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Defining an Economics Research Program to Describe and Evaluate Ecosystem Services

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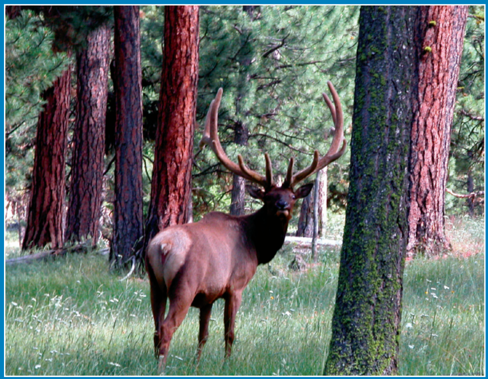


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Abstract

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Balancing society's multiple and sometimes competing objectives regarding forests calls for information describing the direct and indirect benefits resulting from forest policy and management, whether to address wildfire, loss of open space, unmanaged recreation, ecosystem restoration, or other objectives. The USDA Forest Service recently has proposed the concept of ecosystem services as a framework for (1) describing the many benefits provided by public and private forests, (2), evaluating the effects of policy and management decisions involving public and private forest lands, and (3) advocating the use of economic and market-based incentives to protect private forest lands from development. The concept extends traditional economic theory regarding multiple forest benefits and the use of economic incentives to enhance their provision, by emphasizing ecosystems as an organizing structure for benefits. Although the emphasis on ecosystems is new, challenges in evaluating ecosystem services are similar to those long faced by economists tasked with evaluating forest benefits: (1) defining a typology of ecosystem services, (2) describing and measuring ecosystem services units or outputs, and (3) describing and measuring ecosystem services per unit of values or social weights. Progress within the Forest Service in applying the ecosystem services concept to forest policy and management will depend on knowing what information will suffice, working across disciplines, deciding on appropriate analytical frameworks, defining the appropriate role of economic and market-based incentives, and adequately funding economics research.

Keywords: Public goods, nonmarket values, economic analysis, forests and society.

Introduction

Natural resource policy and management in the United States often are characterized by limited budgets and multiple, and sometimes competing, societal objectives. Our use and management of forest lands involve tradeoffs between the current and potential benefits public and private lands provide to society and the effects our policy and management actions have on the resiliency of natural systems (for example, Arrow and others 2000: 1401). However, translating society's multiple forestry objectives into policies and management actions has become more difficult as society's objectives have become more complex (Wear 2003). Public policies both guide the management of public forest lands and influence the management decisions of private forest landowners who control 57 percent of the total forest land base (Smith and others 2004). With limited budgets and demands for fiscal accountability, policymakers and managers often must describe economic rationales for their decisions to justify public expenditures and programs, weigh public preferences and support, and compare the benefits of different policy and management alternatives (King and Mazzotta 2005). Debates about natural resource management—what should be produced, how much, when, where, through what means, and at what cost—are fundamentally social in nature (Clark 2005: 42). Social acceptability of forest conditions and management practices depends in part on economic efficiency and equity (Shindler and others 2002:1). All of these demands have led to increasing interest among forest policymakers and managers for ways to describe, evaluate, and enhance both the direct and indirect benefits arising from public and private forest lands. Those interests increasingly center on the concept of ecosystem services.

Describing multiple forest benefits on public lands and using economic or market-based incentives to enhance their provision on private lands has long been the interest of economists working in forestry.

Ecosystem services are the products of functioning ecosystems that often are available without direct costs to people who benefit from them. They can include clean air and water, protection of water recharge areas and watersheds, detention of floodwaters, reduction of erosion and sedimentation, biotransformation of nutrients, production of topsoil, habitat for pollinators, and preservation of genetic diversity, among others (Science and Policy Working Group 2004). Early economic analyses of multiple-use forestry on public lands tended to focus on select beneficial forest outputs, such as timber, forage, water, recreation, and habitat for species of commercial or recreational interest (for example, Gregory 1955). The public increasingly expects these same benefits from private forest lands, although they sometimes are produced by private landowners only as byproducts of commercial activities such as timber production. Describing these multiple forest benefits on public lands and using economic or market-based incentives to enhance their provision on private lands has long been the interest of economists working in forestry. However, the shift toward ecosystem management in recent decades has increased interest among noneconomists in describing these benefits to advocate ecosystem protection (for example, Collins 2005). Ecosystem services provide a framework for outlining all of the attributes of ecosystems that benefit humans. The only real difference between the ecosystem services concept and economists' traditional conceptualization of multiple forest benefits is the emphasis on ecosystems as an organizing structure of benefits. This emerging interest among policymakers and managers adds to recent trends favoring complex landscape-level research that evaluates the combined policy and management effects on numerous ecosystem conditions and processes simultaneously.

The concept of ecosystem services initially was proposed as a way to describe the contributions of intact ecosystems to human well-being to advocate ecosystem protection (for example, Daily 1997). Recently, the USDA Forest Service has adopted the concept to serve three primary objectives: (1) better describing to Congress, Office of Management and Budget, and the public what the public receives from federally owned forests, (2) providing a comprehensive "forest benefits" framework for evaluating the effects of forest policy and management actions, and (3) providing forest benefits measures to aid in advocating and implementing economic and market-based incentives to protect private forest lands from development. Additionally, the ecosystem services concept can form the basis of empirical performance measures to meet national and global environmental objectives, such as the Kyoto Protocol outlining international commitments to reduce greenhouse gases.

The desire to describe and evaluate the benefits arising from federal forests, policies, and management actions is not new (for example, Bowes and Krutilla 1989, Peterson and Randall 1984, Peterson and others 1988), but unqualified success has remained elusive. Most forest benefits research in the past has tended to focus more on identifying and conceptualizing forest values rather than operationalizing and measuring them (Brown and Reed 2000). Measuring and evaluating multiple forest benefits has always been difficult owing to a general lack of information describing forest benefits outputs and their values. This continues to be true with the adoption of ecosystem services concept as a forest benefits framework. Two lessons learned in recent years about ecosystem valuation in particular are (1) it is easy to spend large amounts of money on valuation studies, and (2) it is easy for benefits information to be misused in ways that undermine public support for natural resource decisions (King and Mazzotta 2005). Still, policy and management decisions must be made, and the case for continued public ownership and management of land must be made as well. A charge of social and economics research is to produce methods and information for making sound policy and management decisions that appeal to the public's desires regarding the Nation's forests (Haynes 2005). Given the needs of policymakers and managers, this charge now must include devising ways to account for benefits associated with ecosystem services on public and private forest lands.

Public policy and management regarding public forest lands first and foremost must be fashioned in response to the desires and preferences of the Nation's citizenry regarding their perceptions of the multiple benefits that public forest lands provide. The management of private forest lands generally is influenced through state-level policies that regulate the forest management activities of private landowners. Meeting our strategic goals calls for comprehensive consideration of all socially valued ecosystem services on both public and private lands—what services are produced and where, how much they are valued by society, in what ways their production might be compatible or incompatible with one another or with other policy and management objectives, and how best to align private forest landowner behavior to augment the provision of services on public lands. This task does not necessarily mean that we will always have perfect and complete information regarding ecosystem services outputs, values, and how they change over time. Rather, it implies that we should be able to at least identify what information might be missing and try to understand its implications for pressing policy and management needs.

This paper provides an overview of public policy and management needs for information describing the benefits of public and private forest lands, highlighting the particular challenges involved in providing information using the ecosystem services concept to support public forest policy and management. The report is not a thorough review of forest benefits or ecosystem services research literature, which is something that may be wanting, nor is it a comprehensive review of valuation methods and issues, which can be found in other sources (for example, Champ and others 2003, Freeman 2003). Rather, this paper is a discussion of why ecosystem services information is needed, why it has not been rapidly forthcoming despite steady advances in benefits estimation methods in recent decades, and what researchers might do to address growing demand for it among policymakers and managers. The paper concludes by suggesting several potential areas for future ecosystem services research to support public forest policy and management in the Pacific Northwest region and the Nation.

The Federal Context of Forest Policy and Management

The ecosystem services concept is quite consistent with the Forest Service mission as it has evolved over time.

A direct federal role in ensuring adequate provision of forest benefits exists because many forest benefits are public goods—there generally is no way of excluding nonpaying beneficiaries (for example, Nicholson 1985: 706-709). This is true as well for an ecosystem services framework for describing forest benefits—that is, many ecosystem services also are public goods. Examples of ecosystem services that are typically thought of as public goods include scenery, wildlife, clean air, and water, among others. The goal of ensuring sufficient national supplies of timber can also be a public good if considered in a national security context. Because beneficiaries of public goods generally cannot be excluded from receiving benefits, beneficiaries have little or no incentive to pay for their enjoyment of ecosystem services. Private forest landowners receive no compensation for providing them. These circumstances can lead to situations where fewer ecosystem services might be produced than are desired by society. To avoid their underproduction, governments generally take on the responsibility for producing public goods on behalf of society with public financing through taxation. In the case of ecosystem services, this government role justifiably is manifested through our system of public-owned national, state, and community forests. A secondary government role could include encouraging the provision of ecosystem services on private lands through policies and programs that provide appropriate incentives to private landowners to provide them. The Forest Service's Forest Legacy Program is an example of such an effort.

As an organizing principle for Forest Service work, the ecosystem services concept is quite consistent with the agency's mission as it has evolved over time. Gifford Pinchot—first Chief of the Forest Service—described that mission as providing the greatest amount of good for the greatest amount of people in the long run (Pinchot and others 1998: 261). Although that original mission focused on protecting timber and water resources, the Forest Service emerged from World War II as a primary supplier of natural resource commodities, including timber as well as rangeland for grazing livestock (USDA FS 2005). Socioeconomic changes, coupled with new legislation passed during the 1960s, 1970s, and 1980s, eventually broadened the range of agency activities and objectives to consider other benefits, including recreation and ecological health among others (Apple 2000). Because many forest benefits are produced at landscape-level scales, effective government provision often must include considering ways in which private forest lands augment public lands in providing benefits. If necessary, this may include inducing private owners to pursue management activities that complement those conducted on public-owned lands through economic and other incentives. For this reason, the Forest Service now advocates strategies for managing forest lands cooperatively across public and private ownerships (for example, Haynes and others 1996, USDA FS 2006a).

As a Forest Service mission, providing multiple benefits to people receives broad public support (Shields and others 2002). As an organizing principle for agency work, the ecosystem services concept provides a convenient link between acknowledging the multiple benefits provided by forests and managing ecosystems. Indeed, within its stated current mission—sustaining the health, diversity, and productivity of the Nation's forests and grasslands for present and future generations—the Forest Service's strategic plan identifies several specific goals, including reducing wildfire risk, reducing invasive species, providing outdoor recreation, providing energy, and improving watersheds (USDA FS 2004). Although the way the mission is described evolves, the overarching goal of providing a "greatest good" remains. However, it implies a particular challenge: How to provide the public with their preferred range of forest uses and benefits in a sustainable manner and at a reasonable cost.

Given a fixed resource base, limited funding, and shifting demands for ecosystem services, the Forest Service mission implies a need to make tradeoffs among multiple and sometimes competing objectives. This process typically occurs through national forest planning, but it also occurs through court cases involving legal challenges to specific policy and management decisions. Translating multiple objectives into policies and management activities is complicated by several factors: (1) many public forest uses can be incompatible with each other (for example, intensive timber production and retaining large trees or uneven-aged stands), (2) policy and management decisions can have significant local socioeconomic effects, especially in Western States, (3) natural resource tradeoffs often must be made with imperfect information regarding resource benefits and values, (4) forest production responses to management often are uncertain or unknown, and (5) forest system complexity creates numerous possible alternatives (Wear 2003: 206). Policymakers and managers also must consider private forest lands as complements to public lands in providing many ecosystem services, and how particular policies designed to influence private forest owner behavior mesh with public lands management. These factors highlight the importance of defining sets of benefits that are appropriate and feasible to produce from the Nation's forests based on society's preferences and values, and existing landscape endowments.

Socioeconomic factors complicate fulfilling the Forest Service mission (for example, USDA FS 2002). United States population growth coupled with rising incomes conceivably increases demands for many ecosystem services—forest and other natural resource commodities, fresh water, and outdoor recreation opportunities, for example—while reducing the land area on which services are produced. Population growth increases demands for housing and other infrastructure, resulting in loss of forest land to development. Rising economic status and a quest for environmental amenities prompts migration of people to rural areas (Cordell and others 2004). Nationally, developed lands increased by 34 percent from 1992 to 1997 and may double by 2025 (Alig and others 2004). Increasing fragmentation of forest land can result in declines in habitat and uncertain changes in the way remaining forest lands are managed (Kline and others 2004b). Population growth and resulting declines in open space also mean that remaining forest lands and the ecosystem services they produce are shared among more and more people. From 1982 to 1997, undeveloped land per capita declined by 15 percent from 8.1 acres to 6.9 acres per person, with greater reductions in the fastest growing regions (USDA NRCS 2001, USDC Bureau of the Census 2000). United States residents are placing ever greater demands on an ever-declining forest land base, for water, recreation, and environmental amenities (Kline and others 2004a).

At the same time, federal forest policymakers and managers must answer calls for fiscal accountability (for example, Office of Management and Budget 1996). Two persistent challenges faced by the Forest Service recently have been describing and defending the expected economic benefits resulting from ecosystem restoration and wildfire management activities. Many of the values represented in current wildfire policy and management decisionmaking processes—the Wildland Fire Situation Analysis decision-support tool, for example—are highly subjective (MacGregor and Haynes 2005). Research is needed to develop decision frameworks that provide a stronger and more consistent basis for justifying policy and management activities based on the benefits and costs expected to result from them. Any forest policy or management path we choose defines a particular ecological trajectory characterized by a flow of goods and services accruing from the natural capital inherent in healthy ecosystems (for example, Science and Policy Working Group 2002, 2004). Ecosystem management decisions ultimately are economic decisions, whereby society evaluates the utility of different management alternatives, including inaction (Weigand and Haynes 1996). Deciding on one policy or management path necessarily carries costs associated with foregone opportunities.

Evaluating the multiple benefits provided by public and private forest lands enables policymakers and managers to better pursue forest policy and management that is socially and politically acceptable, broaden public interest and representation in decisionmaking, and reduce potential conflict and resistance to management decisions by responding to diverse and changing public views and opinions (Tarrant and others 2003). Forest stakeholders increasingly are presenting their own analyses of forest benefits produced on the Nation's forests (for example, Niemi and FiField 2000). Forest Service economics research regarding ecosystem services can build upon and augment past and present forest benefits research by agency researchers and others (for example, Bowes and Krutilla 1989, Champ and others 2003, Peterson and Randall 1984, Peterson and others 1988) to help foster trust among the public that the agency also is acting on its strategic goals in an earnest and methodical manner.

Ecosystem Services Typologies, Outputs, and Values

From an economic perspective, intelligent ecosystem policy and management requires quantifying the costs and benefits of and evaluating tradeoffs associated with different policy and management alternatives (for example, Arrow and others 2000: 1401). Although the financial costs of proposed policy and management actions—the costs of labor, equipment, and other resources expended—often can be readily estimated, describing expected changes in forest benefits can be difficult, particularly when they arise from changes in forest ecosystem processes. Forest benefits derive from socially valued outputs of ecosystem services produced from the characteristics and conditions of forest landscapes. Evaluating the effects of forest policy and management on forest benefits requires information about resulting changes in ecosystem services outputs and their values to society. Toward this end, the primary challenges in applying the ecosystem services concept are (1) defining a typology of ecosystem services, (2) describing and measuring ecosystem services units or outputs linked to policy and management actions, and (3) describing and measuring ecosystem services per unit of values or societal weights. These challenges essentially are the same as those long faced by economists tasked with describing the multiple benefits arising from public and private forests: What is to be valued, how do you measure it, and what is its value to society?

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Ecosystem Services Typologies

Well-designed typologies summarize ecosystem services as sets of well-defined attributes that can be measured. From an economic perspective, a typology should identify those end ecosystem services that directly benefit people. End services are the specific ecosystem attributes that enter peoples' utility functions to produce satisfaction or well-being, or enter production functions to produce goods and services that are valued in the marketplace. End services differ from intermediate services—those services that are instrumental in the production of other services, such as the role of riparian habitat in the production of fish, for example. End

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services also differ from benefits. End services—a fish population, for example—when combined with other market goods, such as fishing tackle, produce benefits such as recreational angling (Boyd 2006, Boyd and Banzhaf 2006). Of particular concern to economists is that ecosystem services typologies identify unambiguous measurable attributes of ecosystems that benefit people. This concern arises in part from economists' long tradition of cost-benefit analysis where avoidance of double counting costs and benefits is of utmost importance. Some economists also suggest that analyses must focus on ecosystem attributes rather than on ecosystem functions or processes; processes and functions, they suggest, are not end services directly enjoyed by people but rather are the biological, chemical, and physical interactions between ecosystem attributes (for example, Boyd 2006, Boyd and Banzhaf 2006). Resolving such issues, although of concern to economists, are not always of concern to others.

One early typology of ecosystem services suggested by Daily (1997) specifically highlighted beneficial ecosystem functions and processes—mitigation of floods and droughts, detoxification and decomposition of wastes, generation and renewal of soil fertility, and pollination of crops and natural vegetation, for example (p. 3-4). Daily's focus on functions and processes makes sense from an ecological perspective; ecosystem functions and processes are what ecologists most often study. Other services listed by Daily (1997) were more vaguely defined—support for diverse human cultures and providing intellectual stimulation, for example. Although useful as a way to inspire thinking about the many ways in which people benefit from functioning ecosystems—arguably Daily's primary intent—Daily's typology is not all that useful for identifying unambiguous measurable ecosystem attributes that benefit people (Boyd and Banzhaf 2006). How do you measure intellectual stimulation, for example? For this reason, Daily's typology is not particularly useful as an organizing structure for ecosystem services measurement and evaluation.

Another ecosystem services typology is from the Millennium Ecosystem Assessment (2005). This particular typology is featured on the initial Forest Service Web site devoted to ecosystem services (USDA FS 2006b). The Millennium Ecosystem Assessment typology defines four general categories of ecosystem services: provisioning, regulating, cultural, and supporting (table 1), providing several examples within each category. As a rally point for advocating ecosystem protection, the typology works by providing a detailed and extensive list of general ways in which ecosystems benefit people. However, as an organizing framework for ecosystem services measurement and evaluation, this typology too has problems (for example, Boyd and Banzhaf 2006). As with Daily's (1997) typology, the Millennium Ecosystem Assessment typology includes items that are ecosystem

Table 1—Example ecosystem services typology from the Millennium Ecosystem Assessment (2005)

General service category	Example services
Provisioning	Food, fiber, fuel, genetic resources, fresh water, biochemicals, ornamental resources.
Regulating	Air quality regulation, climate regulation, erosion regulation, water purification, natural hazard mitigation, pollination.
Cultural	Cultural diversity, spiritual/religious values, knowledge systems, educational values, inspiration, aesthetic values, recreation.
Supporting	Soil formation, photosynthesis, primary production, nutrient cycling, water cycling.

functions or processes—water purification, for example. There also is potential for double counting—the value of pollination, for example, arguably would be already included in the values of food and fiber produced. Lastly, many items listed again are too poorly defined to facilitate measurement. How do you measure inspiration, for example?

One final typology of interest within the Forest Service is that proposed by Brown and others (in press). Their typology attempts to both acknowledge and distinguish between processes similar to those of Daily (1997)—what they call “ecosystem services”—and beneficial attributes—what they call “ecosystem goods” (p. 36). Brown and others (in press) qualify their typology by including only “naturally occurring services”—those that exist without human action, such as agricultural products. In this way, they would seem to distinguish between ecosystem services and human benefits (Boyd 2006, Boyd and Banzhaf 2006). However, Brown and others’ (in press) mingling of ecosystem attributes and processes may not go as far as others (for example, Boyd and Banzhaf 2006) in defining ecosystem services in terms of unambiguous and measurable ecosystem attributes. Arguably, however, this was not their intent. Rather, Brown and others (in press) sought to describe and delineate, in a general way and from an economic perspective, what ecosystem services are and how ecologists and economists might evaluate them. As such, their typology, like those of Daily (1997) and Millennium Ecosystem Assessment (2005), is motivated by specific informational needs that may not always include unambiguous empirical analysis. In contrast, for example, Boyd and Banzhaf (2006) are specifically concerned with developing a “green” gross domestic product (GDP) metric as an environmental counterweight to prevailing GDP, and this objective motivates their strong concerns regarding definitional issues.

Other typologies have been proposed (for example, DeGroot and others 2002), but these suffice to demonstrate the challenges involved in identifying what is to be measured and how to measure it when attempting to describe and evaluate ecosystem services. At issue is the fact that ecosystems are highly nonlinear complex adaptive systems, with extensive interconnections among components; they have potential for dramatic change resulting from endogenous and exogenous factors (Arrow and others 2000: 1401). Translating ecosystem complexity into manageable sets of well-defined ecosystem services metrics—simply defining what to measure and how to measure it—is the first challenge faced in ecosystem services research. Linking those metrics to forest policy and management actions, disturbances (for example, fire, forest-land development), and other factors whose effects forest policymakers and managers would like researchers to examine, is another challenge altogether. In evaluating forest benefits, economists generally have focused on estimating values for specific benefits. They largely have sought information from ecologists and other biophysical scientists that describes ecosystem attributes and how they change over time in response to forest policy and management actions—what many economists sometimes call ecosystem "production functions." Although both types of information are useful in evaluating ecosystem services, those production relationships are absolutely critical but all too frequently lacking or missing altogether.

Ecosystem Services Outputs

Evaluating the ecosystem services effects resulting from forest policy or management activities, or disturbances such as fire or forest-land development, involves compiling output and value measures describing all affected services produced over time under different combinations of resulting forest conditions. For example, if evaluating the wisdom of conducting a postfire restoration action or implementing an incentive program to reduce forest-land development, economists need to know how that action or program will affect ecosystem services production over time relative to doing nothing. Describing such changes often is not possible in practice owing to a general lack of information describing relationships between ecosystem services outputs, forest conditions, and policy and management activities. Ecologists and others have been making progress in describing such relationships (for example, DeStefano and Haight 2002, Guisan and Zimmermann 2000). However, output measures that may exist for one landscape may not be transferable to other landscapes possessing different characteristics. When such measures are available they often do not support evaluating potential policy and management effects, because they may not be based on data or scales relevant to analyzing those effects.

For economists to evaluate tradeoffs among different ecosystem services, they need to express each service output as a function of others.

A problem is that forest ecosystems involve numerous natural processes that are not always fully understood by both economist and noneconomist scientists. Formal bioeconomic models describing these processes, such as TAMM/ATLAS (Adams and Haynes 1996, Mills and Kincaid 1992), often do not exist or are valid only for specific regions or landscapes. Economists generally have had difficulty understanding the complex physical interrelationships of ecosystems and linking their different parts (Bockstael and others 2000: 1384). Among even biophysical scientists, significant uncertainty can exist regarding ecosystems and their functions, and how they change in response to policy and management actions. For economists to evaluate tradeoffs among different ecosystem services, they need to express each service output as a function of others. Defining such interrelationships among ecosystem outputs typically is not the goal of many ecology studies, which tend to focus on how policy and management actions impact single or select groups of species. Much ecology research also is conducted at landscape or finer spatial scales that are not typical of or sometimes even feasible in most economics research. This spatial focus is not consistent with the often temporal focus on economic analysis. Inconsistency between ecology and economic conceptual framing, data, and the units and scales at which analysis is accomplished can be a significant obstacle for ecologists and economists to overcome.

As a result, ecologists have not been forthcoming with the types of ecosystem output measures economists typically desire or expect for formal economic analysis. Because ecology is not particularly well suited to prediction, production relationships may be highly or purely uncertain (Swallow 1996: 85). Ecosystem complexity, including the spatial and temporal dimensions of policy and management effects, coupled with the sheer number of potentially relevant ecosystem outputs to be evaluated makes the task all the more daunting. Add to this the uncertainties posed by one particular issue of significant contemporary interest—wildfire—and the challenges increase (for example, Kline 2004). The general lack of information describing ecosystem services outputs and their sensitivity to changes in forest policy and management actions is perhaps the most significant obstacle to evaluating ecosystem services benefits. Because of this, many ecosystem services analysts suggest that increased research effort first and foremost must focus on defining the units and production relationships associated with ecosystem services, with their valuation as a secondary focus (for example, Boyd 2006).

Ecosystem Services Values

In forestry, economic values typically refer to the instrumental values arising from the role of forest benefits in satisfying human needs and wants or increasing the welfare of human individuals as members of society (for example, Freeman 2003: 6). The concept of instrumental value differs philosophically from the idea that many forest benefits—ecosystem function, for example—may have intrinsic values that are independent of their uses or functions in relation to something or someone else, but rather are valuable in and for themselves (Freeman 2003: 6-7). Although appealing as an argument for recognizing the worth of all things, intrinsic value is not a very useful concept in evaluating changes in economic benefits values resulting from forest policy and management alternatives. Economics is the study of how societies organize themselves to provide for the sustenance and well-being of their members. Thus, economic values of ecosystem services and functions arise from their contributions to human well-being (Freeman 2003: 6-9). Evaluating forest policy and management effects on forest benefits, from an economic perspective, means examining the ways in which resulting changes in forest benefits affect human welfare.

Prevailing opinion among economists is that well-designed studies following accepted protocols will result in useful information about values of nonmarket forest benefits.

This economic notion of value is just one perspective of value found in ecosystem services research literature—other perspectives exist including sociocultural, ecological, biological, and biophysical, for example (Costanza 2004, Farber and others 2002) (table 2). Sociocultural value perspectives focus on the distribution of ecosystem services among members of society. An ecological value perspective measures value as the degree to which ecosystem services contribute to ecological objectives or conditions, such as healthy ecosystem function. Similarly, a biological value perspective measures the value of ecosystem services by their contributions to meeting biological objectives, such as the survival of individual species. A biophysical value perspective defines value in terms of direct and indirect inputs and outputs of mass and energy among ecosystem components. Although each of these noneconomic value perspectives may have merit, my focus in this paper is on economic value.

Natural resource valuation methods at times have involved varying levels of controversy, but associated scientific debate generally has led to significant refinements in method. Prevailing opinion now among most economists is that well-designed studies following generally accepted protocols outlined in published literature generally will result in useful information regarding the values of nonmarket forest benefits such as those arising from ecosystem services. Guidelines for evaluating environmental benefits are now even outlined by federal agencies (for example, Environmental Protection Agency 2000, Office of Management and Budget 1996).

In forestry, the multiple-use mandate of public forests combined with early development of nonmarket benefit valuation methods stimulated significant interest

Table 2—Example perspectives on ecosystem services values

Variable	Description
Economic	Value arises from presence of ecosystem service in utility function, either directly, or indirectly as inputs in the production of final goods and services.
Sociocultural	Concerned with sociocultural implications of resource allocation or use, such as equity.
Ecological	Value arises from degree to which service contributes to ecological objective or ecosystem condition.
Biological	Value arises from degree to which service contributes to the survival of individual species.
Biophysical	Value arises from direct and indirect inputs and outputs of mass and energy among ecosystem components.

Note: Adapted from Costanza (2004) and Farber and others (2002), among other sources.

in how to value wildland resource and amenity benefits arising from forests (for example, Bowes and Krutilla 1989, Peterson and Randall 1984, Peterson and others 1988). Today there are generally accepted protocols for measuring forest benefits values and for transferring values to different locations (for example, Desvousges and others 1992, Loomis 2005, Rosenberger and Loomis 2001). Still, forest benefits valuation can be a tricky and expensive enterprise. Although values for some outputs, such as timber, can be estimated from market prices, values for other outputs, such as recreation, may involve nonmarket values that can only be estimated by using specialized survey methods, such as travel cost and contingent valuation (for example, Champ and others 2003). These methods can be expensive and require specialized expertise to implement. Such demands often place benefits valuation beyond the reach of public agencies for routine policy and management decisions. Also, relative values for different ecosystem services almost certainly change over time. Unless existing inventories of measured values (for example, Loomis 2005, Rosenberger and Loomis 2001) are routinely updated by using new studies, they eventually become inaccurate.

Estimating values for ecosystem services that people are more familiar with, such as recreation, generally is considered easier than estimating values for services with which people may be less familiar, such as biodiversity. Linking technical ecological measures of habitat quality or biodiversity, for example, to attributes that can be understood and perceived as valuable by the public remains difficult (Schaberg and others 1999: 337). Also, values for some ecosystem services may include combinations of use and nonuse values, further complicating estimation of their values. Use values are values that people hold for specific uses of ecosystem services and may include consumptive uses, such as timber harvesting, and nonconsumptive uses such as sightseeing (for example, Freeman 2003: 140-142). Nonuse values on the other hand do not involve direct use of ecosystem services. According to conventional value typology, nonuse values may include option (knowing a resource will be available for future personal use), existence (knowing a resource exists even when the likelihood of using it is small), bequest (knowing future generations will be able to enjoy the resource), and stewardship (knowing forests are maintained in a healthy condition) values (for example, Freeman 2003: 137-159). These types of values can be more difficult for people to comprehend and evaluate. Evaluating changes in nonuse values associated with policy and management actions thus tends to be more complex and attracts more controversy than evaluating use values.

Indeed, some people object to monetary valuation of ecosystem services altogether or question the merit in doing so. Some people object to economists' anthropocentric or utilitarian treatment of natural systems, which may be inconsistent with how some people believe ecosystem management decisions should be made (for example, Bengston and Xu 1995, Mazzotta and Kline 1995). Some people may feel that monetary valuation of ecosystem services is inadequate to address their appropriate management if they believe that human values cannot be reduced to a single measure or that natural resource values transcend human-determined values. People may view particular resources as morally considerable (Booth 1992), believing that nature has a right to exist in its own right. Indeed, even some scientists object to valuing ecosystem services based on their instrument values to people or may feel that such information is irrelevant to questions of ecosystem management and protection (for example, Brown and Ulgiati 1999). To some extent this is why different value perspectives exist in ecosystem services research literature. Although the reasonableness of such views can be debated, their practical effect is to complicate the study and measure of values for a broad range of ecosystem services.

Some economists also warn that deriving hypothetical values for the complex and inter-related parts of the environment and reducing them to a single monetary measure can result in a significant loss of information (for example, Vatn and Bromley 1995: 3). Ecosystems respond to policy and management changes through numerous physical, biological, and chemical feedbacks and cycles, which are central to the processes that link species to each other and to their respective habitats (Bockstael and others 2000: 1387). Evaluating the component parts of ecosystem services, such as habitat for particular fish, habitat for particular animals, or particularly large or old trees, may be subordinate to the continued functioning of the sum of the parts (Vatn and Bromley 1995: 11). Such views question the merit of evaluating tradeoffs among particular ecosystem parts when different parts rely on the existence and health of other parts. Estimating values or changes in values for each part and then summing them to estimate total ecosystem value also can be meaningless, because the functional value of each part can be as valuable as the whole, given that the whole could not exist without each part. Even if accurate, total ecosystem values provide little guidance to policy or management decisions unless those decisions can be expressed as marginal or incremental changes in ecosystem services (Pagiola and others 2004: 18-19). This requires information describing marginal or incremental changes in ecological services outputs, which often is not available from ecologists.

Limitations in measuring nonmarket benefits have led to the use of nonmonetary indicators describing ecosystem benefits. Ecosystem indicators are objective, quantitative measures of factors that give rise to ecosystem services. For example, you might use a habitat suitability index to "indicate" the potential prevalence of a particular species when you do not know the actual population of the species or its value to the public. They are both biophysical and economic in nature, are organized around environmental and economic principles, and provide an alternative to dollar values for describing ecosystem benefits (Boyd 2004). Ecosystem indicators can be used to represent many of the complex relationships among habitats, species, land uses, and human activities to facilitate public policy and management decisions that acknowledge these factors. Indicators also can form the basis of ecological indices similar to gross domestic product (for example, Boyd and Banzhaf 2006). Ecological benefits indicators are appealing for their affordability and ease of use relative to valuation, and have gained acceptance among many academic researchers and policy analysts as one way to address the need for quantitative measures of ecosystem outputs (for example, Boyd and Wainger 2002, Johnston and others 2002, King and Mazzota 2005). Although avoiding value estimation is an advantage, it also is a key weakness. Lack of a common metric of value or social preference, such as dollars, makes it difficult to determine what mix of outcomes might be preferred (Boyd and Wainger 2002). Some type of indicator weighting scheme, such as multiattribute utility analysis, still must be applied to evaluate tradeoffs among indicators.

Other Considerations

One failing of many economists is that they often do not address equity issues related to who does or does not gain from policy and management actions. All taxpayers bear the financial costs of implementing government policies and management actions affecting public and private lands. Those who gain might include neighboring property owners who benefit from increased aesthetics and proximity to outdoor recreation, and individuals who use or value particular forest benefits. Policies and management can affect the welfare of individuals differently because individuals typically bear unequal tax burdens associated with them and reap unequal net gains or net losses from resulting changes in forest benefits. By focusing on the net social effects of proposed policies or management actions, economic (for example, cost-benefit) analyses can support outcomes that are socially suboptimal (for example, Just and others 1982: 334-335). Opportunities that maximize social welfare may be overlooked or not considered. Social welfare considerations must focus on choosing the best policies or management actions to pursue rather than deciding whether or not to pursue a specific alternative (Just and others 1982: 335). Although difficulties exist in evaluating social welfare (Broadway and Bruce 1993: 137-138, Just and others 1982: 42-45), welfare economics can provide help in evaluating policies and management actions by describing their efficiency and distributional implications (Broadway and Bruce 1993, Just and others 1982).

Social welfare considerations must focus on choosing policies or management actions to pursue rather than deciding whether or not to pursue a specific alternative.

Related to social welfare issues are additional concerns about environmental justice. Generally, environmental justice is about relationships between race, poverty, and environmental problems, benefits, and remediation (for example, Albrecht 1995, Floyd and Johnson 2002). Environmental justice is relevant to evaluating forest benefits if policies and management actions might result in widely disproportionate distributions of benefits accruing to select groups of people or to the detriment of others. If, for example, political pressure from relatively affluent landowners living adjacent to national forests results in a disproportionate amount of public funds being allocated to manage nearby lands for a particular recreational activity, less affluent people who do not live adjacent to forests may feel that their own management preferences are underrepresented. Critics of environmental justice suggest that it is a reasonable concept for which strong empirical evidence is lacking (for example, Bowen 2002). In the context of ecosystem services produced on public and private forest lands, although all citizens may have individual preferences regarding different services, there is the potential for some citizens to benefit from specific policies and management actions more than others. To some extent, such concerns form the basis of sociocultural perspectives of ecosystem services values.

Relevance of Past Forest Benefits Research to Ecosystem Services

Three influential research papers written about forest benefits in the context of multiple-use forestry—Gregory (1955), Hartman (1976), and Swallow and others (1990)—help to characterize the relevance and appropriate role of forest benefits in forest policy and management (Sedjo 2003). Along with general economic theory of multiple-use forestry (for example, Bowes and Krutilla 1989), these works characterize economic thinking regarding multiple forest benefits and remain relevant to conceptualizing economics research regarding ecosystem services.

Gregory (1955) applied traditional production economics theory to forestry to develop a conceptual framework that defines multiple-use forest management as a problem of joint production of multiple outputs that benefit people. Joint production defines forests in terms of their production possibilities—combinations of different output levels that are possible to produce on a given landscape given existing resource endowments, inputs (for example, land, labor, and capital), policies, and management. Establishing benefit ranges that are feasible on a given landscape is necessary to evaluate the reasonableness of landscape objectives, and identify policy and management strategies to achieve them. Gregory (1955) formed the foundation of contemporary economics research regarding multiple forest benefits (for example, Calkin and others 2002, Rohweder and others 2000). In Gregory's conceptual framework, ecosystem services would be beneficial forest outputs. His joint production framework thus provides a formal method for examining tradeoffs among different ecosystem services and defines the information needs that tradeoff analyses require. That required information includes (1) information regarding the production of ecosystem services of interest and (2) information regarding the relative values or social weights of those services consistent with public preferences.

Hartman (1976) showed that the presence of recreational or other "nontimber services" provided by standing forests will tend to delay the utility-maximizing rotation age when those services are an increasing function of stand age or volume. For example, if forest owners derive utility (personal benefit or satisfaction) from the aesthetic characteristics of standing large trees as well as from harvesting timber, they may have an incentive to delay harvest beyond the utility-maximizing rotation age that would hold if owners' utility were derived from timber harvesting alone (for example, Bowes and Krutilla 1989: 106-107). Hartman (1976) inspired numerous papers examining the influences of forest amenity effects on optimal rotation age (for example, Binkley 1981; Bowes and others 1984; Dennis 1989, 1990; Englin and Klan 1990; Hyberg and Holthausen 1989; Max and Lehman 1988; Strang 1983; Swallow and Wear 1993; Tahvonen 1999). Their relevance for forest policy and management is that maximization of timber value as an overarching forestry objective is not solely appropriate in understanding private forest owners' behavior regarding harvest, because many private owners are motivated by nontimber objectives (for example, Kline and others 2000a, 2000b; Kuuluvainen and others 1996). Given the multiple objectives motivating society's interest in public lands management, Hartman (1976) also showed that from an economic perspective, public forest managers may be justified in delaying harvest or not harvesting at all when significant nontimber values are present.

What Hartman (1976) called nontimber services translate well as a subset of ecosystem services—recreation opportunities and forest scenery, for example—that benefits forest owners, be they private individuals or the public. The potential for enhancing the provision of these services influences the forest owners' choices about what to produce. A key limitation of Hartman's analysis, however, derives from the assumption that nontimber services increase as a positive function of stand age or timber volume, placing timber production in direct competition with recreation or aesthetic potential. This assumption oversimplifies the role of forest and stand characteristics in providing many ecosystem services. The habitat needs of some wildlife species, for example, may favor younger forests or even open patches. In reality, the individual species present on any given forest landscape change over time as species respond to the stand age, volume, canopy closure, and other site characteristics (for example, Calish and others 1978, Giles 1978). Thus the relationship between stand age or timber volume to the provision of ecosystem services is not always positive nor is it the only factor determining what services are produced at a given location and point in time.

Building upon Hartman (1976) is work by Swallow and others (1990). They showed that variations in the responses of individual timber and nontimber services to stand age and volume can confuse determining an optimal forest rotation age. This confusion occurs especially when nontimber benefits peak well before the optimal timber-producing rotation age and when nontimber benefits are at least as great as timber benefits, potentially leading to premature harvest. As such, Swallow and others (1990) and papers that build upon it (for example, Boscolo and Vincent 2003, Pattanayak and Butry 2003, Swallow and Wear 1993, Swallow and others 1997) began to acknowledge the spatial and temporal complexity involved in managing forests to produce multiple benefits. The ecosystem services produced at a given location can increase or decrease over time depending on stand ages, timber volumes, and other stand and landscape characteristics.

Developing better information regarding ecosystem services depends on economists and ecologists working together.

There are other important economics papers in forestry, but these three serve to illustrate two points regarding the state of conceptual thinking regarding multiple forest benefits and its applicability now to ecosystem services: (1) economists have been thinking about benefits in the context of forestry for a long time and this thinking remains relevant if benefits are now framed as accruing from ecosystem services and (2) economists have well-defined conceptual frameworks for incorporating multiple benefits arising from ecosystem services into analysis of forest policy and management issues. Why then have forest benefits not been more routinely incorporated into the analysis and development of forest policy and management? The reason involves persistent difficulties in the practical application of economics theory regarding multiple-use forestry to real world problems. Those difficulties include (1) a general lack of information describing benefit outputs and their relationship to forest conditions, processes, policies, and management actions and (2) a general lack of information describing the relative values or social weights of different benefits consistent with public preferences regarding forests. Indeed, Gregory (1955) noted these difficulties half a century ago: the principal obstacles to solving joint production problems in forestry are describing forest benefit production functions as returns to management and obtaining values for nonmarket forest benefits (p. 13). As noted before, these challenges remain even with an ecosystem services framing of forest benefits.

Developing better information regarding the production of ecosystem services depends on economists and others—most notably ecologists—working together to address the development of ecosystem services output measures and their responses to policy and management. Economists generally already know how to gather information regarding relative values or social weights of different forest benefits (for example, Champ and others 2003, Freeman 2003, Johnston and others 1999), but such information still can be expensive to gather and frequently pertains to specific sites or situations. Additionally, Forest Service researchers face obstacles in collecting value data; they must seek approval for any survey-based research from the Office of Management and Budget for compliance with the Paperwork Reduction Act of 1995. This can lengthen study times considerably. The costs of obtaining production and value information regarding the ecosystem services produced on forest landscapes and affected by policy and management can be prohibitively expensive. Barring significant new ecological and economics research investment, we may simply never have complete information about ecosystem services benefits and their responses to policy and management in many cases.

Multidisciplinary research into landscape-level policy and management questions are seldom conceptualized as economic or joint production problems.

Evaluating Policy and Management Alternatives

To date, economics has tended to play a fairly limited role in research focused on evaluating the ecological effects of forest policy and management—limited to predicting potential future forest-land development (Kline and others 2003) or timber commodity outputs under different policy and management scenarios (Johnson and others, in press), for example. This limited role arises in part because multidisciplinary research efforts that are intended to address landscape-level policy and management questions tend not to be conceptualized as economic or joint production problems. They are not structured to identify what combinations of policies and management actions will yield the greatest benefit. Rather, they more typically involve merging data and models from different disciplines, predominantly ecology and biophysical sciences, to simulate policy and management effects on select vegetation, habitat, and socioeconomic measures (for example, Hayes and others 2004, Spies and others 2002). Such relatively informal modeling structures enable predicting the likely outcomes of policy and management alternatives under consideration, but these outcomes may not represent maximum amounts of ecosystem outputs possible nor will they necessarily be socially preferred. Defining those production possibilities—expressing one benefit as a function of others— identifies the ranges of outcomes that may be possible, and is what enables evaluating tradeoffs associated with different alternatives (for example, Haynes and Quigley 2001).

From an economics perspective, a production possibilities frontier for two ecosystem services outputs—say, timber and biodiversity—might appear as shown in figure 1. The production possibilities frontier (curved line) represents combinations of timber and biodiversity that are possible given existing landscape endowments and inputs. Points inside the frontier, such as A and B, also represent combinations of timber and biodiversity that are feasible but inferior. We could have more of both timber and biodiversity if we could only choose the correct combination of policies and management to achieve them, such as is the case with point C. The production possibilities frontier also defines necessary tradeoffs between services. If we are at point C on the frontier, for example, we would have to give up some timber production to move to point D where we would gain additional biodiversity. Identifying appropriate or socially optimal target combinations of ecosystem services outputs to produce would depend on additional information describing the relative values society places on each service. Economics attempts to define production possibilities and search for policies and management actions to maximize multiple forest benefits outputs.

Evaluating tradeoffs among benefits necessarily may involve finding ways to ease the difficulties in measuring their ecosystem services outputs and values. Dollar values, for example, may not always be necessary; sometimes it may be more practical to evaluate policy and management alternatives based on rankings or prioritizations of expected outcomes (King and Mazzotta 2005). Ecosystem indictors can be less expensive to use and may be more broadly accepted in policy and management evaluations than dollar values. Advocates for their use have begun to delineate formal typologies (for example, Banzhaf and Boyd 2005). Opportunities

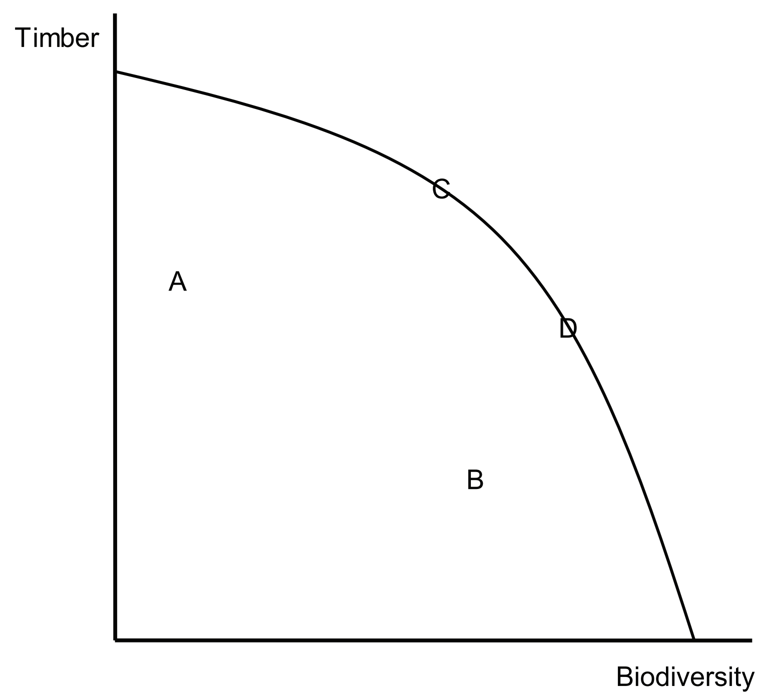

Figure 1—Example production possibilities frontier for timber and biodiversity.

also may exist to inform policy and management decisions by enabling members of the public to evaluate or rank comparative tradeoffs among ecosystem services directly by using conjoint and similar choice modeling methods without having to resort to measuring benefits values (for example, Breffle and Rowe 2002, Dennis 1998, Garrod and Willis 1997, Gregory and Slovic 1997, Gregory and others 1993, Johnston and others 2002, McDaniels and Roessler 1998, Zinkhan and others 1997). Enabling people to consider how much of an ecosystem service output they are willing to exchange for others may provide sufficient guidance to justify particular policy and management decisions. All of these options, however, do still require sufficient information about ecosystem services outputs.

Along with persistent lack of data describing ecosystem services production and value relationships are difficulties in quantitatively solving joint production problems. These typically call for the use of optimization methods and mathematical algorithms (for example, Hof 1993), which can be difficult for policymakers, managers, and even many researchers to understand. There also can be limits in computational feasibility for the most complex problems, which may involve describing multiple ecosystem services outputs in terms of numerous forest conditions, landscape characteristics, and resource inputs over space and time. For example, simulation models that predict the effects of management of various resources often are too complicated and time-consuming to incorporate directly into optimization models (Stevens and Montgomery 2002: 24). Challenges become greater as current research trends increasingly favor fairly complex landscape-level models designed to simultaneously examine multiple ecological and socioeconomic effects. Increasing sophistication of modeling methods coupled with greater availability of data describing interactions among forest uses could improve the future feasibility and usefulness of tradeoff analysis (Stevens and Montgomery 2002: 29).

The complexity of forest ecosystems means that policy and management decisions often must be made with imperfect and uncertain information (Wear 2003: 206-207). When gathering information on ecosystem services outputs and values is infeasible owing to complexity, expense, or lack of expertise, only a partial accounting of potential changes in services associated with alternative policy or management actions may be possible. Partial evaluations can present problems if they lead to biased results favoring one action over another. Policymakers and managers must carefully consider the potential implications of missing information when comprehensive evaluation of the ecosystem services benefits is impractical. Still, it often is possible to provide meaningful value estimates for relatively well-defined consequences we do understand (Bockstael and others 2000: 1388). For others, we simply may never know the exact relationships among all of the potential inputs and ecosystem benefits derived from forests. Choosing not to decide among particular policy or management actions for lack of information is a choice in its own right with its own set of implications. Just as there may be uncertainty about how bad a resource decision might be for a particular ecosystem, there also may be uncertainty that doing nothing (until more information is available) would be better.

Given uncertainties and public concern for ecosystem protection, there can be value in retaining viable options that otherwise might be lost (for example, Krutilla and Fisher 1975: 69-72). Given the many challenges in ecosystem policy and management, evaluating the actual tradeoffs associated with policy and management alternatives may be less useful than taking an adaptive management approach that incorporates precautionary principles (Arrow and others 2000: 1405). Analyses of ecosystem services could incorporate safe minimum standards that constrain policy and management choices to ensure ecosystem protection with some level of certainty (for example, Randall 1994). Policy and management decisions that must be made based on imperfect information and that involve potentially irreversible changes may sometimes call for caution, with policymakers and managers choosing to err on the side of overprotection of species and ecosystems.

Protecting Forest Land

An emerging interest of the Forest Service involves developing and evaluating appropriate and effective economic and market-based incentives to protect or enhance the provision of ecosystem services on private lands to augment those produced on public lands (for example, Collins 2005). This can include both policies designed to prevent the loss of forest land to development and policies to encourage management activities that enhance services on remaining private forest lands. Developing and evaluating such policy instruments has long been an interest of land economists (for example, Barlowe 1978). How do we encourage private forest landowners to continue to provide valued ecosystem services when development presents them with other lucrative opportunities? The success of any policy intended to protect forest land depends on (1) how well it addresses the socioeconomic factors that motivate forest landowners to sell land for development, and (2) how well it balances the interests of private landowners with the land conservation interests of society. Choosing the best approach involves balancing our national desire for forest-land conservation with socioeconomic realities and the needs of individual landowners.

It is uncertain whether taxpayers would support compensating forest landowners for what some view as simply good forest stewardship.

Forest-land development results from market forces. Population, income, and economic growth combine to increase demands for land in residential, commercial, and industrial uses, and public infrastructure. Demands also increase with people's lifestyle choices when, for example, people relocate to rural areas or desire second homes in scenic forest settings. When demands for developed land uses increase, so do the financial incentives some forest landowners have to sell land for development. The incentive is the revenue they can earn from selling land over and above what they can earn from maintaining land in forest. When these market forces are at play, some forest-land development is inevitable. Detailed discussion of different types of policies that can be used to counter these forces can be found in other sources (for example, Bengston and others 2004a). The choice, however, generally is between land use regulations and financial (economic or market-based) incentives (Kline and Alig 2005, Kline and others 2004a).

Regulatory approaches, such as zoning, can be a first line defense, but their long term effectiveness is limited by our national commitment to upholding certain private property rights. For this reason, policies that encourage the voluntary participation of private landowners in providing particular ecosystem services or compensate them for land use restrictions imposed can be important complements to regulation. All states, for example, have preferential taxation programs that reduce property taxes on forest and farm lands, lowering the costs of keeping land in forest even as its potential developed value increases. Greater protection comes at greater expense, such as leasing lands for conservation purposes, or purchasing development rights, easements, and land in fee.

Directly compensating forest landowners for ecological services produced on their lands—through increased forest commodity prices and other economic incentives—is another approach currently of interest to forest policymakers and managers (for example, Collins 2005). Owners would be induced to retain forest land by the creation of markets for the ecosystem services their lands produce and the public enjoys. Examples include enabling forest landowners to sell carbon credits or receive compensation for wetlands banking. Whether such compensation actually could reduce forest-land development in the United States is uncertain. Success would depend on (1) how much compensation would be necessary to outweigh financial opportunities of development and (2) how much consumers and taxpayers would be willing to pay in higher prices for forest commodities and higher taxes to fund economic incentives. Technological innovation, tree planting, and the global transition from extensive forestry to plantations conceivably could greatly increase forest productivity in the near future (for example, Binkley 2001). Much less forest land may be needed to supply world forest commodity demand. It is uncertain whether consumers would be willing to pay sufficiently higher prices for U.S. forest commodities to offset the development opportunities of forest landowners in a global forest commodity market characterized by over-production. Ever-increasing prices for developed lands do not improve the prospects. Also uncertain is whether taxpayers would support compensating forest landowners for what some may view as simply good forest stewardship.

There can be limits to how effective public policies can be at protecting private forest lands. Land use policies and programs tend to emerge from political processes involving concession and compromise. Although they may make sense in theory, what emerges might not always provide ideal solutions, or may work against other policies and programs already implemented. Preferential taxation programs, for example, generally do not differentiate between lands of significant social value and lands of little value. Landowners generally receive preferential property tax treatment as long as they meet broad land use criteria, regardless of how much public benefit their land actually provides. Purchasing development rights, easements, and land in fee simple can yield lasting protection, but these tend to be expensive and limited to willing sellers, often resulting in a spotty patchwork of protected land. Economic and market-based incentives providing direct compensation for ecosystem services produced can be effective, but do favor forest landowners by placing the financial burden of forest-land protection solely on the non-forest-owning public. Policymakers must continually weigh the effectiveness, costs, and equity considerations of policies when devising strategies to protect forest land and the ecosystem services benefits it produces. Ideally, they also should try to structure new policies and programs in ways that complement other measures already in place.

Making Future Progress

The research community has a significant role to play in creating socially acceptable forest policy and management (Shindler and others 2002: 53). The economics discipline, in particular, is uniquely focused on developing and analyzing policies and economic incentives to enhance the provision of ecosystem services. Economics research focused on describing and evaluating the benefits of ecosystem services can provide important input into natural resource decisions and improve the likelihood of socially acceptable outcomes. Forest Service research has a comparative advantage relative to universities and other research organizations in their capacity to integrate social science, including economics, with biophysical science to address difficult forest policy and management issues (Clark 2005: 44). Within Forest Service research, Pacific Northwest Research Station social scientists and economists have been as involved as anybody in multidisciplinary landscape-level research that evaluates ecological and socioeconomic outcomes of forest management alternatives (for example, Hayes and others 2004, Spies and others 2002). Opportunities exist to build on the relationships developed in these efforts to address emerging interest within the Forest Service in describing and evaluating ecosystem services.

Policymakers and managers, however, must have reasonable expectations. Greater use of economics can help to resolve policy and management choices regarding the multiple objectives held by the public regarding the Nation's forests. However, the idea that describing and placing values on all ecosystem services produced on the Nation's forests will cleanly resolve the most complex policy and management issues we face is ill-founded (Knetch 1993: 251). Economics methods and the ecological information necessary to use them are imperfect, budgets and expertise are limited, and the need to make timely resource decisions is often pressing. What, then, can be done to assist forest policymakers and managers when intelligent policy and management calls for information describing ecosystem services benefits associated with policy and management decisions? How can we provide useful information regarding ecosystem services benefits to inform natural resource decisions?

Economics can and should play a central role in defining conceptual structures for evaluating the effects of policy and management alternatives on ecosystem services benefits. Greater success in evaluating benefits will arise when ecosystem services effects are relatively well known and can be readily evaluated by using standard nonmarket valuation methods or alternative approaches. Difficulties increase as researchers move from evaluating ecosystem services effects resulting from relatively specific or localized policy and management actions affecting a small subset of services—closing a specific hiking trail or thinning a specific stand, for example—to evaluating the effects of actions affecting whole landscapes or regions—providing tax incentives to forest landowners to maintain key habitat attributes, for example. Particular challenges exist in defining a typology of services and their appropriate units of measurement over space and time. The greatest difficulty occurs when ecological effects are complex and uncertain, and involve changes bordering on the abstract in the minds of affected people—evaluating the effects of policy or management actions on a species' survival when the species and its habitat needs are poorly understood.

In even the most complex and uncertain situations, some evaluation of ecosystem services benefits may be feasible if we need only evaluate whether the benefits of a proposed action are greater than its costs (Bockstael and others 2000: 1388, Krutilla and Fisher 1975: 125). A comprehensive accounting of benefits may be unnecessary. In some cases, simply adding up the relatively familiar and certain instrumental values associated with known ecosystem services may be sufficient to distinguish desirable policy and management actions from undesirable ones. There may be other situations where evaluating potential benefit changes resulting from ecosystem changes affected by proposed policy and management actions may be so complex that the wisdom of attempting any comprehensive analysis is questionable. These situations are most likely when the potential ecological effects of policy and management actions are spatially and temporally extensive and numerous.

When information for describing resulting changes in ecosystem structure and functions is absent or incomplete and the sheer number of relevant ecosystem services that must be evaluated tax existing budgets and expertise, policy and management decisions may need to derive more from the reasoned professional judgment of policymakers and managers based on incomplete information. Many natural resource decisions simply cannot be made without some uncertainty. Often we have to rely on professional judgment (Haas 2003). Basing policy and management decisions on imperfect information need not be viewed as negligent. Indeed, detailed information about ecosystem services outputs and values may be unnecessary in a wide variety of situations. As a society, we have routinely made many complex and lasting environmental decisions with incomplete (and sometimes no) information regarding their costs and benefits (Vatn and Bromley 1995: 20). This includes the decision to create national forests as well as our seemingly persistent assumption that the current extent of public and private forest lands is socially optimal. Economists must continue to engage and encourage ecologists and biophysical scientists to address persistent uncertainties regarding ecosystem structure, function, and their relationships to the provision of ecosystem services. In the near term, significant marginal gains also are likely to result from research focused on developing conceptual frameworks and methods for describing forest benefits provided by public and private lands, and using these to design and evaluate policy and management alternatives consistent with public preferences.

Ecosystem services can be thought of as a key factor of interaction between human and ecological systems.

Identifying Potential Research Areas

Conceptually, ecosystem services can be thought of as a key factor of interaction between human systems comprising socioeconomic and political processes and ecological systems comprising ecosystem functions and processes (fig. 2). Human systems affect ecological systems through human use and management of natural resources, environmental degradation and remediation, and natural resource and environmental policies, among other factors. How ecological systems respond to these human factors influences what human systems get in return—ecosystem services. The cycle of interaction involves numerous socioeconomic, political, ecological, and biophysical factors, which alone and in combination shape the disciplinary and topical bounds of potential inquiry regarding ecosystem services. Very generally, an economist might study human demands for and supply of natural resources and environmental amenities provided by ecological systems, and consider policies for alleviating critical scarcities. An ecologist might study the numerous interactions among different components or agents within ecological systems, and the effects of human actions on specific components. Significant opportunities exist for multidisciplinary research.

To meet the needs of Forest Service policymakers and managers, the greatest gains are likely to come from research focused on areas where Forest Service scientists have a comparative advantage. Within the Forest Service, Pacific Northwest Research Station, for example, opportunities exist to build on existing research capacities in land economics, which is fundamental to addressing adequate provision of ecosystem services. Virtually any land use or land cover anywhere in the United States is the result of human decisions (or lack of decisions) about where and when to pursue particular uses or covers, including natural succession, and of management actions that influence ecological conditions and processes and ecosystem services produced. Economics research conducted by Pacific Northwest Research Station scientists and their cooperators has focused on examining how

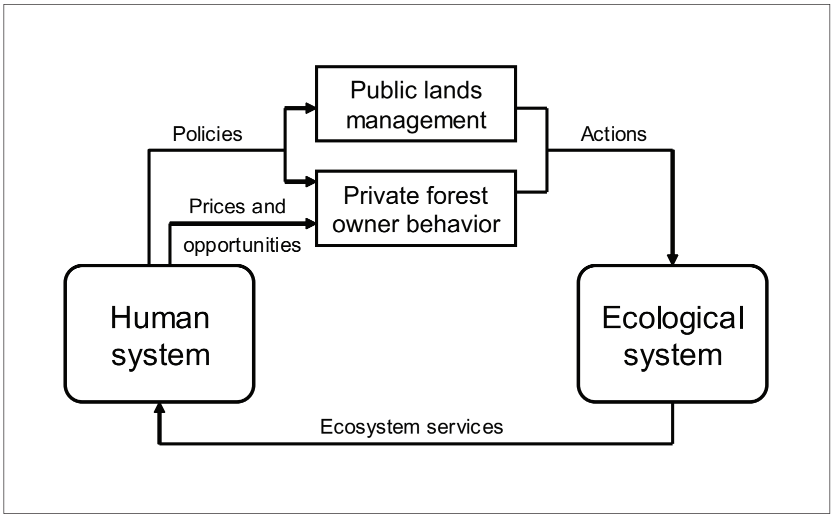

Figure 2— Human and ecological systems interactions: examples of related economics research areas existing within the Pacific Northwest Research Station.

private forest owners respond to policies and socioeconomic factors (for example, prices and other opportunities) in their land use and forest management actions with implications for ecological systems (for example, Alig 1986, Alig and Healy 1987, Butler and others 2004, Kline 2005, Kline and Alig 1999, Kline and others 2000a, 2000b, 2004b). Significant work also has focused on projecting how these factors will influence future land use and management changes on private lands (for example, Alig and others 2003, 2004; Kline and Alig 2005; Kline and others 2003) and expected outputs of select ecosystem services such as timber and carbon sequestration at various spatial scales (for example, Alig 2003, Alig and Butler 2004, Alig and others 2002, Haynes 2003).

Much of this work has been done as part of multidisciplinary research to evaluate forest policy and management effects on public and private lands and resulting beneficial outputs (for example, Hayes and others 2004; Spies and others 2002, in press; USDA FS 2001) or to facilitate such multidisciplinary efforts (for example, Everest and others 2004; Houston and others 2002; Kline 2003, 2004; Kline and others 2001). Scientists also have examined issues involved in protecting and managing forest lands across public and private ownerships to augment the ecosystem services produced on public lands with private lands protection (for example, Kline, in press; Kline and others 2004a). This includes examining socioeconomic and other factors that influence public demands for select ecosystem services produced on public and private lands (for example, Garber-Yonts 2005, Houston and others 2003, Kline and Swallow 1998) and demands for open space protection generally (for example, Kline 2006; Kline and Wichelns 1994, 1996a, 1996b, 1998).

This large body of research remains relevant to current Forest Service interests in ecosystem services and is a foundation on which to expand and initiate new ecosystem services research tailored to current and specific needs of policymakers and managers. It augments existing comparative advantages of economics programs at other research stations. For example, economics research at the Rocky Mountain Research Station focuses largely on valuation methods (for example, Brown 1984, Brown and others in press, Champ and Bishop 2001, Champ and Loomis 1998, Champ and others 2002, 2003; Peterson and Randall 1984; Peterson and others 1988). At the Northern Research Station, related economics research focuses on the dimensions of human perceptions, attitudes, and values concerning ecosystem management (for example, Bengston 1994; Bengston and Fan 2002; Bengston and others 2004b; Bengston and Xu 1995, 2001; Manning and others 1999) and designing and evaluating conservation strategies (for example, Haight and others 2005, Ruliffson and others 2003, Snyder and others 2004). At the Southern Research Station, research focuses on improving methods for measuring nonmarket forest values, their distribution across society and regions, and incorporating them into policy (for example, Scarpa and others 2000, Schaberg and others 1999, Sills and Abt 2003, Zinkhan and others 1997). Other research programs exist, but these suffice to show the diversity of interests within Forest Service research. Opportunities exist as well to work collaboratively across research stations.

Economists can be fundmental to addressing the public goods characteristics of ecosystem services produced on both public and private lands.

Economics can be fundamental to designing and evaluating polices for addressing the public goods characteristics of ecosystem services produced on both public and private lands. In also can contribute to conceptualizing and evaluating the ways in which forest landowners respond to polices, prices, and other socioeconomic factors in making land use and management decisions that affect ecological systems and ecosystem services. Economics also can help describe and evaluate human demands for ecosystem services that are unpriced in markets, including describing the perceptions, attitudes, and values people hold for the Nation's public and private forest lands. Among these more general contributions, specific areas where Pacific Northwest Research Station economics research might be most helpful and productive in ecosystem services analysis and evaluation are:

- Reviewing past and current forest benefits research to identify situations in which forest benefits information was effectively used in forest policy and management decisionmaking, with a focus on merging ecological information with economic conceptual frameworks and benefits measurement and valuation (or weightings). Examples of studies might include:
    - Synthesizing research studies that have evaluated policy and management effects on one or more forest benefits at a landscape level, and evaluating

the usefulness of specific approaches and information produced.
  - Developing frameworks for developing and using ecosystem benefits indicators to evaluate forest policy and management alternatives (for example, Boyd and Banzhaf 2006) and providing empirical examples of evaluations using real landscapes.
- Defining aspects of changing demands for ecosystem services as public goods, including their production on both public and private lands, their relative importance or value to society, and how demands influence and are influenced by socioeconomic change. Examples of studies might include:
  - Evaluating demands for preserving open space and how they are influenced by changing socioeconomic factors such as population growth, incomes, and open space scarcity, building upon work by Kline (2006) and Kline and others (2004a).
  - Collaborating with ecologists and other biophysical scientists to describe ecosystem services production functions and outputs to facilitate describing ecosystem services produced by public and private forest lands, and analyzing policy and management effects. Such work might build upon past multidisciplinary research efforts (for example, Hayes and others 2004, Spies and others 2002).
  - Describing and evaluating the ways in which ecosystem services and their relative scarcities are perceived by rural and urban residents, and how these are shaping land use patterns and forest land development arising from inmigration of new residents attracted to forest amenities, including what economic effects these changes bring for rural communities (for example, Garber-Yonts 2004).
- Defining specific ecosystem services, measuring the relative magnitudes of their social benefits, and evaluating their changes resulting from specific forest policy and management actions when those actions are well-defined and potential resource changes known with fair certainty. Examples of studies might include:
  - Measuring health benefits of outdoor recreation opportunities and other quality-of-life factors resulting from proximity to national forests, and commenting on their national implications, building upon Rosenberger and others (2005), for example.
  - Measuring and evaluating the effects of specific policy or management actions (for example, fuel treatments, riparian buffers, or access fees) or disturbances such as fire on specific recreation uses in well-defined locations, including potential changes in users' welfare and potential changes in

local economic activity (for example, Brown 2006).

- ✦ Identifying and evaluating the potential interrelationships in the production of multiple ecosystem services, their responses to specific management changes, and ways to mitigate potential conflicts and enhance potential complementarities.

- Identifying examples of and evaluating opportunities for joint production of ecosystem services, including evaluating and describing ways in which forest policies and management actions can contribute to joint production opportunities. An example of a study might include:
  - ✦ Estimating production possibility frontiers describing the production of ecosystem services (for example, timber and biodiversity) on specific landscapes, and evaluating the potential effects of policies and management actions on benefit production relationships (for example, Calkin and others 2002, Stevens and Montgomery 2002).
- Identifying the practical limitations of existing economic conceptual theory in evaluating ecosystem services effects of policy and management, and consider ways to remedy existing limitations and identify alternative approaches that are consistent with economic theory. Examples of studies might include:
  - ✦ Examining and evaluating the practical usefulness of alternative approaches for including and evaluating ecosystem services in analyses of forest policy and management alternatives, such as ecosystem indicators and multiattribute decision criteria, among others (for example, Kline 2004).
  - ✦ Examining the conceptual and practical applicability and current use of the "safe minimum standards" and adaptive management approaches (for example, Stankey and others 2005) to public forest policy and management decisionmaking.
- Identifying and evaluating policies, incentives, and other strategies to induce private forest owners to internalize externalities associated with public benefits provided by private forest lands. Examples of specific studies might include:
  - ✦ Building on existing research to examine the factors motivating land use decisions of private forest landowners, and identify and evaluate potential policy instruments for influencing those decisions (for example, Alig and others 2004, Kline 2005).
  - ✦ Building on existing research to examine the factors that motivate forest management decisions of private forest landowners, identify methods for differentiating among different types of owners, and identify and evaluate potential market-based and regulatory policy instruments for influencing diverse owners' decisions (for example, Kline and others 2000a, 2000b).

- Evaluating the policy or management effects on the provision of specific ecosystem services, such as the effect of land use regulations on maintaining stored carbon (for example, Cathcart 2000, Kline, in press).

Although economics can contribute to addressing ecosystem services, any economic evaluation of services can only offer additional information needed for effective policy and management decisionmaking. A single correct answer regarding what policy or management path might be most appropriate where and when will never be forthcoming—"No one would suggest that economic values should rule the day" (Bockstael and others 2000: 1389). Rather, economics, as other disciplines, can only help to provide better and more complete information with which to weigh the effects of different policy and management alternatives. Progress toward evaluating ecosystem services will require that economists and ecologists work together. That process will demand that economists gain some fundamental level of understanding of the biophysical and other processes involved in the production of ecosystem services. It also must involve ecologists, as well as policymakers and managers, in gaining at least some fundamental level of understanding of economics. Economics offers a powerful set of tools that can be useful to examining and resolving ecological and natural resource issues. To take full advantage of those tools, economists must find effective ways to help ecologists and biophysical scientists, policymakers, and managers see how their interests align with economic approaches to evaluating ecosystem services.

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