Author | Type of study | Low 2008 USD AC/YR | High 2008 USD AC/YR |
|---|---|---|---|
| Ingraham | US Wildlife Reserve | 220.00 | 239.00 |
| DeGroot | General | 1.55 | 1066.72 |
| Chen | Wetlands | 14.52 | 148.00 |
| Curtis | Forest | 5.45 | 6.32 |
| Troy | Forest | 4.35 | 4.72 |
| **Median** | | 5.45 | 148.00 |
| | | WTP | WTP |
| Nijkamp | Wildlife preservation | 2.32 | 2.38 |
| Loomis | South Platte lands | 64.01 | 82.66 |
| **Mean** | | 33.17 | 42.52 |

***Habitat (refugia): $76.73 per ac/yr***
***WTP to preserve habitat: $37.85 per household per year***

## Cultural Services

**Religious/spiritual, aesthetic, inspiration**
Spiritual and religious values: many religions attach spiritual and religious values to ecosystems or their components. Inspiration: ecosystems provide a rich source of inspiration for art, folklore, national symbols, architecture, and advertising. Aesthetic values: many people find beauty or aesthetic value in various aspects of ecosystems, as reflected in the support for parks, “scenic drives,” and the selection of housing locations. (Alcoma 2003:56-60)

| Lead Author | Type of study | Low 2008 USD AC/YR | High 2008 USD AC/YR |
|---|---|---|---|
| DeGroot | General | .52 | 17.51 |
| | General | 3.63 | 1232.71 |
| Curtis | Forest | 3.20 | 4.00 |
| Troy | Forest | 3.34 | 3.63 |
| Vejre | Open Lands | | 351674 |
| Lindberg | PSI | 3.32 | 10.64 |
| **Median** | | 3.32 | 14.08 |
| | | WTP | WTP |
| Satout | Forest | 11.93 | 12.99 |
| Becker | Forest | 2.30 | 2.30 |
| Nijkamp | Forest | 74.01 | 76.12 |
| **Mean** | | 11.93 | 12.99 |

Religious/spiritual, aesthetic, inspiration: $8.70 per ac/yr
WTP for these services: $12.46 per year per household

**Cultural Heritage, Sense of Place**
Cultural heritage values: many societies place high value on the maintenance of either historically important landscapes ("cultural landscapes") or culturally significant species. Sense of place: many people value the "sense of place" that is associated with recognized features of their environment, including aspects of the ecosystem. (Alcoma 2003:56-60)

| Lead Author | Type of study | WTP Low 2008 USD | WTP High 2008 USD |
|---|---|---|---|
| Satout | Forest | 8.65 | 9.43 |
| Ruijgrok | Cultural lands | 16.55 | 18.03 |
| Becker | Old Growth Forest | 2.07 | 2.07 |
| **Mean** | | 9.09 | 9.84 |

***WTP to visit and keep cultural heritage sites and sense of place: $9.47 per household per year***

## Direct Use

**Recreation**
Recreation and ecotourism: people often choose where to spend their leisure time based in part on the characteristics of the natural or cultivated landscapes in a particular area. (Alcoma 2003:56-60) Recreation: Providing opportunities for recreational activities. Eco-tourism, sport fishing, and other outdoor recreational activities. (Costanza 1997:254)

| Lead Author | Type of study | Low 2008 USD AC/YR | High 2008 USD AC/YR |
|---|---|---|---|
| Ingraham | US Wildlife Reserves | 1.04 | 4202.43 |
| Guo | Forest | 3.37 | 4.56 |
| Anielski | Forest | 13.95 | 16.08 |
| Curtis | Forest | 1.48 | 1.84 |
| Troy | Forest | 209.00 | 227.00 |
| Lindberg | PSI Forest | 22.63 | 73.32 |
| **Median** | | 8.66 | 44.70 |
| | | WTP | WTP |
| Satout | Forest | 8.43 | 9.18 |
| Ruijgrok | Open land | 1.70 | 1.85 |
| Loomis | South Platte | 64.01 | 82.66 |
| **Median** | | 8.43 | 9.18 |

***Recreation: 26.68 per ac/yr***
***WTP for recreation: $8.81 per household per year***

## Non-Use Values

**Option Value:**
Option value is willingness to pay so ecosystem services are still available for future generations.

| Lead Author | Type of study | WTP Low 2008 USD | WTP High 2008 USD |
|---|---|---|---|
| Satout | Forest | 12.65 | 13.78 |

***WTP Option value: $13.22 per household per year.***

**Bequest value:**
Bequest value is the willingness to pay to give the ecosystem services to future generations.

| Lead Author | Type of study | WTP Low 2008 USD | WTP High 2008 USD |
|---|---|---|---|
| Satout | Forest | 17.67 | 19.25 |
| Becker | Forest (Old Growth) | 2.90 | 2.90 |
| **Mean** | | 10.29 | 11.08 |

***WTP Bequest value: $10.68 per household per year***

**Existence value:**
Existence value is willingness to pay to just knowing the ecosystem is there even though the respondent may have no intention to personally use the ecosystem.

| Lead Author | Type of study | WTP Low 2008 USD | WTP High 2008 USD |
|---|---|---|---|
| Satout | Forest | 17.79 | 18.73 |
| Becker | Forest: Old Growth | 3.28 | 3.28 |
| **Mean** | | 10.54 | 11.01 |

***WTP Existence value: $10.77 per household per year.***

**Non-use values combined (not specified by type)**
Combined includes option, bequest, and existence values.

| Lead Author | Type of study | Low 2008 USD AC/YR | High 2008 USD AC/YR |
|---|---|---|---|
| Anielski | Forest | .04 | .04 |
| Curtis | Forest | 1.95 | 2.42 |
| **Mean** | | 1.00 | 1.23 |
| | | | |
| Lead Author | Type of study | WTP | WTP |
| Becker | Forest: Old Growth | 9.98 | 9.98 |

***Non-Use: $ 1.12 per ac/yr***
***WTP Non-Use values combined: $9.98 per household per year***

# Appendix B

## Direct Use

### Recreation

The economic values for recreational activities came from Lindberg and Loomis (2009) [9]. Using an input output model Lindberg and Loomis were able to produce economic values in 2008 dollars for virtually all of the national forests in the United States. The values shown in the table below are in millions of dollars for Employment Income and Output. Output is the inter-industry sales and sales to final demand[10]. Output and Labor Income are separate categories and cannot be added together. Number of jobs is in full and part-time jobs combined.

**Pike San Isabel National Forest: 2008 USD and Number of Jobs**

| Activity | Output in Millions | Labor Income in Millions | Number of Jobs | Dollars per ac/yr based on output | Dollars per ac/yr based on Labor |
|---|---|---|---|---|---|
| Camping | 13.1 | 4.3 | 141.8 | 5.24 | 1.72 |
| Backpacking/ hiking/walking | 40.1 | 12.5 | 455.8 | 16.04 | 5.00 |
| Viewing Natural Features | 26.6 | 8.3 | 304.6 | 10.64 | 3.32 |
| Viewing Wildlife | 9.1 | 2.8 | 103.9 | 3.64 | 1.12 |
| OHV, Snowmobiling, and other motorized | 10.7<br>COHVCO[11] 949 | 3.1<br>COHVCO 370.5 | 115.7<br>--- | 4.28<br>42.18 | 1.24<br>16.47 |
| Driving for Pleasure | 9.2 | 2.8 | 105.8 | 3.68 | 1.12 |
| Fishing | 12.8 | 3.8 | 139.5 | 5.12 | 1.52 |

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[9] Lindberg, Kreg and John Loomis. 2009. Economic Impact Decision Support System (DSS). Version 2.0. Central Oregon Recreation Services.

[10] University of Vermont, Department of Community Development and Applied Economics. IMPLAN Methodology for the study of the Impact of Tourism on the Vermont Economy. Prepared for the Vermont Department of Tourism and Marketing. (Date unknown) http://www.uvm.edu/~snrvtdc/publications/implan_method.pdf Retrieved: 8/16/2009. Output includes materials such as: recreational equipment purchases, maintenance costs for equipment, purchases of materials for lodging and restaurants, travel costs to take part in the recreational activity. These would be all direct, indirect and induced dollars (See the IMPLAN section of this paper).

[11] COHVCO. 2009. Louis Berger Group. Economic Contribution of Off-Highway Vehicle Recreation in Colorado. Executive Summary July 2009. **http://cohvco. org/?p=229**. Retrieved: 11/15/09. 949 represents all 2008 output in Colorado and was divided by 22.5 million acres of public lands in Colorado to get ac/yr. Same process was used for labor income.

| **Activity** | **Output in Millions** | **Labor Income in Millions** | **Number of Jobs** | **Dollars per ac/yr based on output** | **Dollars per ac/yr based on Labor** |
|---|---|---|---|---|---|
| Hunting | 12.1 | 3.5 | 128.8 | 4.84 | 1.40 |
| Horseback riding | 2.1 | 0.7 | 23.9 | 0.84 | 0.28 |
| Bicycling | 5.5 | 1.7 | 62.9 | 2.20 | 0.68 |
| Downhill skiing | 11.7 | 3.9 | 127.5 | 4.68 | 1.56 |
| Cross-Country skiing | 1.7 | 0.5 | 20.0 | 0.68 | 0.20 |
| Non-motorized water | 0.6 | .02 | 6.5 | 0.24 | 0.01 |
| Nature Center Activities and Nature Study | 1.5 | .05 | 16.9 | 0.60 | 0.02 |
| Picnicking | 2.6 | 0.9 | 28.3 | 1.04 | 0.36 |
| Resort Use | 0.6 | 0.2 | 7.1 | 0.24 | 0.08 |
| Visiting Historic Sites | 0.6 | 0.2 | 7.1 | 0.24 | 0.08 |
| Relaxing | 9.7 | 3.2 | 106.2 | 3.88 | 1.28 |
| Gathering Forest Products | 2.2 | 0.7 | 23.6 | 0.88 | 0.28 |
| Other Non-Motorized | 10.8 | 3.4 | 123.7 | 4.32 | 1.36 |
| **Total**[12] | 183.5 | 57.1 | 2049.6 | 73.32 | 22.63 |

[12] Total only uses Lindberg and Loomis and does not include COHVCO's higher estimates for motorized recreation.

# Appendix C

## Dollar Adjustments and Statistics Used

Varieties of studies have been conducted to assess the value of ecosystem services. These studies began in the 1970s and continue through the present. Similarly, economic evaluations have been done throughout the world. Because of these differences, adjustments to the studies need to be made in order to make the results from different studies similar.

**Conversion to 2008 USD**

In this study, the economic value of ecosystem services is calculated in 2008 US dollars. 2008 dollars are used because data for 2009 conversions are not available yet. Because the studies reviewed were conducted throughout the world, it was also necessary to transform foreign currency into US dollars. The following sections discuss the processes used in this study.

MeasuringWorth (www.measuringworth.com) was used to convert past into present dollars. While the consumer price index is commonly used in order to convert past into present dollars, it is only one of many indices that can be used. MeasuringWorth provides the results from six different data sets resulting in a dollar range that can be quite wide. Williamson (2009 MeasuringWorth) describes the differences in the six indices used by MeasuringWorth:

- **"The CPI** is most often used to make comparisons partly because it is the series with which people are most familiar. This series tries to compare the cost of things the average household buys such as food, housing, transportation, and medical services. For earlier years, it is the most useful series for comparing the cost of consumer goods and services. It can be interpreted as how much money you would need today to buy an item in the year in question if its price had changed the same percentage as the average price change.
- **The GDP Deflator** is similar to the CPI in that it is a measure of average prices. The "bundle" of goods and services here includes all things produced in the economy, not just consumer goods and services that are reflected in the CPI.
- **The Consumer Bundle** is the average dollar value of the annual expenditures of a "consumer unit". The consumer unit could be a family or another type of household. The main point is that spending is a joint decision of the members of the unit. The bundle increases over time as household income increases. Unlike the CPI, not only the cost but also the amount of goods and services increases over time.
- **The Unskilled Wage Rate** is good way to determine the relative cost of something in terms of the amount of work it would take to produce, or the relative time it would take to earn its cost. It can also be useful in comparing different wages over time. The unskilled wage is a more consistent measure than the average wage for making comparisons over time.
- **The GDP per capita** is an index of the economy's average output per person and is closely correlated with the average income. It can be useful in comparing different incomes over time.

- **The GDP** is the market value of all goods and services produced in a year. Comparing an expenditure using this measure, tells you how much money in the comparable year would be the same percent of all output." (MeasuringWorth: http://www.measuringworth.com[13])

Using the six different indices, $100 in 1998 could be worth from $126 to $164 in 2008 depending on the index used.

| | |
|---|---|
| CPI = | $132.09 |
| GDP deflator = | $126.86 |
| Consumer bundle = | $143.52 |
| Unskilled wage rate = | $134.92 |
| GDP per capita = | $148.93 |
| GDP = | $164.23 |

An ecosystem service could fit within any of these six indicators as it is something someone could purchase. It also is something that could be reproduced through some type of substitution, or it is a part of the GDP. Therefore, this study will use the highest and lowest conversions to create the highest and the lowest possible value for an ecosystem service.

### Currency Conversions

Currency conversions were made using the historical currency calculator found at http://www.x-rates.com/calculator.html. This calculator contained conversion statistics from 1990 through 2008.

An example of both the conversion to USD and the conversion to 2008 USD is shown in Figure 1. The following *hypothetical* study was conducted in China in 2002. The complete conversion process is shown in Figure 1 below. Carbon sequestering was found to have: **1)** a high value of 5000 yuan per hectare per year, and **2)** a low value of 1250 yuan per hectare per year. **3)** Hetares are then changed to acres [1 ha = 2.47 ac]. **4)** Yuan were converted to 2002 dollars. **5)** 2002 dollars are converted to their highest value in 2008 dollars by multiplying by 1.36, and **6)** converted to their lowest 2008 dollars by multiplying by 1.18. [The currency conversion rates of 1.18 and 1.36 were found at www.measuringworth.com.]

**Figure 1: Conversion Process for Obtaining Ecosystem Service Values**

| | Chinese yuan (2002)/ha/yr | 2002 USD ac/yr | 2008 USD ac/yr |
|---|---|---|---|
| Carbon sequestering → | **1**) **High** = 5000 yuan/ha/yr | | |
| | **3**) = 2024.49 yuan/acre/yr (5000/2.47 = 2024.49) | = 285.14 USD ac/yr | **5**) 285.14 x 1.36 = $387.79 ac/yr |
| | **4**) 7.1 yuan = 1 USD (2002) (2024.49/7.1 = 285.14 USD) | | |
| Carbon sequestering → | **2**) **Low** = 1250 yuan/ha/yr | | |
| | = 506.07 yuan/acre/yr | = 71.28 USD ac/yr | **6**) 71.28 x 1.18 = $84.11 ac/yr |

[13] http://www.measuringworth.com/calculators/uscompare/result.php (retrieved Sept. 14, 2009)

Figure 1 shows the value of carbon sequestering from this *hypothetical* study falls somewhere between $84.11 and $387.79 per acre per year. In studies that presented a single value for an ecosystem service or when the study was conducted in the United States, the conversion process was much simpler.

**Statistics Used: Mean vs. Median**

When distributions are skewed with either a very high or very low score, the mean is is pulled in the direction of the outlier. This makes the mean a poor descriptor of the skewed distribution. The example below demonstrates the difference between using the mean vs. the median in a skewed distribution.

| $ per acre | |
|---|---|
| 300 | Mean (average) = 455/7 = $65 |
| 50 | |
| 40 | |
| 30 | Median (middle score) = $30 |
| 20 | |
| 10 | |
| 5 | |
| 455 | |

In this situation where six of the scores are $50 or less, and only one score is extremely high, the median score of $30 is a much better representative score for this distribution than the mean of $65.

# Appendix D

## Reliability

Reliability is based on the number of studies, consistency of study results, location where studies took place, and whether a logical conservative result could be obtained. Each ecosystem service table in Appendix A was rated for reliability using the following scoring criteria.

| Number of Studies | Consistency of study results | Location<br>Regions of the World | Logical Result |
|---|---|---|---|
| 1-2 = 1 | Little Similarity = 1 | 1 region = 1 | Overly Liberal = 1 |
| 3-5 = 2 | Very Similar = 2 | 2-3 regions = 2 | Conservative = 2 |
| ≥ 6 = 3 | | > 3 regions =3 | |
| | | | |

Composite scores: 8-10 = High Reliability
5-7 = Medium
1-4 = Low

| **Category** | **Number of studies Per/ac yr** | **Reliability Score Per/ac yr** | **Number of WTP studies** | **Reliability Score WTP** |
|---|---|---|---|---|
| Food and Fiber | 6 | 10 = High | | |
| Genetic Resources | 2 | 5 = Medium | 1 | 4 = Low |
| Raw Materials | 3 | 6 = Medium | | |
| Ornamental Resources | 2 | 5 = Medium | 1 | 4 = Low |
| Pollination | 6 | 9 = High | | |
| Fresh Water, water purification, water cycling | 9 | 9 = High | 1 | 4 = Low |
| Clean Air, Oxygen production, Air Quality | 5 | 8= High | | |
| Climate Regulation, Carbon Sequestering | 9 | 8 = High | | |
| Water Regulation, Erosion Control, Natural Hazard Control | 7 | 10 = High | 1 | 4 = Low |
| Disease Regulation | 1 | 4 = Low | | |
| Pest Regulation | 2 | 5 = Medium | | |
| Waste Control | 6 | 8 = High | 1 | 4 = Low |
| Soil Formation | 3 | 7 = Medium | | |
| Nutrient Cycling | 3 | 6 = Medium | | |
| Provisioning Habitat | 1 | 4 = Low | | |
| Biodiversity | 1 | 4 = Medium | 3 | 6 = Medium |
| Healthy Ecosystem | 1 | 4 = Low | 1 | 4 = Low |
| Habitat (Refugia) | 5 | 7 = Medium | 2 | 4 = Low |
| Religious, Aesthetic, Inspiration | 6 | 9 = High | 3 | 6 = Medium |
| Cultural heritage/sense of place | | | 3 | 7 = Medium |
| Recreation | 6 | 9 = High | 3 | 7 = Medium |
| Option | | | 1 | 4 = Low |
| Bequest | | | 2 | 4 = Low |
| Existence | | | 2 | 4 = Low |
| Non-use, combined | 2 | 6 = Medium | 1 | 4 = Low |