The Wilderness Society

Economic Value of Forest Ecosystem Services: A Review

By Douglas J. Krieger, Ph.D.

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an analysis prepared for The Wilderness Society

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The importance of natural forest ecosystems to human well-being cannot be overstated. Forests provide raw materials for food, fuel and shelter. In forests, ecosystem components such as microorganisms, soils and vegetative cover interact to purify air and water, regulate the climate and recycle nutrients and wastes. Without these and many other ecosystem goods and services, life as we know it would not be possible.

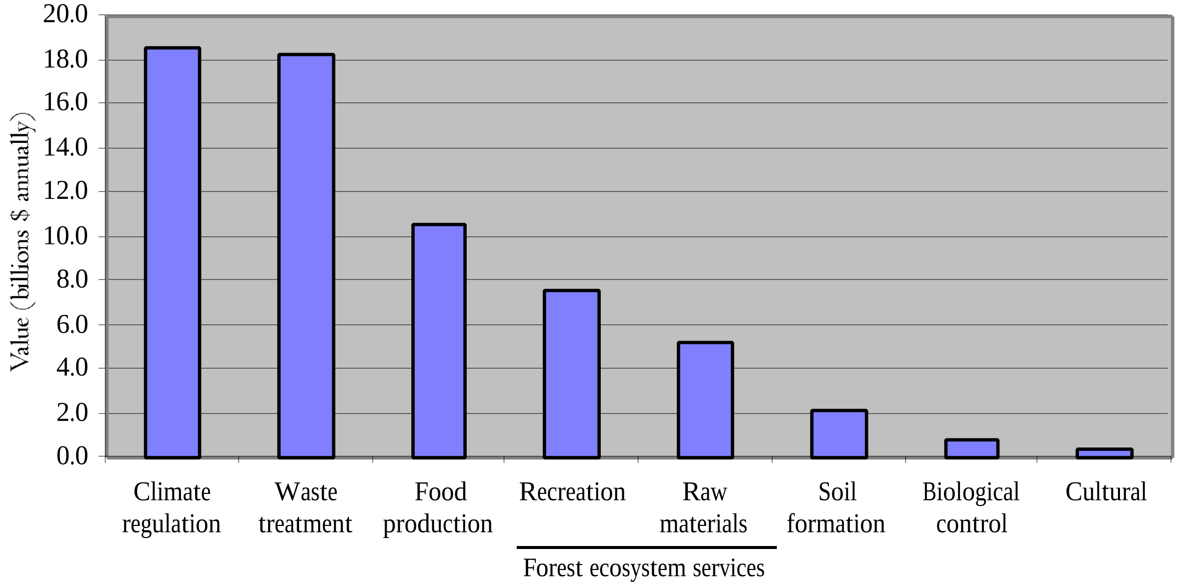
When we make decisions to alter natural forest ecosystems, we often give little thought to the consequences that change may have on forest ecosystem services or to the ultimate cost of losing those services. This oversight stems from our incomplete knowledge about how changes in ecosystems affect the level of services that the systems provide and our inadequate understanding of the roles played by seemingly trivial ecosystem components.

Perhaps the most significant factor is that few ecosystem services have clearly established monetary values. And this can have a strong impact, considering that many decisions about resource use are made by comparing benefits and costs. The decision to log a forest tract, for example, should be based on a comparison of the expected monetary value of the timber and the costs associated with the ecosystem goods and services foregone as a result of logging. Any ecosystem goods and services that do not have monetary values are generally not accounted for in the decision calculus. Neither is the fact that the benefits of many resource use decisions are usually enjoyed by small, fairly cohesive groups of people or the current generation, while the costs of foregone ecosystem goods and services are borne by larger, more dispersed groups or future generations.

Resource economists have long recognized the market distortions caused by unpriced goods. They have developed techniques to estimate monetary values, and ecological economists have applied those methods to estimate values for ecosystem services. This paper reviews estimates of the economic value of forest ecosystem goods and services in the United States. Globally, Costanza et al. (1997b) estimated the total value of forest ecosystem goods and services at $4.7 trillion annually and the total annual value of all temperate/boreal forests at $894 billion. There are about 520 million acres of temperate/boreal forest in the United States (Pimentel et al. 1997), with an implied annual value for services of about $63.6 billion, using Costanza's estimates (Figure 1). Climate regulation, waste treatment and food production account for approximately 75 percent of this total.

Forest ecosystem values estimated in studies reviewed for this paper are grouped into eight categories: watershed services (water quantity and quality), soil stabilization and erosion control, air quality, climate regulation and carbon sequestration, biodiversity, recreation and tourism, non-timber products and cultural values. Table 1 reports ranges of the estimated values within each category for the entire United States and by region. These values are not necessarily comparable across regions because they often correspond to different aspects of a forest ecosystem service, were arrived at using different methods and are expressed in different units. While the estimates do not provide meaningful comparisons of value across regions, they nevertheless indicate the magnitude of values by region.

Figure 1. Ecosystem service values of U.S. forests



The remainder of this summary briefly reviews sources of value and value estimates for each ecosystem service category. Chapter 1 discusses the economic concept of value and introduces techniques used to estimate monetary values for ecosystem goods and services. Chapter 2 reviews the literature relevant to estimating monetary values for forest ecosystem services.

Watershed Services

Forested watersheds capture and store water, thus contributing to the quantity of water available and the seasonal flow of water. Forests also help purify water by stabilizing soils and filtering contaminants. The quantity and quality of water flowing from forested watersheds are important to agriculture, the generation of electricity, municipal water supplies, recreation and habitat for fish and other wildlife species. Estimates of water quantity values focus primarily on streamflow and range from $0.26 per acre-foot for electricity generation to as much as $50 per acre-foot for irrigation and municipal use. Most values for recreational use are $10 per acre-foot or less (Sedell et al. 2000). In general, recreational values are probably higher in arid regions such as the Southwest and in regions that experience substantial seasonal variation in streamflow. Studies in Colorado and Alabama found substantial existence values for streamflow. On average, Colorado households were willing to pay $95 and Alabama households $57 a year to preserve natural streamflow in rivers (Brown 1992).

Water quality is particularly important for municipal uses. The U.S. Environmental Protection Agency estimates that as many as 3,400 public water systems serving 60 million people obtain their water from watersheds that contain national forests. The value of the water purification services of forested watersheds is reflected in the costs that some communities incur to protect their watersheds. New York City spent $1.4 billion to protect the quality of water from the 80,000-acre forested watershed that serves much of the city. To protect their watersheds, Portland, Oregon spends $920,000 and Portland, Maine $729,000 per year.

Table 1. Range of Estimated Forest Ecosystem Service Values by Region

Ecosystem Service	Region Entire United States	Rocky Mountains	Southeast	Pacific Northwest	Northeast	Southwest
Watershed services						
Quantity	$0.26 to $50.86 / acre-foot	$4.07 to $940 / acre-foot	$57 / household / year			
Quality	$64.16 / house-hold / year			$920,000 to $3.2 million / year	$729,000 to $35 million / year	
Soil stabilization			$1.94 / ton	$5.5 million / year		$90,000
Air quality						$4.16 / tree (urban)
Climate regulation and carbon sequestration	$1 to $6 billion / year					$20.75 / tree (cost to cool buildings)
Biological diversity	$4 to $54 billion					
Recreation						
Economic impact	$1.3 to $110 billion (national forests)	$736 million (wilderness)	$6 billion (all) to $407 million (hunting)	$1 billion (fishing)		
Wilderness recreation	$600 million / year	$14 / visitor day	$12 / visitor day		$29 million / year	
Hunting and fishing		$2.07 to $12.3 million	$237 to $637 million			$13 to $25 / deer
Non-timber products			$300 million / year			$910,000 / year
Cultural values						
Aesthetic and passive use	$280 million / year	$14 to $92 / household / year	$12 to $99 / household / year	$48 to $144 / household / year	$4.5 to $167 million	
Endangered species	$2 to $3.7 billion / year			$15 to $95 / household / year		$40 / house-hold / year
Cultural heritage						$4.5 million

Soil Stabilization and Erosion Control

Forest vegetation helps stabilize soils and reduce erosion and sedimentation. Estimated values associated with soil stabilization primarily reflect the costs associated with sedimentation. Values range from $1.94 per ton in Tennessee to $5.5 million annually in Oregon's Willamette Valley. In Tucson, Arizona, a half million mesquite trees are expected to reduce runoff that would otherwise require construction of detention ponds costing $90,000.

Air Quality

Trees trap airborne particulate matter and thus improve air quality and human health. This paper discusses only one study of the value of air quality services from trees. That study concluded that the 500,000 mesquite trees which Tucson, Arizona intends to plant will, once they reach maturity, remove 6,500 tons of particulate matter annually. Tucson spends $1.5 million on an alternative dust control program. Therefore, the air quality value of each tree equals $4.16.

Climate Regulation and Carbon Sequestration

Trees help regulate climate by trapping moisture and cooling the earth's surface. Costanza et al. (1997b) imply that U.S. forests yield $18.5 billion per year in climate regulation benefits. Studies in urban settings conclude that 100,000 properly planted, mature trees in U.S. cities may save as much as $2 billion in heating and cooling costs. Trees also capture atmospheric carbon dioxide, thereby reducing global warming. The U.S. Forest Service estimates that such carbon sequestration services yield benefits of $65 per ton, which totals to $3.4 billion annually for all U.S. forests.

Biological Diversity

Biological diversity is important for many reasons, including its role as a storehouse of genetic material that can be used to selectively breed plants and animals, its contribution to natural pest and disease control and its ability to provide valuable pharmaceutical products.

Few studies have addressed the value of biological diversity in forest ecosystems, but it is estimated that the cost to U.S. agriculture of using chemical pesticides to replace the natural pest control services from all natural ecosystems would be about $54 billion annually. The U.S. Forest Service estimates that it would cost more than $7 per acre to replace the pest control services of birds in forests with chemical pesticides. In addition, the pollination services of natural ecosystems provide U.S. agriculture benefits of $4 billion to $7 billion annually.

Recreation and Tourism

Scenic beauty and recreational amenities associated with forests make them popular recreation destinations. The U.S. Forest Service estimated that recreational activities on national forests alone contribute $110 billion annually to this nation's Gross Domestic Product. Regionally, the economic impact of forest-based recreation depends to some extent on the proximity of population centers as well as on the unique characteristics of a region's forest resources. Estimates of the economic impact of forest-influenced recreation vary from $736 million annually in Montana to $6 billion annually in the Southern Appalachians region.

Wild, unroaded lands offer a unique form of outdoor recreation, and many studies have estimated the value of wilderness-related recreation. Based on an average value of $41.87 per visitor day, the economic value of recreation on the 42 million acres of roadless areas in U.S. national forests is $600 million annually. Among residents of the Northeast, use values for eastern wilderness total $29 million annually. Visitors to wilderness areas in Colorado are willing to pay $14 and in Utah $12 per visit for wilderness recreation.

Forest ecosystems are also important destinations for hunters and anglers. In 1996, hunters spent 19.4 million days hunting on national forests, and more than 18 million people fished in national forests. The economic impact of these activities is substantial — between $1.3 and $2.1 billion for hunting and $1.4 and $2.9 billion for fishing nationwide. In the Southern Appalachians region, hunting generated impacts of $594 million and fishing $407 million in 1996. Hunters on federal lands in the Columbia River Basin spend as much as $150 million annually. In the Pacific Northwest, commercial and recreational fishing generate more than $1 billion in income annually. In Montana, anglers were willing to pay $2.07 million to protect high-quality recreational fishing in just one roadless study area.

Non-Timber Commercial Forest Products

Forests produce many commercially valuable products other than timber, including mushrooms, floral greens, medicinal plants and edible plant and wildlife species. The total market value of these non-timber products harvested in the Pacific Northwest amounted to about $300 million in 1992. In New York, a single community generated $910,000 in sales of non-timber forest products. Non-timber forest products are also important sources of subsistence foods in some regions. In southeastern Alaska, the average household consumes an average of 889 pounds of edible resources annually. This includes 295 pounds of salmon with a market value of $590 and 118 pounds of venison with a market value of $472.

Cultural Values

Cultural values associated with forests include what economists call passive use values for forest goods and services (including endangered species habitat), the aesthetic value of forest scenery and values associated with a region's cultural heritage. The scenic characteristics of forests attract tourists to forested regions, and the resulting economic impact can be substantial. Visitors to the scenic Blue Ridge Parkway in North Carolina and Virginia, for example, contribute $1.3 billion to local economies. Visitors to the Southern Appalachians region reported a willingness to pay $18 to $99 per household per year to maintain the scenic quality of the region's forests. Forest ecosystems also provide habitat for some endangered species. Values attached to Pacific Northwest old-growth forests for northern spotted owl habitat range from $35 to $95 per household per year.

Many people attach value to knowing that forests exist now and into the future. Estimates of such existence value for old-growth forests west of the Cascade Mountains extend from $48 to $144 per U.S. household per year. Residents of Wisconsin revealed a willingness to pay $7 million to protect wilderness areas in Utah that they are unlikely to visit. A study in Vermont found passive use values associated with protecting eastern wilderness of more than $167 annually (aggregated) for all residents in the Northeast. In the Rocky Mountain region, passive use values for wilderness protection range from $14 to $92 per household per year.

ECOSYSTEM SERVICES: VALUES AND VALUATION

Goods provided by natural ecosystems are the basic building blocks of human welfare. Natural ecosystems provide much of the food we eat, the water we drink, the clothes we wear, material for shelter, fuel to keep us warm and inspiration and experiences that enrich our lives. The ability of ecosystems to provide these goods depends on the less obvious ecosystem services or processes through which the goods are created and maintained. The quantity and quality of water available for human use — an ecosystem good — depends on the water purification services of an ecosystem. The process by which ecosystems provide clean water depends on complex interactions between vegetative cover, soils, wetlands, microorganisms and other ecosystem components (Daily et al. 1997). When the components that contribute to water purification are damaged or altered, water quality and human welfare may suffer.

Some goods and services from natural ecosystems cannot be produced simultaneously at a single location. Cutting down trees for wood products may reduce, at least for a time, the level of carbon sequestration or erosion control services of natural forests. Clearing land for food production may eliminate wildlife habitat for some species and reduce genetic diversity. Such conversion of natural ecosystems causes the most concern when it takes place on a large scale or when it alters a rare ecosystem that provides globally or regionally valuable goods or services such as habitat for an endangered species.

A necessary part of providing for human existence involves making tradeoffs among different ecosystem goods and services. Decisions to use one ecosystem good at the expense of other goods and services are often based on a comparison of the associated benefits and costs. Many of the benefits associated with ecosystem goods are measured as profit or income. The costs, on the other hand, often include reductions in the levels of other ecosystem goods and services that have no easily determined market value. The value of these non-market ecosystem services is rarely accounted for in tradeoffs among ecosystem goods and services. In addition, the benefits from use of some ecosystem goods and services often accrue to relatively small, concentrated groups in the here and now, while the costs in relation to lost goods and services are often borne by a larger, more dispersed population and future generations.

Resource economists have developed a variety of techniques to estimate the monetary value of non-market environmental goods such as hunting, fishing, outdoor recreation and water quality, and ecological economists have applied these methods to estimate the economic value of various ecosystem services (Costanza et al. 1997b). This chapter introduces the economic concept of value and briefly reviews several methods to estimate economic values for ecosystem goods and services. The objective is to provide background needed to interpret the estimates of forest ecosystem values summarized in Chapter 2.

Economic Value of Environmental Goods and Services

In economics, a good or service is valuable if it increases human well-being. This implies that goods and services have no value in their own right. Rather, their value is defined only in the context of human welfare. The economic concept of value does not imply, however, that an ecosystem's ability to add to monetary wealth is the only determinant of how ecosystem goods and services should be used. Many people gain pleasure from non-consumptive use of ecosystem goods and services — hiking, birdwatching and additional kinds of outdoor recreation. Other people value ecosystem goods and services even though they have not and may never intend to experience those goods and services directly. Such non-monetary sources of value are part of the economic value of ecosystem goods and services.

Economists classify the values associated with ecosystem goods and services into two broad categories — use and passive use, the latter also known as non-use values (Freeman 1979). Use values are derived from the direct use of environmental goods and services, including logging, commercial and recreational fishing, outdoor recreation, subsistence hunting and gathering and the enjoyment of environmental amenities such as a scenic view. Another source of use values is the indirect provision of goods and services through processes such as a watershed's ability to maintain water quality, a wetland's ability to provide habitat for migratory birds or a forest's ability to store carbon and thus help control global temperatures.

Passive use values are unrelated to the physical impacts of an ecosystem good or service on individual well-being. There is ample evidence that people value many environmental goods and services even though they never intend to use them or experience them (Randall 1991). People may value a natural ecosystem simply because it makes them happy to know that the ecosystem exists. They may value endangered species because of a belief that species have a right to exist regardless of their use by humans. These passive use values are called existence values. Bequest values are also passive use values. They are associated with a desire to protect ecosystem goods and services for the use or enjoyment of future generations. Option values, a third kind of passive use values, are associated with maintaining the option of use by either the current or future generations. An example is the value of protecting rainforest biodiversity to preserve the option of extracting genetic material for future agricultural or pharmaceutical products.

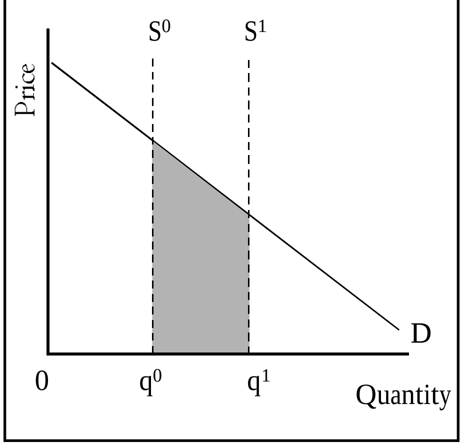
While the concept of economic value is not necessarily based on money, economists often estimate monetary values for ecosystem goods and services. Some people argue that this should not be done because ecosystems and species have an inherent right to exist independent of their use by humans (Goulder and Kennedy 1997). A counter argument is that failure to place monetary values on environmental goods and services will ultimately lead to their exploitation and loss (Costanza et al. 1997a). As an example, one consequence of refusing to determine the monetary value of recreation, wildlife habitat, scenery and other forest ecosystem services may well be an emphasis on logging — which generates monetary value — to the detriment of the unpriced goods and services.

Measurement of Economic Values

The economic measure of the value of ecosystem goods and services is consumer surplus. This is the difference between the maximum amount an individual would be willing to pay for a good and service and the amount that person actually pays. The concept is based on the fact that some people are willing to pay more for a good or service than others. Therefore, when all consumers are charged the same price, some people pay less than what they are willing to pay. Since these people pay less for the good than the maximum they are willing to pay, they enjoy an increase in well-being relative to not purchasing the good. Consumer surplus for society as a whole is the sum of consumer surplus for all individuals.

Figure 2 illustrates the concept of consumer surplus for a typical ecosystem good or service. The demand curve, D, defines the quantity of the good or service that individuals in the aggregate demand at each price. With high prices, few individuals are willing to purchase the good and the quantity demanded is low. As prices fall, more individuals judge the good to be worth the price and purchase it, thus increasing the quantity demanded.[1]

Figure 2. Consumers surplus for a change in an ecosystem good or service



While a demand relationship exists for any good or service, estimating the demand for many ecosystem goods and services may be challenging, in part because many ecosystem goods and services are public goods available to everyone in fixed quantity regardless of price. The scenic beauty of forests, for example, is available to everyone with no price attached. It is impossible or prohibitively expensive to exclude people from the benefits of such goods and services if they don't pay. Thus, markets do not exist, and ecosystem goods and services are often unpriced. A demand curve represents changes in the quantity demanded as price changes. Since neither price nor changes in quantity are easily observable for many ecosystem goods and services, demand is difficult to determine.

Assume that the demand relationship for a specific ecosystem good and service can be defined. The supply curve, S^0, in Figure 2 represents the quantity of the good or service available under specific conditions. The height of the demand curve at any quantity represents society's maximum willingness to pay for a marginal increase in quantity. The consumer surplus associated with the marginal change in quantity is the difference between the height of the demand curve and the price, which in this case is zero. The consumer surplus associated with quantity q^0, therefore, is the sum of consumer surplus for each marginal change in quantity from zero to q^0. This is the area under the demand curve between a quantity of zero and q^0.

Suppose that an activity increases the quantity of the good or service available to everyone — a stream restoration project, say, increases the quantity of ecosystem services associated with a natural stream. The line S^1 represents this new quantity. The consumer surplus associated with the stream restoration project is the difference between consumer surplus prior to the restoration and consumer surplus after the restoration. The shaded area of Figure 2 represents this value.

For a complete discussion of consumer surplus and valuation of ecosystem ser-

[1] In the context of ecosystem goods and services, the horizontal axis can represent either quantity or environmental quality.

vices, see resource economics texts such as Randall (1987) or Freeman (1993).

Valuation Approaches and Value Measures.

Economists have developed several specialized techniques to address the difficulties inherent in estimating demand — and thus consumer surplus measures — for unpriced or non-market goods and services. The remainder of this section reviews the most common techniques to provide an understanding of how the resulting value measures relate to the economic concept of value depicted in Figure 2.

Travel cost method. One commonly used method to estimate the value of non-market goods relies on travel expenditures incurred to visit a site (Freeman 1979). This approach is applied to recreational and other site-specific activities or resources that necessitate travel costs to experience the goods or services associated with the site. Consider, for example, the challenge of estimating the value of a wilderness area. Wilderness is a non-market good - visitors rarely pay to use it. But they do incur travel costs to visit a wilderness area. The travel cost approach queries visitors to a site to determine the relationship between visitation rates and distance traveled. The observed variation in visitation rates (quantity of visitors) and travel cost (a proxy for price) describes demand for the site. The demand function permits consumer surplus estimates of the economic value of the site.

Hedonic approach. The hedonic approach applies to situations where the price of a market good reflects access to an ecosystem good or service (Freeman 1979). In the case of estimating the value of air quality, we know that levels of air quality may vary across an urban area. If homebuyers are aware of this variation and care about air quality, then housing prices should reflect differences in air quality. The hedonic approach would collect information on home sales (prices) and the environmental amenities available at locations where homes were sold. It would employ statistical techniques to separate the influence of air quality from other factors that affect housing prices and then estimate the portion of the sale prices of the homes that is attributable to air quality. This observed willingness to pay for air quality, as an addition to the price of a home, is used to calculate a demand function for air quality and thus the consumer surplus associated with different levels of air quality.

Contingent valuation. The travel cost and hedonic methods use observations of actual behavior — traveling or purchasing a home — to estimate demand and consumer surplus. Both techniques rely on the ability to link market behavior to a non-market ecosystem good or service. This is not possible for passive use values. An alternative valuation method, called contingent valuation, was developed to estimate passive use values.

Instead of relying on observed behavior, the contingent valuation method asks people what they would be willing to pay for an ecosystem good or service (Mitchell and Carson 1989). The approach uses a questionnaire or interview to present respondents with a market-like situation where they can express a monetary value for a carefully described non-market good or service. For example, the referendum format asks whether respondents would vote for or against a referendum that would raise taxes a specified amount to provide a non-market public good. Responses across a representative sample of people provide the information necessary to estimate demand and economic value.

The travel cost, hedonic and contingent valuation methods are the only valuation approaches that estimate demand relationships and, thus, consumer surplus for non-market goods. There are a number of other approaches, described below, that estimate proxies for consumer surplus and other measures of economic impact.

Defensive (averting) expenditures. One such method relies on the existence of technological substitutes for some ecosystem services. A water treatment plant is a substitute for the water purification services of a forested watershed. Such defensive (or averting) expenditures to prevent or counteract the loss of an ecosystem service with a substitute provide one measure of the value of the service (Freeman 1993).

Note that defensive expenditures are a valid measure of value only if the expense is actually incurred (Heal 2000). New York City spent $1.4 billion to protect its watershed and the water purification services that the watershed provides. In doing so, the city avoided spending a much greater amount on a water treatment plant. In this case, the cost to replace the water purification services of the forest with a water treatment plant is not a measure of value because the city chose the less expensive alternative of protecting the watershed. Instead, the cost the city incurred to protect the watershed and avert a reduction in water quality is the correct measure of value. The measure does not correspond to consumer surplus because it measures actual expenditures rather than maximum willingness to pay.

Defensive or averting expenditures represent the lower end of the scale regarding the value of ecosystem services. First, they rely on actual expenditures for the least-cost alternative rather than maximum willingness to pay. If it were not possible to protect the watershed that supplies New York City, residents would likely be willing to pay the much greater cost for a water treatment plant to ensure the quality of their water. Even if the city had incurred the cost of a water treatment plant, the expenditure would still be less than the proper consumer surplus measure of value because it is based on actual expenditures rather than maximum willingness to pay.

Second, technological alternatives are rarely perfect substitutes for ecosystem services. A water treatment plant provides clean water for municipal use but not for recreational activities, fish habitat or other uses that stem from a healthy forest ecosystem.

Benefits transfer. Under certain conditions, value estimates for ecosystem goods and services in one location or setting can be used to estimate value in another location or setting. This approach is called benefits transfer. The validity of the benefits transfer approach depends on the quality of the original estimation and on how closely the valued good and valuation setting match the new setting (Boyle and Bergstrom 1992, Brookshire and Neil 1992). Benefits transfer is a widely used approach because it is relatively easy and inexpensive to apply.

Commercial value. The methods above cover situations where market prices for ecosystem goods and services are not available. In some cases, market prices do exist. Coastal wetlands provide important habitat for many commercial fish species that have well-defined market values. In this case, the commercial value of the wetlands for fish production is the present value (based on market prices) of the future fish that will result from protection of the wetland. The measure is only partial because it incorporates only the value of the wetland for the production of commercial species, while ignoring other values.

Gross expenditures. Another common method estimates the gross expenditures incurred to enjoy a good or service. This approach is often used in relation to recreational activities such as the total expenditures on travel, equipment and supplies for a fishing trip to measure the value of fishing. Gross expenditure is an indication of the importance of an activity, but it does not measure economic value as defined by consumer surplus. The gross expenditure measure allocates expenses to an activity that are not specific to the activity. Also, it does not estimate demand curves and maximum willingness to pay (Sorg and Loomis 1984).

Economic impact. Many studies estimate the total economic impact of an activity on a regional economy. As an example, a wilderness area may attract visitors to the region in which the wilderness is located. Those visitors will have a direct impact on the local economy through their spending on food, gas, lodging and supplies. Measures of these direct impacts include income, profits, employment and tax revenue. Local businesses directly impacted by tourist activity will indirectly affect businesses that supply them goods and services — for example, the firm that supplies food products or kitchen appliances to a restaurant. And increased local income generated from the direct and indirect impacts of tourism will generate induced impacts such as increased spending by workers and the additional income and jobs supported by that spending. While measures of economic impact provide an indication of the impact of an activity on a local economy, they do not measure economic value as defined by consumer surplus.

THE VALUE OF FOREST ECOSYSTEM GOODS AND SERVICES

A recent study of the attitudes of forestry professionals, environmentalists and the general public suggests that each of these groups attach greater significance to the life support processes and moral values of national forests now than they did a decade ago (Xu et al. 1997). Similarly, in a study conducted by Schaberg et al. (1999), residents of North Carolina ranked five non-market goods and services — clean water, contributions to global oxygen, endangered species habitat, stable forest cycles and climate stability — as the most important benefits that forests provide.

While people appear to value the non-market services associated with forest ecosystems, quantifying the value of these goods and services in monetary terms is difficult. Costanza et al. (1997b) identified 17 specific goods and services provided by ecosystems: gas regulation, climate regulation, disturbance regulation, water regulation, water supply, erosion control and sediment retention, soil formation, nutrient cycling, waste treatment, pollination, biological control, refugia, food production, raw materials, genetic resources, recreation and cultural services.

The authors employed various methods to estimate the economic market and non-market values of these goods and services in 16 different ecosystems, including tropical and temperate/boreal forests. While forest ecosystems probably contribute in some way to the production of all 17 goods and services, Costanza et al. were able to estimate economic values for only 14 and temperate/boreal forest values for 8. Table 2 summarizes the study findings relevant to forest ecosystems. The final column of the table was calculated by applying the estimates from the study — reported on a per-hectare basis — to the approximately 520 million acres of temperate/boreal forests in the United States.[2] Values are reported in U.S. dollars per acre.

The Costanza study provides a revealing but rough estimate of the magnitude of ecosystem service values on a global scale, and the reported values can serve as a basis for estimates relevant to specific regions or ecosystems. This chapter reviews existing estimates of economic values associated with forest ecosystems in the United States. Forest ecosystem services are organized into eight categories, rather than Costanza's 17, to reflect the findings of specific studies reviewed for this paper. Those categories are watershed services (water quantity and quality), soil stabilization and runoff control, air quality, climate regulation and carbon sequestration, biological diversity, recreation and tourism, non-timber products and cultural values.

Watershed Services

Forest ecosystems are key determinants of the quantity and quality of water available for human use. Inadequate water quantity and quality affect agricultural production, quality of life and human health in many regions of the world. As the human population increases and the availability of high-quality water declines, the watershed services of forests will likely become increasingly important.

Forests influence water quantity — both total quantity and seasonal variation in flows — through a number of interrelated processes. The so-called "albedo" effect refers to the process by which forest vegetation increases evaporation of water

[2] Pimentel et al. 1997

Table 2. Estimates of forest ecosystem values

Ecosystem good or service	Market nature of service[a]	Global values by forest type ($/acre)[b]			Value of all U.S. forests[c] (billion $)
		All forests	Tropical	Temperate/Boreal	
Climate regulation	NM	57.1	90.2	35.6	18.5
Disturbance regulation	NM	0.8	2.0	n.a.	n.a.
Water regulation	NM	0.8	2.4	0.0	0.0
Water supply	M,NM	1.2	3.2	n.a.	n.a.
Erosion control and sediment retention	NM	38.8	99.1	0.0	0.0
Soil formation	NM	4.0	4.0	4.0	2.1
Nutrient cycling	NM	146.1	373.1	n.a.	n.a.
Waste treatment	NM	35.2	35.2	35.2	18.3
Biological control	NM	0.8	n.a.	1.6	0.8
Food production	M	17.4	12.9	20.2	10.5
Raw materials	M	55.8	127.5	10.1	5.3
Genetic resources	M,NM	6.5	16.6	n.a.	n.a.
Recreation	M,NM	26.7	45.3	14.6	7.6
Cultural	NM	0.8	0.8	0.8	0.4
Total		392.1	812.2	122.2	63.6

Note: n.a. = not available.

[a] "NM" denotes a good or service that is primarily non-market in nature. "M" denotes a primarily market good or service. "M,NM" denotes a good or service that has significant market and non-market characteristics.

[b] Calculated from the $/hectare estimates of Costanza et al. (1997b) based on a conversion factor of 2.471 acres/hectare. All values are in U.S. 1994 dollars.

[c] Estimates for the United States were based on a total area of 520 million acres of temperate/boreal forest

from the earth's surface to cause increased cloud formation and rainfall (Myers 1997). Through the albedo effect, large-scale clearing of forests can alter rainfall patterns over entire regions by decreasing the amount of rain. Forest ecosystems also act as a sponge, soaking up and storing water when it is abundant and releasing it during dry periods. This process serves to even out annual water flows from forested watersheds and reduce the impacts of downstream flood/drought cycles (Myers 1996).

In the United States, forest ecosystems play a key role in providing water. Sedell et al. (2000) estimated that as much as two-thirds of the runoff in this country outside Alaska comes from forests, and 14 percent of that amount from national forests. Forests east of the Mississippi produce more water per acre than forests in the West and account for about 60 percent of the total runoff from all forests nationwide. In the West, national forests are relatively more important than non-federal forests as sources of water. In California, 45 percent of runoff is from national forests, and national forests in the Pacific Northwest (the Columbia River Basin and the coastal rivers of Oregon and Washington) account for 38 percent of the total runoff in the region.

Forests also contribute to water quality by reducing soil erosion and filtering pollutants from water. The vegetative cover of forests shelters soil from the force of rain while roots help hold soil in place and reduce soil erosion (Myers 1996). The interaction of vegetation and soils also filters other contaminants from water. Clean water from forest ecosystems is particularly important to the many municipalities that obtain their water from forested watersheds. The Environmental Protection Agency estimated that 3,400 public water systems serving about 60 million people obtained their water from watersheds containing national forests in 1999 (Sedell et al. 2000). National forest watersheds are particularly important sources of municipal water in Oregon and Washington.

Water Quantity. The quantity of water from forest ecosystems contributes to many valuable activities and services. The U.S. Forest Service estimates that national forest watersheds produce 530.4 million acre-feet of water annually with an average consumptive use value of $50.86 per acre-foot. If all water produced from national forests alone were valued at its average value for consumptive use, it would have a total value of $27 billion annually (Dunkiel and Sugarman 1998).

Of course, not all water flowing from national forests is consumed. Sedell et al. (2000) estimated consumptive use of water flowing from national forests at almost 34 million acre-feet per year. At a marginal value of about $40 per acre-foot, the study estimated a conservative consumptive use value of water from national forests of about $1.4 billion annually. A recent study of economic benefits from all forests in the Sierra Nevada region of California concluded that the productive value of water from the forests was $1.32 billion annually (Stewart 1996). Most of the value was attributable to agricultural use.

In addition to its value in consumptive use, water quantity enhances many recreational activities. The quantity of water available in a stream (the streamflow) can affect fish populations and fishing activity as well as recreational boating and rafting. Brown (1992) reviewed studies that addressed the value of streamflow and concluded that increased streamflow has positive value up to some maximum above which additional flow is detrimental to the recreational experience. The studies used contingent valuation and travel cost methods to estimate the marginal value of an additional acre-foot of water used to augment low seasonal flows in streams in a number of regions.

Estimated values ranged from $1 to $45 per acre-foot. In general, smaller rivers and more heavily used rivers generated the largest values. In most regions of the country, anglers placed a marginal value of less than $10 on an additional acre-foot of water. In the Southwest, however, values were considerably more. A study in Colorado (reviewed in Moskowitz and Talberth 1998) reported streamflow value estimates of $810 to $940 per acre-foot in the Upper Gunnison River Basin.

Sedell et al. (2000) reviewed values associated with water flowing from national forests and found that the average (across reviewed estimates) value of water in streams was about $40 per acre-foot for offstream uses (irrigation, industrial and municipal use). Estimates of the marginal value of streamflow for generating electricity ranged from $0.26 to $17.00 per acre-foot, with most values below $2.00, and most estimates of the marginal value of streamflow for recreation were below $10.00 per acre-foot.

There are also passive use values associated with streamflow. Some people value the knowledge that the habitats, species and conditions supported by natural streamflows are preserved even though they may never directly experience them. Several contingent valuation studies estimated total values (use plus passive use) for different aspects of streamflow. Two studies estimated willingness to pay of $95 and $57 per household per year to preserve natural streamflow in 11 rivers in Colorado and 15 in Alabama, respectively (Brown 1992). Another study, cited in Brown (1992), estimated that households were willing to pay $115 per year to improve lake levels in Mono Lake, California to reduce salinity, improve bird survival and diversity and improve visibility. These studies consistently found that most (69 perent to 80 percent) of the total value was associated with bequest and existence values rather than use values.

A contingent valuation study in Montana estimated the average total value of increasing summer streamflow in five rivers to maintain trout populations, birds, wildlife and plants at $4.07 to $35.94 per household per year, with an average of $15 per household per year (Duffield 1992). The higher values corresponded to a greater scope of the proposed streamflow program (five rivers versus one river), respondents who lived closer to the river(s) in question and respondents who actively used the rivers. Duffield (1992) also reviewed four other contingent valuation studies of the total value of streamflow in Montana. Estimated values again fell within the range of $4.07 to $35.94 per household per year.

Table 3 summarizes values associated with water quantity.

Water Quality. Many municipalities depend on forested watersheds as a source of clean water. When these ecosystems are disturbed, water quality often suffers. The cost of constructing and operating water treatment plants to purify polluted water is one common measure of the value of the water purification function of forested watersheds. The city of New York obtains drinking water for about eight million people from the 80,000-acre Catskill watershed. In the late 1990s, the New York State and federal governments committed $1.4 billion to protect the quality of the water in the watershed (Reid 1999, Moskowitz and Talberth 1998) and thus avoided a cost of $4 billion to $6 billion to construct a filtration plant and $300 million a year to operate the plant. New Jersey chose to spend $55 million to protect the Sterling Forest watershed rather than incur an estimated $160 million in filtration costs (Lerner and Poole 1999). Portland, Oregon spends $920,000 annually to protect its Bull Run watershed, thereby avoiding the $200 million expense of constructing a filtration plant. Portland, Maine spends $729,000 annually on watershed protection, preventing an expenditure of $25 million for a water filtration facility and $750,000 in annual operating costs (Reid 1999). In each of these cases, the money actually spent — rather than the expenditure avoided — is the more appropriate measure of the value of water purification services.

Intact forests in watersheds prevent erosion that can reduce water quality. Salem, Oregon's watershed, for example, lies within the Willamette National Forest. In the

Table 3. Water Quantity Service Values of Forests

Study	Geographic scope of values	Basis for valuation	Value estimates
Entire United States			
Dunkiel and Sugarman (1998)	All national forests	Consumptive use value of all water flowing from forests	$50.86 / acre-foot $27 billion / year
Sedell et al. (2000)	All national forests	Consumptive use value of water actually consumed	$40 / acre-foot $1.4 billion / year
		Offstream and onstream value of all water	$3.7 billion / year
		Average marginal offstream value of water	$40 / acre-foot
		Marginal value for hydroelectric use	$0.26 to $17.00 / acre-foot
		Marginal value of streamflow for recreation	< $10 / acre-foot
Brown (1992)	All national forests	Recreational value of streamflow	$1 to $45 / acre-foot
		Value of streamflow to anglers	< $10 / acre-foot
		Total value of maintaining streamflow or lake levels	$15 to $115 / household / year
California region			
Stewart (1996)	Sierra Nevada region	Productive use value of water flowing from forests	$1.32 billion / year
Rocky Mountain region			
Moskowitz and Talberth (1998)	Colorado	Value of streamflow	$810 to $940 / acre-foot
Duffield (1992)	Montana	Total value of maintaining streamflow (contingent valuation)	$6.38 to $35.94 / household / year
Brown (1992)	Colorado	Willingness to pay to preserve natural streamflow in 11 rivers	$95 / household / year
Duffield (1992)	Montana	Willingness to pay to augment streamflow	$4.07 to $35.94 / household / year
Southeast region			
Brown (1992)	Alabama	Willingness to pay to preserve natural streamflow in 15 rivers	$57 / household / year

winter of 1996, severe storms caused mudslides in the heavily logged watershed, and the city was forced to spend $700,000 on a temporary pre-treatment facility, $200,000 to treat turbid water and $1.2 million on a permanent pre-treatment system. Additional related expenses included a $100 million water treatment plant and $3.2 million in annual operating costs (Moskowitz and Talberth 1998). Mitsubishi Corporation, located in Salem, also spent $2 million on a private well to provide clean water when the city's water system was shut down.

Water quality affects recreational and passive use values associated with water. A contingent valuation study in Montana estimated the value of protecting water quality in Flathead Lake and the Flathead River (Sutherland and Walsh 1985). On average, households allocated $7.37 per household per year to recreational use values associated with maintaining water quality. Passive use values totaled $56.96 per household per year - $10.71 for option value, $19.88 in existence value and $26.37 in bequest value. The total value of maintaining water quality was $64.16 per household per year.

Table 4 summarizes estimates of the value of the water quality services of forests.

Soil Stabilization and Erosion Control

Forest vegetation helps stabilize soils and prevent erosion. The costs associated with erosion include reduced soil productivity, damaged roads and structures, filled ditches and reservoirs, reduced water quality and harm to fish populations. Moskowitz and Talberth (1998) reviewed studies of the costs associated with logging, including costs attributable to logging-induced erosion on national forests in several regions. Several studies reviewed by the authors addressed the costs associated with sedimentation such as in the Little Tennessee River Basin where sedimentation costs residents an average of $1.94 per ton. In the Willamette Valley of Oregon, with its large expanses of national forest land, sedimentation imposes costs of about $5.5 million per year. Sedimentation in Portland, Oregon's Bull Run reservoir reduced capacity from 10 billion gallons to 5.5 billion gallons between 1964 and 1972. The sedimentation corresponded to substantial logging activity in the watershed that supplies the reservoir.

Erosion also damages roads and harms fish populations. The U.S. Forest Service spent about $125 million repairing landslide damaged roads on national forests in Washington and Oregon[3] and more than $4 million over a four-year period to repair logging roads damaged by erosion on the Siuslaw National Forest in Oregon alone. Erosion and sedimentation associated with logging on the Siuslaw also caused an estimated $1.7 million in damages to recreational fishing over a 30-year period (Moskowitz and Talberth 1998).

Forests also help control storm water runoff. In Tucson, Arizona, one mature mesquite tree is expected to reduce storm water runoff by nine cubic feet. Based on the cost of constructing detention ponds to control runoff, the value of a tree for runoff control is $0.18 annually (McPherson 1992, Dwyer et al. 1992). Tucson plans to plant 500,000 mesquite trees in the city. The total estimated value of these trees for runoff control is $90,000 per year.

Air Quality

Trees can trap airborne particulate matter and ozone that can be harmful to humans and thus contribute to improved

[3] No time period was given for this estimate.

Table 4. Summary of Water Quality Values of Forests

Study	Geographic scope of values	Basis for valuation	Value estimates[a]
Northeast region			
Reid (1999) Moskowitz and Talberth (1998)	New York City	Defensive expenditures to protect water purification services of forested watershed	$1.4 billion
Lerner and Poole (1999)	New Jersey	Defensive expenditures to protect water purification services of forested watershed	$55 million
Reid (1999)	Portland, Maine	Defensive expenditures to protect water purification services of forested watershed	$729,000 / year
Pacific Northwest region			
Reid (1999)	Portland, Oregon	Defensive expenditures to protect water purification services of forested watershed	$920,000 / year
Moskowitz and Talberth (1998)	Salem, Oregon	Defensive expenditures to purify water affected by erosion in damaged watershed	
		City of Salem	$2.2 million plus $3.2 million annual operating costs
		Mitsubishi Corporation	$2 million
Rocky Mountain region			
Sutherland and Walsh (1985)	Montana	Recreational and passive use of water quality (contingent valuation)	$64.16 / household / year (total): $7.37 (use), $10.71 (option), $19.88 (existence), $26.37 (existence)

[a] The magnitude of values depends to a great extent on the number of people who obtain water from the watershed.

air quality and human health. Air purification functions of forests are particularly important in urban environments. Once the 500,000 mesquite trees that Tucson, Arizona plans to plant reach maturity, they should reduce airborne particulate matter by an estimated 6,500 tons annually (Dwyer et al. 1992, McPherson 1992). Tucson's current street paving program, which was designed to reduce dust, costs an average of $0.12 per pound of dust controlled every year. Using that amount as the defensive expenditure required to replace the dust control service of trees implies that the trees have a dust control value of $1.5 million per year, or, adjusting for mortality, $4.16 per tree.

Climate Regulation and Carbon Sequestration

Forests help regulate local climate through their ability to contribute to and regulate rainfall and temperature. Loomis and Richardson (2000) estimated that the climate regulation benefits associated with the 42 million acres of roadless areas on national forests are $490 million annually. Those estimates were based on the per-acre benefits reported by Costanza et al. (1997b). Forests also contribute to cooling. In an urban setting, properly located trees can reduce cooling costs and energy use as demonstrated in Madison, Wisconsin, where air conditioning and heating costs for a typical home increased from $671 per year with an energy efficient tree planting design to $700 with no trees and $769 for an inefficient planting design. Nationally, computer simulations estimate that 100 million mature trees in U.S. cities could reduce annual energy costs by $2 billion dollars (Dwyer et al. 1992). The 500,000 mesquite trees planned for Tucson, Arizona should save an estimated $20.75 per tree in cooling costs for buildings every year (McPherson 1992).

On a global level, forest vegetation absorbs atmospheric carbon dioxide and thereby reduces the potential for global warming. Tropical forests — because they contain so much vegetation — are particularly valuable for carbon sequestration. The temperate/boreal forests of the United States also provide carbon sequestration benefits, which the U.S. Forest Service estimated at $65 per ton of carbon sequestered, or $3.4 billion every year from this country's national forests (Dunkiel and Sugarman 1998). Loomis and Richardson (2000), also using the $65 per ton value, estimated carbon sequestration benefits of about $1 billion every year associated with just the 42 million acres of roadless areas on the national forests. The present value of these benefits — assuming a four percent discount rate — is $26.7 billion annually. Pimentel et al. (1997) estimated the value of carbon sequestration services by using estimates of the coastal flood damages that would be avoided if increases in sea levels caused by global warming were prevented. Based on this approach, the carbon sequestration value of the roughly 520 million acres of forest in the United States is $6 billion per year.

To put these values in perspective, Costanza et al. (1997b) estimated the carbon sequestration benefits of all forests worldwide at $684 billion annually. By forest type, benefits from tropical forests were $424 billion and benefits from temperate/boreal forests were $260 billion. In another summary of ecosystem values, Myers (1996) reported the carbon sequestration value of the rainforests in the Brazilian Amazon at $46 billion and the replacement cost of the carbon storage capacity of all tropical forests at $3.7 trillion.

Table 5 summarizes estimates of the carbon sequestration value of forests.

Biological Diversity

Protecting biological diversity ensures a wealth of potentially valuable genetic material such as that used in selective breeding to improve yields of commercial crops and livestock (Pimentel et al. 1997). Genetic diversity also contributes to development of pharmaceuticals that improve the quality and length of human life and to biotechnology that improves crop yields and reduces the use of chemical pesticides. Natural ecosystems also provide habitat for numerous species that naturally control potential agricultural pests (Daily et al. 1997). Moskowitz and Talberth (1998) report that the cost to U.S. agriculture of replacing natural pest control services with chemical pesticides would be about $54 billion annually. Natural ecosystems also provide pollination services on which a large portion of commercial agriculture depends (Nabham and Buchmann 1997). Natural pollination services may be worth as much as $4 to $7 billion annually to U.S. agriculture

Table 5. Summary of Carbon Sequestration Values of Forests

Study	Geographic scope of values	Basis for valuation	Value estimates
Dunkiel and Sugarman (1998)	U.S. national forests	Benefits transfer	$65 / ton $3.4 billion annually
Loomis and Richardson (2000)	42 million acres of roadless area on U.S. national forests	Benefits transfer	$65 / ton $1 billion annually and $26.7 billion present value
Pimentel et al. (1997)	Entire United States	Coastal flooding damages avoided	$6 billion / year
Myers (1996)	Brazilian Amazonia	Defensive expenditure	$46 billion[a]
Costanza et al. (1997b)	All forests All tropical forests All temperate / boreal forests	Unknown	$684 billion $424 billion $260 billion

[a] The study does not indicate whether the reported values are in annual or present value terms.

(Moskowitz and Talberth 1998).

Some portion of these benefits can be attributed to forest ecosystems, although few estimates specific to forest biological diversity values exist. In one case in Costa Rica, a banana plantation pays an adjacent forested conservation area $1 per hectare ($0.40 per acre) every year to provide natural pest control services (Reid 1999). In the United States, birds control many insects that damage forests, and the U.S. Forest Service estimated that the use of pesticides or genetic engineering to accomplish the level of pest control provided by birds would cost at least $7.34 per acre (Moskowitz and Talberth 1998). Because the cost has not actually been incurred, however, this estimate represents only the cost of replacing the natural pest control services of birds and not the value of pest control services.

Balick and Mendelsohn (1992), in a study conducted in Belize, estimated that the market value of medicinal plants from a tropical forest ranged from $350 per acre in a 30-year-old forest to $1,624 per acre in a 50-year-old forest. When labor costs were considered, net revenues per acre were $228 and $1,236, respectively. The present value of a sustainable harvest of medicinal plants was $294 per acre with a 30-year rotation and $1,346 per acre with a 50-year rotation.

Recreation and Tourism

Forests hold a wide range of recreational opportunities. They are crucial habitat for game animals and fish sought by hunters and anglers, and they also serve as the source of rivers and streams used for recreational purposes. Forests are the backdrop for non-consumptive recreational activities such as hiking, birdwatching, wildlife viewing and other such pursuits. In addition, wilderness areas — many of which are forested — attract substantial recreational activity. A large number of studies address the economic value of outdoor recreational activities, incorporating common valuation perspectives such as estimating the value of an activity day for different activities, the value of access to recreational opportunities and the regional economic impact of recreational activities.

General Recreation. Moskowitz and Talberth (1998) cite a number of measures of the economic importance of forests for recreation. The U.S. Forest

Service, for example, estimated that the economic value of recreation in all national forests was $6.8 billion in 1993 and projected a value of $12.7 billion for the year 2045. In 1996, national forest-based recreation supported 139,000 full-time jobs. Regionally, recreational activities focused largely on forest ecosystems accounted for 2770 jobs in southeast Alaska, $379 million in annual value in Southern Appalachian national forests and a value of $1 billion in five national forests in the southern Rocky Mountains. The Forest Service further estimated that by the year 2000, recreation on national forests would contribute $110 billion to the nation's Gross Domestic Product, compared to a $3.5 billion contribution from logging on national forests (Dunkiel and Sugarman 1998).

National forests contain much of the remaining undeveloped forestland in this country — lands that contribute valuable recreational experiences. The 42 million acres of roadless areas on the national forests attract an estimated 14.6 million recreation days annually. Based on an average value of $41.87 per visitor day,[4] the economic value of recreation on these roadless areas is $600 million annually (Loomis and Richardson 2000). Spending by recreational visitors to forested areas has a substantial impact on local economies in some regions. Considering total economic impacts (direct, indirect and induced), recreation in roadless areas generates an estimated $576 million in income, $916 in value added and 23,700 jobs annually to local economies (Loomis and Richardson 2000).

Yuan and Christensen (1992) found that as many as 60 percent of out-of-state visitors to Montana in 1990 were attracted by the abundance of undeveloped forestlands and the recreational activitiesthose lands offer. Visitors that were influenced by wildlands were defined as those who engaged in fishing, hunting, camping or viewing scenery or wildlife. On average, this subset of all visitors described in the study spent $546 per group in Montana during their trips - substantially more than visitors not influenced by wildlands. Throughout Montana, wildland-related recreation generated more than $736 million in direct spending and supported almost 12,000 jobs. By activity, fishing generated the greatest direct expenditure ($450 million), supporting more than 3,900 jobs directly and 3,200 through indirect impacts. Nature study generated $97 million in direct spending and supported 6,000 jobs, while backpacking generated $19 million in wages and salaries and supported 1,200 jobs (Power 1992).

Recreational tourism in the Southern Appalachians region (portions of Alabama, Georgia, North Carolina, South Carolina, Tennessee and Virginia) generates nearly $6 billion per year in total economic impacts (Barnhill 1999). National forests were the setting for much of this activity. Forest ecosystems in the region contribute to clear water in the scenic rivers that attract substantial whitewater rafting activity. In 1996, rafting on the Ocoee River generated more than $3 million in commercial and private user fees and contributed more than $300,000 in tax revenues to Polk County, Tennessee. Rafting on the Nantahala River generated local economic impacts of more than $14 million in 1993. And the impacts of recreational spending ripple outward from localities. For five regional rivers, including the Nantahala, every job in rafting created between 1.67 and 1.90 jobs else-

[4] Estimated from 20 existing travel cost and contingent valuation studies of the value of a roadless area recreation day.

where in the Southern Appalachian states' economies. For every $1,000 spent on rafting, $2,000 to $2,400 were added to total income levels within the states (Barnhill 1999).

While the economic impact of forest-based recreation is an indicator of the importance of forest ecosystems to local economies, it is not a measure of the value of the ecosystem. Several studies have estimated consumer surplus measures of the economic value of forest ecosystems, primarily for wilderness lands. A contingent valuation study in Vermont, for example, asked respondents how much they would pay to protect both the Lye Brook Wilderness Area in the Green Mountain National Forest in Vermont and all designated wilderness areas (lands that Congress has included in the National Wilderness Preservation System) east of the Mississippi River (Gilbert et al. 1992). Respondents reported willingness to pay of $9.04 (median) per household per year to protect the Lye Brook area and $10.42 per household per year to preserve all eastern wilderness areas. For both scenarios, respondents who had visited an eastern wilderness area were willing to pay more than those who had not - $9.71 versus $8.64 to protect Lye Brook and $14.28 versus $6.40 to protect all eastern wilderness. Respondents in all categories attributed about 85 percent of their total valuation of wilderness to passive use value and the remaining 15 percent to passive use value. Summed over all households in the study area (a zone from within 26 miles to 75 miles of the Lye Brook area), annual passive use values totaled $5.7 million, while use values totaled $1.1 million.

Walsh et al. (1984) used contingent valuation to estimate use and passive use values associated with protecting wilderness in Colorado. Based on a $14-per-visitor day use value of wilderness, the study concluded that the 1.2 million acres of designated wilderness that existed in 1980 had a use value of $13.2 million and that increasing the total amount of designated wilderness to 2.6 million acres would increase the use value to $21 million. Use values for protecting 5.0 million and 10.0 million acres of wilderness in the Colorado were $33.1 million and $58.2 million, respectively. When use values to residents of other states were factored in, the marginal value of increasing wilderness in the state to 2.6 million acres was $78 per acre, or $125 million.

In another contingent valuation study, cited by Walsh and Loomis (1989), visitors to the Ramseys Draft Wilderness in Virginia reported a use value of about $12 per day.

Many people also gain value from viewing wildlife species that depend on forested habitats. By one estimate, the value of wildlife viewing alone on national forests was between $118 and $514 million in 1990 (Moskowitz and Talberth 1998). Clayton and Mendelsohn (1993) estimated use values associated with the opportunity to view grizzly bears on the McNeil River in Alaska, employing the contingent valuation method to estimate a willingness to pay that ranged from $227 to $277 per person for a four-day visit.

Hunting and Fishing. Forest ecosystems support crucial habitat for many game animals and fish species. Forests are thus a key factor in generating the substantial economic benefits associated with hunting and fishing activity. In 1996, hunters spent 19.4 million days hunting on national forests and generating a total economic value between $1.3 and $2.1 billion (1990 dollars; Moskowitz and Talberth 1998). The U.S. Fish and Wildlife Service estimated that hunters in the Southern Appalachians region spent about $1.3 billion on equipment and trip expenses in 1988. Barnhill (1999) estimated the total economic impact of hunting activities and wildlife viewing in the Southern Appalachians region at $594 million and $407 million, respectively, in 1996. In the Columbia River Basin, hunters on federal lands, including national forests, spend as much as $150 million annually to pursue their sport.

While estimates of economic impacts provide evidence of the regional importance of specific activities on forests, they lack the links between land use, wildlife populations and value that would be most useful to forest management decisions. Two studies reviewed here estimate unit values for animals sought by hunters, and one links those values to forest management decisions. The first study (Livengood 1983) used the hedonic travel cost approach to estimate the value that lease hunters in Texas placed on taking a deer. On average, those hunters were willing to pay about $25 to be assured of taking one deer and about $13 for an additional deer.

The second study (Loomis 1992) employed a habitat model to link the presence and number of forest roads to reduced elk populations. It then applied the model to estimate the expected decline in the probability of taking a six-point or larger bull elk that would be associated with logging in an undeveloped forest, applying the model to the 145,000-acre Hyalite-Porcupine Buffalo Horn Wilderness Study Area in the Gallatin National Forest in Montana. On average, hunters were willing to pay $108 per trip for the expected increased potential of taking a six-point or better elk associated with wilderness. Total estimated benefits to elk hunters from protecting the area as wilderness were more than $12.3 million (1978 dollars).

More than 18 million people fished in national forests in 1996. The economic value of this activity was between $1.4 and $2.9 billion (Moskowitz and Talberth 1998). Regionally, the national forests of the Southern Appalachians region contribute to excellent cold-water fish habitat, and the consumer surplus associated with fishing in those forests was estimated to be between $237 and $637 million in 1997 (Moskowitz and Talberth 1998). Another study of the Southern Appalachians region found that fishing opportunities in the region generated 3.3 million fishing days with related retail sales totaling $173 million in 1996 (Barnhill 1999). The total economic impact of recreational fishing in the six-state region was estimated at $407 million. Moskowitz and Talberth (1998) report that in Washington and Oregon where national forests contribute to the habitat of valuable salmonid species, commercial and recreational fishing generate more than $1 billion in income and support 60,000 jobs every year.

Undeveloped forestland contributes to the quality of streams for trout species that are particularly sensitive to changes in water quality and temperature. Loomis (1992) estimated expected trout populations and catch rates for two scenarios — wilderness designation and opening the area to logging — for the 145,000-acre Hyalite-Porcupine Buffalo Horn Wilderness Study Area in the Gallatin National Forest in Montana. The study used the travel cost approach to estimate the economic value of changes in trout fishing conditions associated with development. Wilderness protection generated recreational fishing benefits with a present value of $2.07 million (1978 dollars), for a total present value in added fishing benefits of $2.1 million over a 40-year planning period.

Table 6 summarizes estimates of recreational values associated with forest ecosystems.

Table 6. Recreation and Tourism Values of Forests

Study	Geographic scope of values	Basis for valuation	Value estimates
Entire United States			
Moskowitz and Talberth (1998)	All national forests	Economic impact of national forest recreation	$6.8 billion in 1993 and 139,000 jobs in 1996.
Dunkiel and Sugarman (1998)	All national forests	Contribution of national forest recreation to Gross Domestic Product	$110 billion annually
Moskowitz and Talberth (1998)	All national forests	Total economic value of fishing	$1.3 to $2.1billion in 1996
Moskowitz and Talberth (1998)	All national forests	Total economic value associated with fishing (method unknown)	$1.4 to $2.9 billion
Loomis and Richardson (2000)	42 million acres of roadless areas on national forests	Aggregate user day values for roadless area recreation Economic impact of roadless area recreation	$600 million annually $1.49 billion and 23,700 jobs.
Rocky Mountain region			
Loomis (1992)	Montana wilderness study areaa	Elk hunting value of wilderness protection (contingent valuation)	$108 / trip $12.3 million total
Loomis (1992)	Montana wilderness study areaa	Present value of recreational fishing benefits associated with protecting wilderness (travel cost)	$2.07 million in 1978 dollars
Walsh and Loomis (1989)	Colorado	Use value of wilderness protection (benefits transfer)	$14 / visitor day
Yuan and Christensen (1992); Power (1992)	Montana	Economic impact of wildlands influenced recreation	Total of $736 million in direct spending and 12,000 jobs.
Southeast region			
Walsh and Loomis (1989)	Virginia	Use value of wilderness protection (contingent valuation)	$12 / visitor day
Moskowitz and Talberth (1998)	Southern Appalachian region[b]	Expenditures on hunting equipment and trip expenses	$1.3 billion in 1988
Moskowitz and Talberth (1998)	Southern Appalachian region[b]	Consumers surplus of recreational fishing	$237 to $637 million in 1997
Barnhill (1999)	National forests of the Southern Appalachian region[b]	Economic impact of recreational fishing	$407 million
Barnhill (1999)	National forests of the Southern Appalachian region[b]	Total economic impact of hunting and wildlife viewing	$594 million and $407 million, respectively, in 1996
Barnhill (1999)	National forests of the Southern Appalachian region[b]	Economic impact of recreation on the national forests	$6 billion annually

Table 6. Recreation and Tourism Values of Forests *continued*

Study	Geographic scope of values	Basis for valuation	Value estimates
Northeast region			
Gilbert et al. (1992)	Lye Brook Wilderness, Vermont	Use value of wilderness preservation (contingent valuation)	$29 million total use value of eastern wilderness
	All eastern wilderness	Lye Brook area	Median willingness to pay of $9.04/household/year
		All eastern wilderness	Median willingness to pay of $10.42/household/year
Pacific Northwest region			
Moskowitz and Talberth (1998)	Federal lands in the Columbia River Basin	Total expenditures for hunting	$150 million
Moskowitz and Talberth (1998)	Pacific Northwest national forests	Economic impact of commercial and recreational fishing	$1 billion and 60,000 jobs annually
Southwest region			
Livengood (1983)	Texas	Value of taking a deer in hunting (hedonic travel cost)	$25 for one deer, $13 for second deer

a The Hyalite-Porcupine Buffalo Horn Wilderness Study Area in the Gallatin National Forest.

b The Southern Appalachian region consists of Alabama, Georgia, North Carolina, South Carolina, Tennessee and Virginia.

Non-Timber Commercial Forest Products

Forests produce many commercially valuable products besides timber. These include mushrooms, floral greens, medicinal and edible plants and wildlife resources. Oregon's Willamette National Forest produced $72 million in sales of the ornamental greens salal, huckleberry, sword fern and beargrass in 1991. More than 1.3 million pounds of seven medicinal plants were harvested from Missouri's national forests in 1993. Floral greens and holiday and evergreen boughs from national forests in Oregon and Washington generated sales of $128 million in 1989 and employed 10,000 people. The entire non-timber forest products industry associated with national forests in Oregon and Washington contributed about $300 million to the regional economy in 1992, with $41 million attributable to mushroom harvests (Moskowitz and Talberth 1998).

Forest ecosystems are critical components in maintaining viable habitat for salmonid species. In some regions, these fish have substantial commercial and recreational value and generate large local economic impacts. In southeastern Alaska in 1987, commercial harvest of five salmon species totaled more than 14 million fish with a market value of more than $71.8 million. The commercial fishing industry in the region directly employed 1,496 people in fishing in 1984 and, between 1981 and 1984, an average of 1,000 people annually in seafood processing (Glass and Muth 1992). As noted in the previous section, commercial and recreational fishing combined in the Pacific Northwest generate more than $1 billion in income and support 60,000 jobs annually (Moskowitz and Talberth 1998).

Forest products are also important for subsistence living in many regions. In southeastern Alaska, residents took 174,456 salmon in 1987 for subsistence purposes, which was an average of 143 pounds per household (Glass and Muth 1992). Muth and Glass (1989) found that households in that region consumed an average of 889 pounds of edible forest products annually, including 295 pounds of salmon and 118 pounds of venison. Based on market prices for commercially available meat and adjusted for protein content, the economic value of the salmon and venison to a household were $590 and $472, respectively.

In Crown Point, New York, the average household generated about $1,500 in gross value (based on market prices) from forest products every year, while the total value of products collected by the entire community was $910,780 (Muth and Glass 1989).

Cultural Values

The cultural values associated with forest ecosystems include their aesthetic value and the value people attach to knowledge that forests exist. They also include the values people attach to forests as habitat for endangered species that they may or may not ever see in the wild.

Aesthetic and Passive Use Values of Forests and Wilderness. Barnhill (1999) attributed a portion of the economic impact of tourism along the Blue Ridge Parkway to the scenic beauty of the adjacent forests. The study found that visitors spend $1.3 billion in North Carolina and Virginia counties contiguous to the Parkway, that these expenditures generate $98 million in tax revenues annually, and that visitor spending directly supports more than 26,500 jobs.

Holmes et al. (1997) used the hedonic travel cost approach to rank the importance of scenic characteristics of wilderness forests in the Southern Appalachian Highlands. The study concluded that large trees were an important scenic characteristic of forest landscapes. Two additional studies estimated willingness to pay for the density of large trees in forests and wilderness areas and associated tree density with forest quality. Walsh et al. (1990) in a contingent valuation study in Colorado asked respondents how much they would be willing to pay for a forest quality-protection program that would maintain stand densities at 125 to 175 trees per acre relative to zero to 50 trees per acre without the program. The average response was $47 per household per year. Statewide, this implies a present value of a forest quality program of $675.9 million, or $50 per acre. Recreation value accounted for $13 of the total value while option, existence and bequest values accounted for $10, $10 and $14, respectively.

In the other study, Haefele et al. (1992) used a contingent valuation survey of households within 500 miles of Asheville, North Carolina, to estimate use and non-use values for protecting forests in the Appalachian Mountains from further mortality. Respondents were willing to pay between $18 and $59 per year to protect the remaining undamaged forests along trails and roadways. They were willing to pay between $20 and $99 to protect all remaining high-quality forests. Existence values accounted for more than half of the total value of forest protection. Bequest values accounted for almost 30 percent, and use values accounted for about eight percent to 12 percent (Aldy et al. 1999).

Champ et al. (1977) designed a contingent valuation survey of Wisconsin residents elicit passive use values and found that respondents were willing to make actual cash donations to support a program to remove roads from the North Rim of the Grand Canyon and convert the area to wilderness. Aggregated to the entire population of Wisconsin, passive use values for the created wilderness totaled $7 million. Gilbert et al. (1992) also employed a contingent valuation study to ask how much respondents would pay to protect both the Lye Brook Wilderness in Vermont and all eastern wilderness. The study estimated passive use values associated with protecting eastern wilderness at more than $167 million annually aggregated over all households in the Northeast.

Four studies of passive use values for wilderness provide additional insight into this issue. Walsh et al. (1984) undertook a contingent valuation survey of Colorado residents and estimated passive use (option, existence and bequest) values associated with increasing the number of acres of wilderness in Colorado. On average, households attached a passive use value of $14 (1980 dollars) to the state's 1.2 million acres of designated wilderness, essentially equal to use values. Passive use values associated with protecting an additional 1.4 million acres, for a total of 2.6 million acres, were $19 per household per year. Passive use values for protecting 5.0 million and 10.0 million acres were $25 and $32 per household per year, respectively. Respondents also indicated they would be willing to pay $21 per year to protect 125 million acres of additional wilderness in other states.

A second contingent valuation study, cited by Walsh and Loomis (1989), applied the design of the Colorado study to Utah residents. Total values (use and passive use) associated with wilderness protection in Utah were $53 per year to protect 2.7 million acres of wilderness, $64 for 5.4 million acres, $75 for 8.1 million acres and $92 for 16.2 million acres. The study did not distinguish between use and passive use values.

The third contingent valuation study, cited by Walsh and Loomis (1989), elicited passive use values for the Washakie Wilderness Area (adjacent to Yellowstone National Park) from respondents in Wyoming. Wilderness users reported passive use values of $46 per household per year, while respondents in five cities at varying distance from the area reported passive use values of $9.70 (urban) and $8.40 (rural). The fourth study, also cited by Walsh and Loomis (1989), was a contingent valuation survey of visitors to the Ramseys Draft Wilderness Area in Virginia. That study reported a consumer surplus of $12 per day for use values and about as much for passive use values.

Loomis and Walsh (1992) in their contingent valuation study of willingness to pay for wilderness preservation in Colorado estimated current values and projected those values 30 years into the future based on changes in the demographic makeup of the population. Per household willingness to pay for protecting 5.0 million acres of wilderness rose from $25.30 in 1980 to $30.76 in 2010 (1980 dollars). When projected population increases were factored in, total preservation value rose from $28 to $49 million over the same time period.

Loomis and Richardson (2000) in their study of the economic benefits of roadless areas on national forest land used a benefits transfer approach to estimate passive use values associated with roadless areas. Based on contingent valuation estimates from previous research, the study applied passive use values of $6.72 and $4.16 per acre to western and eastern roadless areas, respectively. The study estimated passive use values of $274 million per year for roadless areas in the West and $6.24 million annually for roadless areas in the East. The total passive use value associated with protecting the 42 million acres of roadless area on the national forests was $280 million.

Endangered Species Habitat. One rationale for passive use values is that people attach a value to knowing that forests exist and provide habitat for wildlife species. Estimates of existence value for old-growth forests west of the Cascade Mountains range from $48 to $144 per U.S. household per year (Moskowitz and Talberth 1998).

Loomis and Ekstrand (1997) used contingent valuation to estimate the value of forest ecosystems as habitat for the threatened Mexican spotted owl, which lives primarily in the Four Corners region of Arizona, Colorado, New Mexico and Utah. The average respondent was willing to pay $40.49 annually to protect 4.6 million acres of old-growth forest habitat necessary for this species. The present existence value associated with protecting the owl's habitat was between $2.0 billion and $3.7 billion.

At least three contingent valuation studies have estimated the economic value of protecting old-growth forest ecosystems as habitat for the northern spotted owl. One concluded that the average Washington State household was willing to pay $34.84 per year to protect spotted owl habitat (Rubin et al. 1991). The analysis extrapolated the estimates to Oregon, California and the entire United States based on the assumption that willingness to pay declines by 10 percent for each 1000 miles of distance from the site. Corresponding willingness to pay estimates were $36.91 per household per year in Oregon, $20.88 per household per year in California and $15.21 per household per year in the rest of the country. The study estimated the total value of protecting spotted owl habitat at almost $1.5 billion per year.

A second study estimated average willingness to pay for a program to increase protection from fire for three million acres of old-growth forest set aside as habitat for the northern spotted owl in Oregon (Loomis et al. 1994). The average household in the sample was willing to pay just over $90 per year for the program. In the third study, Hagen et al. (1992) estimated that the average Oregon household was willing to pay $95 annually to protect old-growth forest habitat for the owl.

Howard (1997) estimated the opportunity cost associated with protecting old-growth forests as endangered species habitat for the northern spotted owl, pileated woodpecker and marbled murrelet in Washington State's Olympic National Forest. The study estimated the timber revenue that would be lost by shifting management priorities from logging to protection of old-growth stands. The study concluded that the difference in present value of timber was $17,411 per acre (calculated over a 200-year stand rotation and expressed in 1994 dollars) before logging costs were considered. This figure represents the present value of timber revenue that would be foregone to manage the forest primarily for old-growth habitat rather than for timber production.

Cultural Heritage Values. Forests can also contribute to quality of life through their role as part of an area's cultural heritage. A recent decision involving the conversion of forestland in Weston, Massachusetts illustrates the importance of cultural heritage as a source of value (Fausold 1999). To expand Boston's water supply infrastructure, the Massachusetts Water Resources Authority wanted to purchase a 36-acre parcel of forested conservation land, which had been owned by the town of Weston since 1974. While the fair market value of the parcel was $236,000, the water authority eventually had to pay the town $4.5 million to purchase a similar parcel. The magnitude of the difference between fair market value and the final settlement reflects, in part, the value attached to the cultural significance of a particular site.

Table 7 summarizes existing estimates of cultural values associated with forests.

Table 7. Summary of Cultural Values of Forests

Study	Geographic scope of values	Basis for valuation	Value estimates
Entire United States			
Loomis and Richardson (2000)	National forest roadless areas	Passive use values of roadless areas (contingent valuation)	$280 million annually (nationwide)
Southeast region			
Barnhill (1999)	Blue Ridge Parkway, North Carolina and Virginia	Economic impact of forest scenery	$1.3 billion in tourism expen-ditures, $98 million in annual tax revenues, 26,500 jobs.
Haefele et al. (1992) Aldy et al. (1999)	North Carolina	Use and passive use values of healthy forest (contingent valuation) (contingent valuation)	$18 to $99/ household/year total value (use and passive use)
Walsh and Loomis (1989)	Virginia	Use and passive use values for wilderness (contingent valuation)	$12/day use value, $12/day passive use value
Rocky Mountain region			
Walsh et al. (1990)	Colorado	Use and passive use values of healthy forest (contingent valuation)	$47/household/year: $13 (recreation), $10 (op-tion), $10 (existence), $14 (bequest)
Walsh and Loomis (1989)	Colorado	Use and passive use value of wilderness — 1.4 to 10 million acres (contingent valuation)	$14 to $32/household/year
Walsh and Loomis (1989)	Utah	Use and passive use value of wilderness — 2.7 to 16.2 million acres (contingent valuation)	$53 to $92/household/year
Walsh and Loomis (1989)	Colorado	Use and passive use value of wilderness (contingent valuation)	$25.30/household/year to protect 5 million acres; total preservation value of $28 million.
Walsh and Loomis (1989)	Wyoming	Passive use values for wilderness - 5 million acres (contingent valuation)	$8.40 to $46/household/year
Pacific Northwest region and California region			
Moskowitz and Talberth (1998)	Western states	Existence value for old-growth forest (contingent valuation)	$48 to $144/household/year
Rubin et al. (1991)	Oregon, Washington, California and United States	Value of habitat for endangered species protection (contingent valuation)	Total value of $1.5 billion/ year: $34.84/household/year (Washington), $36.91 (Oregon), $20.88 (California), $15.21 (United States)
Loomis et al. (1994)	Oregon	Value of protecting old-growth forest habitat for northern spotted owl (contingent valuation)	$90/household/year

Table 7. Summary of Cultural Values of Forests *continued*

Study	Geographic scope of values	Basis for valuation	Value estimates
Hagen et al. (1992)	Oregon	Value of protecting old-growth forest habitat for northern spotted owl (contingent valuation)	$95 / household / year
Howard (1997)	Washington	Opportunity cost of endangered species protection (contingent valuation)	$17,411 / acre
Northeast Region			
Gilbert et al. (1992)	Vermont and eastern states	Passive use value of eastern wilderness (contingent valuation)	$5.7 and $167 million for Vermont residents and all residents of the east, respectively
Fausold (1999)	Massachusetts	Replacement cost of public forest area	$4.5 million for 36 acres
Upper Midwest region			
Champ et al. (1977)	Wisconsin	Total passive use value of wilderness (contingent valuation)	$7 million (residents of Wisconsin)
Southwest region			
Loomis and Ekstrand (1997)	Arizona, Colorado, New Mexico, Utah	Value of protecting old-growth forest habitat for Mexican Spotted Owl (contingent valuation)	$40.49 / household / year
Moskowitz and Talberth (1998)	Southwest	Existence value of threatened species (contingent valuation)	$2.0 and $3.7 billion (nationwide)

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