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Ecosystem Services as a Framework for Forest Stewardship: Deschutes National Forest Overview

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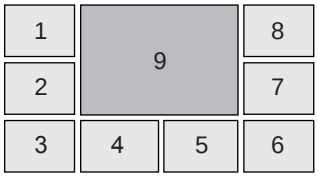

Cover photos: (1) Stream, by Tom Iraci, (2) Fly fishing, USDA Forest Service; (3 through 7) Elk, mushrooms, Deschutes River rafters, northern spotted owl, and ponderosa pines, by Tom Iraci; (8) Honey bee, by David Cappaert, Michigan State University, Bugwood.org; (9) Todd Lake and Mount Bachelor, Deschutes National Forest, by Tom Iraci.

Abstract

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The concept of ecosystem services has emerged as a way of framing and describing the comprehensive set of benefits that people receive from nature. These include commonly recognized goods like timber and fresh water, as well as processes like climate regulation and water purification, and aesthetic, spiritual, and cultural benefits. The USDA Forest Service has been exploring use of the framework of ecosystem services as a way to describe goods and services provided by federal lands and attract and build partnerships with stakeholders and nongovernmental organizations. More recently, the agency has sought place-based example applications of the ecosystem service framework to explore its possible use as a tool to guide forest management, and better illustrate the concept for policymakers, managers, and potential national forest partners. Meeting this call, the Forest Service's Deschutes National Forest and Pacific Northwest Research Station are collaborating to explore how an ecosystem service approach can enhance forest stewardship in central Oregon. This effort includes (1) describing the ecosystem services provided by the forest, (2) investigating how an ecosystem service framework can support an integrated management approach across program areas to sustain ecological functions and processes, including examination of the potential outcomes and tradeoffs among services associated with proposed management activities, (3) assessing the relationship between supply and demand for services and strategies to sustainably manage service flows while conserving resources over time, and (4) attracting and building partnerships with stakeholders who value the services the forest provides. In this report, we (1) characterize the concept of ecosystem services as it could apply to national forests; (2) describe the value of an ecosystem service approach and provide examples of how management actions support the provision of these services; (3) compare the Deschutes National Forest's current accomplishment reporting system to ecosystem service outcomes that potentially result from management activities; (4) identify partners with potential to collaboratively plan, fund, or implement projects to enhance or conserve ecosystem services; (5) describe current research efforts to support management application of the ecosystem service concept; and (6) identify research needs.

Keywords: Deschutes National Forest, management applications, public benefits, nonmarket valuation, tradeoffs, stakeholder partnerships.

Introduction

> "A healthy and prosperous America relies on the health of our natural resources, and particularly our forests."
>
> —*U.S. Department of Agriculture Secretary Tom Vilsack*

The work of the USDA Forest Service has come to reflect a growing public recognition and demand for natural resource stewardship and the multiple benefits that forests provide. Although the importance of healthy, functioning ecosystems is widely recognized (Carroll et al. 2008, Daily 1997a, McKenzie et al. 2004), uncertainties arising from population growth, loss of forest land to development, and impacts of climate change have brought renewed attention to the role that forests play in enhancing public welfare (Collins and Larry 2008). Concerns about rising global temperatures, drought, more extreme fire and flood events, habitat degradation, regulation of greenhouse gases, and the sustainability of water supplies (IPCC 2007) have highlighted the importance of natural resource management in securing desired resource conditions. The connection between forests and people is particularly acute in the face of these challenges.

The concept of ecosystem services has emerged as a way of framing and describing the comprehensive set of benefits that people receive from nature.

The concept of ecosystem services has emerged as a way of framing and describing the comprehensive set of benefits that people receive from nature. Ecosystem services are the products of functioning ecosystems that benefit people (Brown et al. 2007, Costanza et al. 1997, Daily 1997a, Kline 2006). These services have been described in a number of ways, including the Millennium Ecosystem Assessment or MEA (MEA 2005) which developed a frequently referenced classification of ecosystem services into the four categories of provisioning, supporting, regulating, and cultural services. Provisioning services are familiar commodities such as food, fresh water, timber, fiber, and many pharmaceuticals for direct human use. Supporting services are the underlying processes that maintain the conditions for life on Earth, such as nutrient cycling, soil formation, and primary production. Regulating services are the benefits obtained from ecosystem impacts on natural processes, such as flood and disease control, water purification, climate stabilization, and crop pollination. Cultural services include recreational, spiritual, educational, and aesthetic benefits that enrich and revitalize the human experience.

Although the Forest Service has been exploring use of these concepts to describe the benefits provided by forests, the ecosystem service approach has not been applied operationally in a management context. Agency management accomplishments have been defined by Congress in terms of output-oriented program targets, such as board feet of timber sold or acres treated to reduce fuels. These measures describe management actions undertaken but do not account for the full suite of benefits provided by public lands. The promise of an ecosystem service

approach is to try to bring a more complete accounting of forest benefits to national forest management—one that highlights ecological functions and processes at site and landscape scales, and that provides a more comprehensive rationale for specific management actions.

To make ecosystem services relevant to land managers there is a need for place-based application. The Forest Service Pacific Northwest Research Station and Deschutes National Forest (NF) have partnered to explore how this approach can be implemented by a national forest to enhance forest stewardship. This includes describing the services provided by the forest, examining potential outcomes and tradeoffs among services associated with management actions, and exploring the potential of an ecosystem service framework to support collaborative decisionmaking with the public and strengthen partnerships with stakeholders. Broadly speaking, this effort is a three-stage process that includes:

(1) An overview of ecosystem services in national forest terms and investigation of how the concept could apply to Forest Service management, using the Deschutes NF as an example.

(2) Initial research to:
   a. Design a place-based classification of ecosystem services specific to the Deschutes NF, incorporating the values and perceptions of stakeholders and Forest Service staff.
   b. Develop an outcome-based ecosystem service framework for landscape analysis and decision support.

(3) Future research to further develop an ecosystem service approach to management by:
   a. Addressing the relationship between supply and demand for services the forest provides and exploring how to sustainably manage service flows while conserving resources.
   b. Collaboratively developing ecosystem service metrics.
   c. Applying ecosystem service concepts to a demonstration project.

The intent of this report is to provide a foundation for the above process, with an emphasis on the first stage. Its objectives are to (1) characterize the concept of ecosystem services as it could apply to national forests and the mission of the Forest Service; (2) use the Deschutes NF as a case study to describe the value of an ecosystem service approach and provide examples of how management actions and performance measures could be characterized in terms of ecosystem services; (3) identify partners with potential to collaboratively plan, fund, or implement projects to enhance and conserve ecosystem services; (4) describe current ecosystem service research; and (5) identify future research needs.

Ecosystem Services and the Forest Service Mission

The ecosystem service approach is not completely new for the Forest Service, and builds on decades of research by resource economists such as Michael Bowes and John Krutilla, who described and evaluated public benefits arising from multiple-use management of federal forests (Bowes and Krutilla 1989). Moreover, the agency mission itself has always been one of natural resource stewardship and multiple resource values. The Forest Service was established to protect and manage natural resources—specifically water and timber—because of their importance to national security and for the significant public benefits they provide. The federal government, acting on behalf of the American people, recognized that unless forested lands were set aside, critical water and timber assets might not be adequately protected for future generations. After World War II, the Forest Service emerged as a primary supplier of natural resource commodities, including timber and rangeland for grazing livestock (USDA FS 2005). Socioeconomic changes, coupled with new legislation passed during the 1960s, 1970s, and 1980s, broadened the range of agency activities and objectives to consider other benefits in addition to water and timber, including wildlife, recreation, and ecological health, among others (Apple 2000). Still more recently, the agency mission has expanded further to include ensuring the healthy functioning of forest ecosystems that are seen as critical to maintaining public welfare over time. 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 strategic plan identifies several specific goals, including providing and sustaining benefits to the American people, conserving open space, sustaining and enhancing outdoor recreation opportunities, and providing science-based applications and tools for sustainable natural resource management (USDA FS 2007b).

Although the Forest Service mission has evolved over time to serve the public good more broadly, the agency's current management context does not adequately highlight the full scope of benefits that forests provide. Current reporting mechanisms and processes do not illustrate the value of much of what managers accomplish, particularly with regard to the regulating, cultural, and supporting services provided by forests that are critical to human well-being. The emerging concept of ecosystem services can enhance implementation of the Forest Service mission in a management setting, illustrate the value of forest management, and provide resource specialists with new ways to approach decisonmaking.

Ecosystem Services as an Emerging Opportunity for the Forest Service: Incorporating an Ecosystem Service Context into National Forest Management

> "Our markets—and our regulations, for that matter—need to be designed not with outputs, but with long-term outcomes in mind: to ensure a sustainable flow of all the ecosystem services that Americans want and need from their forests."
>
> —*Forest Service Chief Tom Tidwell*

The Forest Service is regarded as a "can do" organization. It prides itself on its ability to produce—to supply timber, build roads, fight fire, and offer areas for hunting, grazing, and gathering of mushrooms and horticultural products. Historically, the provisioning services the agency produces have received more attention than other ecoysystem services (Collins 2007; Collins and Larry 2008; Patterson and Coelho 2008, 2009). Protection of soils, water, wildlife, and recreation opportunities, among others, have emerged over time as important non-commodity-related goals of forest management. For Washington, Oregon, and northern California, the signing of the Northwest Forest Plan in 1994 helped address this issue by prioritizing multiple management objectives within the range of northern spotted owl (*Strix occidentalis caurina*). The plan was based on a key principle of managing for the long-term sustainability of habitat as well as for forest products (USDA FS and USDI BLM 1994). Although the Northwest Forest Plan was an important step toward an ecosystem management approach that combined human needs and multiple uses with sustaining a functional old-growth and late-successional forest system, there is still a need to extend the classification of these uses to address regulating, cultural, and supporting services (Collins and Larry 2008) and to incorporate related considerations into the goals of resource professionals across program areas.

The reward system for national forest staff has been based upon accomplishment of targets assigned by Congress. The performance evaluations of forest supervisors, district rangers, and the staffs they supervise are based on annual outputs such as the amount of timber sold, the amount of firewood offered, the number of animal unit months provided to grazing permittees, and the miles of road constructed or decommissioned, among others. This method of characterizing and rewarding success can have unintended consequences. For example, it can lead to decisions that are fragmented by resource specialty, prompting the agency to focus its efforts on accomplishment of narrowly defined targets rather than approaching management of ecological processes and functions through integrated resource programs.

There is an alternative. Viewing the benefits from national forest lands in terms of ecosystem services, or "benefits from nature," provides a subtle shift in viewpoint that can have profound effects (Collins 2007). As articulated by former Forest Service Associate Chief Sally Collins and Ecosystem Services Specialist Elizabeth Larry, "an ecosystem services perspective moves land managers to frame a purpose that reflects a broader set of values" (Collins and Larry 2008). Framing Forest Service actions in terms of ecosystem services allows staff to conceptualize all the benefits from ecosystems (Collins 2007, Collins and Larry, 2008). Setting an expectation that all employees view their accomplishments in terms of outcomes, highlighting the entire suite of ecosystem services provided (including an evaluation of tradeoffs), broadens their approach to their job responsibilities and necessarily requires integration of efforts across disciplines. It is important for Forest Service employees to recognize that altering ecosystems may change the services they deliver. Daily choices made in Forest Service operations also influence the ecosystem services needed to support agency activities (water, fuel, etc.). Although these changes in expectations may be subtle, they could inspire a new approach to management by leading to differences in project implementation and garnering support from local communities. This shift in approach can be supported by the development of tools, methodologies, and reward systems that allow managers to work collaboratively across programs and consider management objectives in terms of interdisciplinary outcomes.

In addition to supporting a more integrated approach to decisionmaking, the language of ecosystem services can help managers highlight connections between forests and people and strengthen relationships with the public (Collins and Larry 2008). Much of the Forest Service's vocabulary for speaking about the management of forests came from the production forestry era (Collins 2007). This technical language is based on the provision of forest products but does not fully address the relationship between forests and public benefits. Words reflect culture, defining and subtly perpetuating beliefs (Collins 2007). The way managers speak about forests reinforces practices and a mindset that may need to evolve to reflect changing public expectations and concerns about climate change, the increasing human demand for resources, and greater awareness of the interconnectedness between forests and human well-being (Collins 2007, Collins and Larry 2008).

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National forest lands can also serve as a laboratory for testing ideas (Collins 2007). By modeling use of the ecosystem service concept in management decisonmaking and reporting, the Forest Service can support application of related outcome-based approaches to natural resource management in other contexts. This can include piloting methodologies for use in ecosystem service markets

that compensate private forest landowners for public benefits provided by their land stewardship. National forests can demonstrate a multitude of metrics for these markets, including those that measure nutrients, wetland function, biodiversity, water quality improvements, and carbon sequestration, with minor adjustments in the way that the agency currently accounts for land management accomplishments. These demonstration efforts can highlight the value provided by both public and private forests, draw connections between forests and people who benefit from the services they provide, and underscore the importance of sustaining healthy forests across the landscape.

The Value of an Ecosystem Service Approach

The ecosystem services concept, as a framework for forest management, has potential usefulness to the Forest Service in four primary ways. The first potential use is as a way to **describe to the public and to Congress the value of national forests to the American people**. This is particularly important as timber revenue declines and the funding base for programs like restoration becomes insufficient to meet management needs. Defining ecosystem service values addresses the agency's need to better describe and market the benefits provided by national forest management as a rationale for continued public funding of the National Forest System. Value here need not be expressed exclusively in terms of monetary measures. Rather, as a marketing tool for Forest Service management of national forest lands, an ecosystem service framing of public benefits may simply involve enumerating and describing a broad set of services, both quantitatively and qualitatively, to improve public understanding of what a well-funded Forest Service provides for the tax dollars expended.

A second potential use of this framework is to **characterize Forest Service management activities in terms of ecosystem service outcomes to complement output-related targets required by Congress**. This approach can also help managers highlight the connection between public benefits and ecological conditions, establish management priorities, and evaluate tradeoffs among different landscape attributes, functions, or goods and services. The agency's current reporting system for articulating management accomplishments emphasizes units of measure in output-oriented terms—related to acres, miles, or board feet produced—that do not adequately illustrate management objectives or outcomes related to ecological functions and processes, and the public benefits they provide. For example, management actions such as timber harvest, fuel treatments, road building or decommissioning, riparian enhancement activities, or trail construction are generally conducted to achieve particular ecological outcomes (e.g., fire risk

reduction, maintenance of threatened or endangered species, or forest productivity) that are not clearly communicated or known when reported only in terms of an acre treated or mile restored, which describe activities in spatial units rather than the services or benefits that result. As forest managers contend with increasingly complex objectives and limited budgets, new tools are needed to help them set priorities and describe and evaluate the outcomes that result from their management actions.

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In addition to articulating outcomes, an ecosystem service approach can help agency staff identify and communicate why and where particular management actions are needed. An ecosystem service framework can clarify relationships between the quantity or quality of services provided by forests and the condition of ecosystems supplying them (Daily 1997b). This approach can bring attention to the functions performed by healthy ecosystems, distinguish between those that are low and high functioning, lead to investigations about causes of ecosystem degradation or impeded function, and identify where restoration or other actions are needed. Managing to sustain functions and processes also encourages a landscape-scale perspective, and serves dual objectives of enhancing land stewardship while providing public benefits. This framework can help highlight functions and processes within a decisionmaking framework, clarify priorities and management needs, and support the design and implementation of projects with clearly articulated goals and results. This approach can also assist managers with analysis of the impacts of projects across resource areas, and consideration of potential tradeoffs among ecosystem services provided, rather than focusing on just one objective or working in independent and isolated programs.

A third potential use of the ecosystem service framework is to **assess whether particular ecosystem service flows are in decline over time, and if they are, assemble the widest possible range of management alternatives and policies to stem those losses**. This range may include management and stewardship efforts that restore and sustain ecosystem service flows. It may also include planning and education to address overconsumption, crowding, or other negative impacts when demand for ecosystem services becomes concentrated or is projected to increase owing to population growth or other factors.

Lastly, an ecosystem service framework, if developed collaboratively, can **strengthen relationships with communities, tribes, private stakeholders, and nongovernmental organizations by defining common natural resource stewardship objectives**. Inherent in an ecosystem service approach is identifying services provided by a landscape, and understanding human use and dependency on those services (Collins and Larry 2008). By providing a clear framework for

describing these relationships, the ecosystem service concept potentially can promote collaboration and dialogue among interest groups that share stewardship goals. This includes working together to plan, fund, or implement work needed on national forest lands with partners who have a common stake in particular ecosystem services, such as providing water to a municipality, fishing and hunting opportunities to recreation groups, and others. Presenting objectives in terms of ecosystem service outcomes, and evaluating tradeoffs that might occur as a result of particular management activities, could also clarify decisionmaking processes for the public and build trust in the agency's actions.

This report establishes a foundation for development of the potential uses of the ecosystem service framework described above. Using the Deschutes NF as a case study, the following sections will (1) characterize the Deschutes NF management context, (2) describe the ecosystem services provided by forests, (3) provide examples of how management activities and performance measures could be characterized in terms of ecosystem services, (4) identify current and prospective partners with potential to collaboratively plan, fund, or implement projects based on shared interests in ecosystem services, and (5) describe ongoing research and future research needs. These research efforts will address knowledge gaps to more fully account for ecosystem services provided by forests, explore how to approach management decisionmaking in terms of ecosystem service outcomes, and investigate the potential of an ecosystem service framework to support collaborative decisionmaking with stakeholders.

Place-Based Application of the Ecosystem Service Framework

A primary goal of this research effort is to apply the ecosystem service framework to management in a place-based context. The geographic, ecological, and socioeconomic characteristics of the Deschutes NF affect the benefits the forest provides, the services valued by surrounding communities, and the nature of related management challenges. It is important to consider these conditions when designing an ecosystem service approach to forest stewardship.

Deschutes National Forest

The Deschutes NF encompasses 1.6 million acres of forested land along the eastern slope of the Cascade Range in central Oregon (fig. 1). It lies mostly in Deschutes County but extends into Jefferson County to the north and into Klamath and Lake Counties to the south and east.

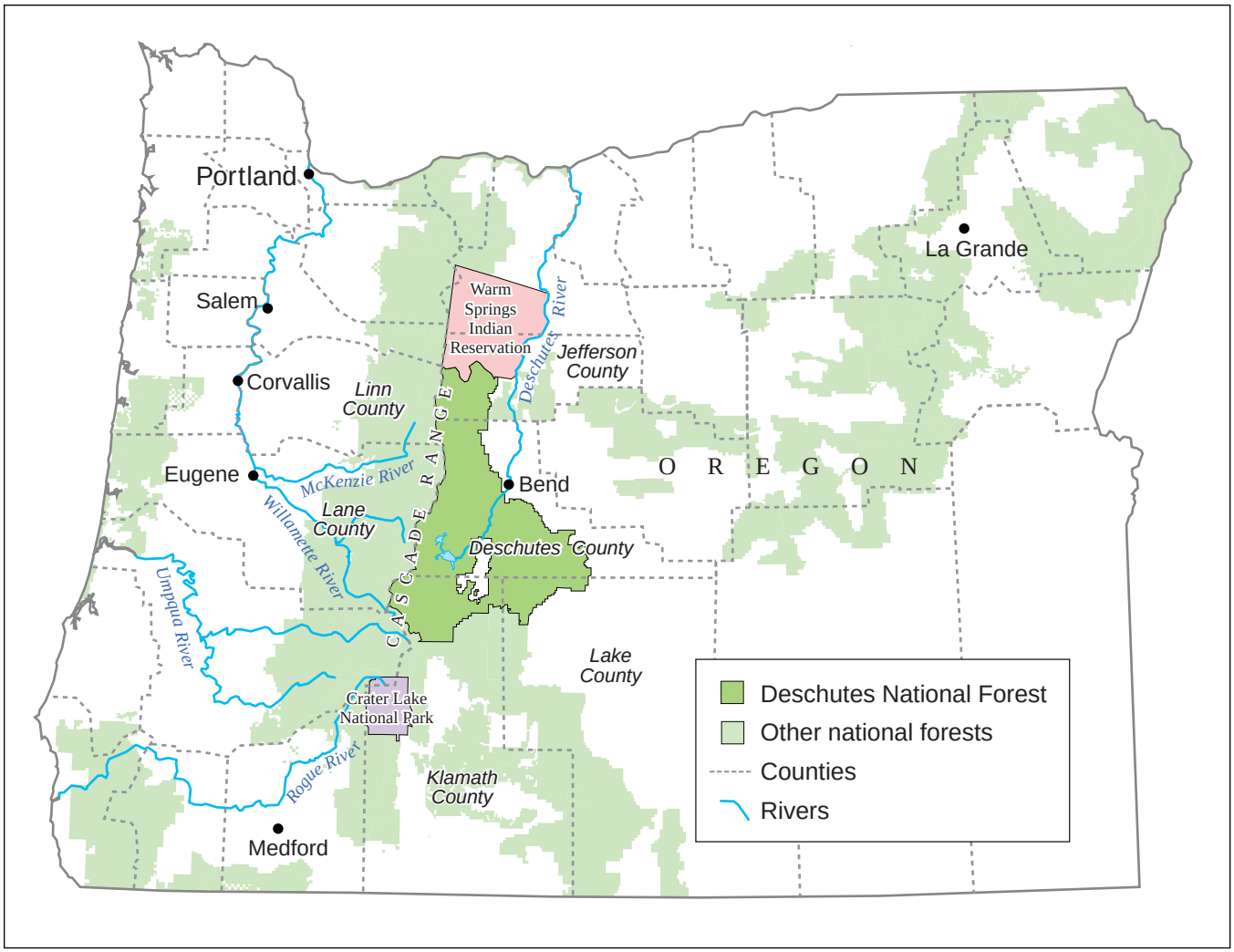

Figure 1—The Deschutes National Forest encompasses 1.6 million acres of forested land along the eastern slope of the Cascade Range in central Oregon.

The forest is a diverse landscape of wet upper montane areas with mixed-conifer forest, volcanic formations, and dry desert, and includes habitat for more than 350 species of fish and wildlife (USDA FS 1990). Forests are predominantly ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) and lodgepole pine (*Pinus contorta* Dougl. ex Loud.), mountain hemlock (*Tsuga mertensiana* (Bong.) Carr.), Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), white fir (*Abies concolor* (Gord. & Glend.) Lindl. ex Hildebr.) and grand fir (*Abies grandis* (Douglas ex D. Don) Lindley). Juniper (*Juniperus occidentalis* Hook.) encroachment is occurring in some areas, principally in higher elevation big sage (*Artemisia tridentata* Nutt.) communities. As a result of fire suppression, some mixed-conifer areas, particularly those with high densities of Douglas-fir and white fir, are at risk for stand-replacing fire. Other multistory ponderosa pine stands are vulnerable to stress from drought,

The Deschutes National Forest is a diverse landscape of wet upper montane areas with mixed-conifer forest, volcanic formations, and dry desert, and includes habitat for more than 350 species of fish and wildlife.

disease, and bark beetle attacks.[1] The forest also supports several sensitive, threatened, and endangered species such as the northern spotted owl, which prefers dense forest canopies and complex vegetation. Other species are valued for recreation or cultural significance, like mule deer (*Odocoileus hemionus*), which require a range of zones from dry forests and shrub steppe in winter to moist forest types in summer.

Managers must consider how to maintain forest health while meeting several multiple-use objectives, including protecting critical habitats, defending homes from fire in the wildland-urban interface, supporting high recreational use, and providing timber, range, and forest products. Managing to meet one objective sometimes means compromising on another, while at other times objectives are complementary. The wide range of climatic gradients on the forest causes assessment of this balance to vary considerably across sites. Staff must weigh tradeoffs when evaluating management activities under consideration in different locations. This requires sharing information and collaborating across staff areas to identify and address site-specific priorities.

Many management issues are also landscape-scale and cross ownership boundaries, requiring collaboration with private landowners, Native American tribes, and other federal and state agencies. Public interests differ among ranger districts and project types. For example, in some settings, protection of wildlife habitat is a primary concern, whereas in others, reduction of fire risk near residential areas or expansion of recreation opportunities for user groups is in demand. Decisionmaking therefore involves evaluation of ecological, social, and economic expectations from a range of stakeholders in a specific context.

By incorporating ecological, social, and economic values, an ecosystem service framework offers a more extensive articulation and accounting of the costs and benefits of different management strategies.

An ecosystem service approach potentially can help managers address these challenges by enabling a more complete accounting of the range of goods and services that the forest provides, including analysis of relationships among multiple services and identification of ways in which various stakeholders might benefit from particular management actions. Ideally, an ecosystem service approach would complement traditional performance measures that focus on discrete targets for commodities, such as timber production, as indicators of successful management (Maleki 2008). By incorporating ecological, social, and economic values, an ecosystem service framework offers a more extensive articulation and accounting of the costs and benefits of different management strategies.

[1] Hemstrom, M. 2009. Skyline/Cascades timberlands analysis—VDDT Models. Unpublished document. On file with: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Forestry Sciences Laboratory, 620 SW Main Street, Suite 400, Portland, OR 97205. 38 p.

Describing the Value of the Deschutes National Forest in Terms of Ecosystem Services

> "Water, wildlife, carbon storage, opportunities for outdoor recreation and aesthetic enjoyment—all these values and more have elevated the importance of America's forests in the last 20 to 30 years. What we are doing is more valuable to the American people than ever."
>
> —*Forest Service Chief Tom Tidwell*

The Ecosystem Service Concept

Ecosystem services have been classified in a number of ways, depending on the intended use of the classifications (Patterson and Coelho 2009). However, one typology of services—the Millennium Ecosystem Assessment (MEA) (2005)—has received the most attention. In 2000, the United Nations called for a study to evaluate the status of the world's ecosystems and the services they provide. Research was conducted from 2001 to 2005 to assess the extent of ecosystem change caused by people and related consequences for human well-being. The resulting classification of ecosystem services focused on defining services by category and function. This provided a useful starting point for dialogue among policymakers, managers, stakeholders, and the public about how best to define the benefits that forests provide to people. Ongoing research efforts are building upon this foundation by developing a customized typology that more fully represents the ecosystem services provided by the Deschutes NF specifically (see "Ongoing Research" section).

The MEA grouped ecosystem services into four broad categories: provisioning, regulating, supporting, and cultural (fig. 2). These categories are described here, with an emphasis on the ecosystem services that forests provide, including examples from the Deschutes NF.

Provisioning services—
Provisioning services are the products or commodities obtained from forest ecosystems including timber, food, and fresh water. Wood forest products consist of building and chipable materials as well as fuel wood. Several projects on the Deschutes NF, including logging and fuel treatments, generate small-diameter material that can be used for traditional timber products such as dimension lumber, chips, and firewood, as well as other new product markets such as shavings, pellets, hogg fuel, biofuels, and mulch. In addition, forests provide important indigenous "first foods," including plants, berries, roots, and mushrooms, to tribes and other populations. Forests also offer a variety of nontimber products such as decorative cones, boughs, and grasses, as well as fiber, resins, and medicinal plants.

Ecosystem Services	
Supporting services Nutrient cycling Soil formation Primary production	**Provisioning services** Food (crops, livestock, wild foods, etc.) Fiber (timber, cotton/hemp/silk, wood fuel) Genetic resources Biochemicals, natural medicines, pharmaceuticals Fresh water
	Regulating services Air quality regulation Climate regulation (global, regional, and local) Water regulation Erosion regulation Disease regulation Pest regulation Pollination Natural hazard regulation
	Cultural services Aesthetic values Spiritual and religious values Recreation and ecotourism

Figure 2—The Millennium Ecosystem Assessment developed a commonly referenced classification of ecosystem services.

Fresh water is one of the most valuable ecosystem services provided by forests (fig. 3). Forested land absorbs rain, recharges underground aquifers, cools and cleanses water, and sustains watershed stability and resilience (USDA FS 2000). Water provided by forests supports vegetation, supplies fresh drinking water, sustains agricultural production, enables power generation, and creates habitat for aquatic species with subsequent economic, recreational, and cultural benefits (Postel and Carpenter 1997).

The total volume of surface water that drains off the Deschutes NF is approximately 714 billion gallons per year, and provides half of the city of Bend's drinking water supply. Several local irrigation districts also use this water source for agricultural production on private land. The Avion Water Company, one of the area's largest water utilities, irrigates 20,000 acres with water from Wickiup Reservoir, which is located on the Bend-Fort Rock Ranger District.

Tom Iraci

Figure 3—Approximately 714 billion gallons of fresh water flow from the Deschutes National Forest annually.

Streams on the Deschutes NF are predominantly spring fed, which means they rely on ground water as a source for surface and subsurface flow. The aquifer volume for the high Cascades is estimated to be about the same as the Great Salt Lake, or almost 8 trillion gallons. The advantage of ground water dominance in the Deschutes NF is that water can continue to discharge in late summer and provide critical habitat for such fish species as the threatened bull trout (*Salvelinus confluentus*), which requires cold water temperatures for reproduction. The fish stocks of the Pacific Northwest that depend on forest freshwater systems are central to the cultural values of many local communities, and contribute to the region's economy (USFS 1993 as cited in Myers 1997). Water bodies such as lakes, reservoirs, and streams are a draw for multiple recreational uses (USDA FS 2000), which are discussed further in the "Recreation" sidebar on page 19.

Biomass Partnership With the Confederated Tribes of Warm Springs

Biomass utilization is being explored across the country as a potential alternative to fossil fuel use, as well as a source of forest product revenue for communities. On its reservation in central Oregon, the Confederated Tribes of Warm Springs (CTWS) is developing a 20 megawatt (MW) cogeneration powerplant located at a CTWS sawmill. This plant will provide steam to Warm Springs Forest Products Industries for lumber-drying purposes and will provide at least 15.8 MW of electrical generating capacity. This could increase electricity generated from biomass in Oregon by nearly 11 percent (Nielsen et al. 2006). The plant is currently seeking investment funds, and relationships with public land management agencies are helping to attract financial support. The Deschutes, Ochoco, and Mount Hood National Forests, as well as the Bureau of Land Management's Prineville District, have entered into a memorandum of understanding with the CTWS to provide a reliable supply of material to the plant. The agencies have committed to offering 80,000 bone dry tons of biomass annually to markets near the reservation.

In addition to providing biomass for the cogeneration plant, thinning operations on public lands can create important co-benefits, like improvements in forest health, resilience to climate change, habitat restoration, and recovery of native plant and animal distributions. Thinning can also support production of important “first foods” valued by tribes and diverse constituencies. As discussed below, management activities aimed at one ecosystem service objective have the potential to create other beneficial outcomes.

Regulating services—

Regulating services are the benefits obtained from an ecosystem’s impact on natural processes, which influence climate, water flows, and plant reproduction. Forests play a critical role in the water cycle by capturing, storing, and transferring water, and enabling its gradual discharge over time (fig. 4). Precipitation infiltrates forest soils, where water is stored and slowly released to plant roots, surface water resources, ground water, and the atmosphere through transpiration (Neary et al. 2009). This regulates flows, reduces flood peaks, and returns moisture to the atmosphere. Vegetation is key to this process. Leaves, plants, and litter protect soil from the potentially destructive force of raindrops, preventing runoff and soil erosion. This helps retain a site’s production potential, infiltration, and nutrient levels (Daily et al. 1997a). Wetlands are particularly important for reducing flood

Tom Iraci

Figure 4—Forests and wetlands regulate water flows by capturing, storing, and transferring water and moderating its discharge over time. This reduces flood peaks, supports the growth of vegetation, and returns moisture to the atmosphere through transpiration.

impacts by moderating flows and allowing sediments to be deposited rather than be transported downstream. Wetland systems also purify water and treat wastes through nutrient cycling, which is discussed further in "Supporting Services."

Daily et al. (1997a) articulated the importance of these services by highlighting erosion's costs to natural and human-made systems. They explained that "downstream costs [of erosion] may include disrupted or lower quality water supplies; siltation that impairs drainage and maintenance of navigable river channels, harbors, and irrigation systems; increased frequency and severity of floods; and decreased potential for hydroelectric power as reservoirs fill with silt" (Pimentel et al. 1995 as cited in Daily et al. 1997a). The integrity of forest soils and vegetation has considerable impact on hydrology, aquatic habitats, and economic uses of water supplies and waterways.

Forests also influence climate by regulating air quality, temperature, and concentrations of atmospheric greenhouse gases (fig. 5). Trees sequester many pollutants from the air, including nitrogen dioxide, sulfur dioxide, ozone, and carbon monoxide. They provide shade and surface cooling, block winds, and restore moisture to the atmosphere through transpiration, which eventually returns to the earth as precipitation. Because plants sequester carbon in biomass through photosynthesis, they have the potential to mitigate climate change caused

Tom Iraci

Figure 5—Forests regulate climate and remove pollutants from the air. Management of land cover is critical to stabilizing runoff, preventing erosion, and maintaining carbon stores over time.

by increasing concentrations of atmospheric carbon dioxide (CO_2) (IPCC 2007). Forest type, stand age, and growth rates have a considerable impact on carbon sequestration in biomass over time. Comprehensive forest management policies that integrate climate change and ecosystem services have the potential to address climate concerns while protecting ecosystem functions (Deal et al. 2010).

David Cappaert, Michigan State University, Bugwood, org

Figure 6—Forests provide habitat for pollinators, which are essential to the functioning of ecosystems and the benefits they provide. Pollinators support plant reproduction and ecosystem health, and sustain habitat and food supplies for humans and wildlife.

Pollination is another regulating service supported by forests through provision of habitat for pollinators, including bats, bees, beetles, birds, butterflies, and flies, which are required for the successful reproduction of many flowering and wild plants (fig. 6). Approximately 90 percent of plants for which the mode of pollination is known require an animal to accomplish this task, including about 70 percent of agricultural crop species (Daily et al. 1997a). Maintaining healthy populations of pollinators is essential to sustaining human food supplies as well as wildlife habitat and forest ecosystems.

Supporting services—

Supporting services are necessary for the maintenance and support of all other ecosystem services. Their impacts on people are often indirect, but they are critical building blocks of functioning systems. Examples include such processes as soil formation, nutrient cycling, and primary production.

Soil is formed from the weathering of rocks and minerals and the accumulation of organic matter over time. This process can take hundreds to thousands of years, and is crucial to the functioning of ecosystems and human societies (Adams 1981 as cited in Daily et al. 1997a). In addition to moderating the water cycle as discussed above, soil provides several other important services by supporting and sheltering seeds as they mature into adult plants, and retaining nutrients near the soil surface in humus and clays so they are available to plant roots (Daily et al. 1997b). The ability of soils to supply nutrients to plants largely results from the presence of organisms, including bacteria, fungi and worms, which serve a variety of roles including nitrogen fixation and decomposition of dead organic matter and wastes. Organic material in the forest floor and surface mineral horizon can also adsorb and decompose polluting inputs, including pesticide residues (Neary et al. 2009). Forested wetlands have particularly positive impacts on nutrient cycles by reducing nitrogen, phosphorus, and sulfur concentrations through plant growth, soil adsorption, and anaerobic processes (Osmond et al. 1995, MEA 2005). Soils and soil organisms therefore are critical to transforming potentially harmful nutrients, transferring them to plant growth, and improving water quality.

In addition to playing an important role in the nitrogen, phosphorus, and sulfur cycles, soils are a crucial component of the carbon cycle. Nearly all life forms directly or indirectly rely on this process. A critical step in the carbon cycle is primary production, or the creation of organic compounds and plant biomass from atmospheric CO_2 through photosynthesis. After plants and trees die, their branches, leaves, and roots are decomposed by micro-organisms, which release some CO_2 to the atmosphere, while retaining carbon in the forest floor and soil (fig. 7). In the Pacific Northwest, mineral soil represents 21 percent of all carbon stored in a forest ecosystem, with an additional 16 percent stored by detrital and forest floor material (Smithwick et al. 2002). Management of these components has a considerable impact on carbon stored by forests.

Duncan Berry

Figure 7—Forests play an important role in life-supporting processes, including primary production and nutrient cycling.

Cultural services—

> "Perhaps the rebuilding of the body and spirit is the greatest service derivable from our forests, for what worth are material things if we lose the character and quality of people that are the soul of America."
>
> *—Arthur Carhart, Forest Service landscape architect, 1919*

Cultural services are the nonmaterial benefits people derive from forests, including recreation, spiritual enrichment, and aesthetic experiences (fig. 8). For many, nature is indispensible for the wonderment and inspiration, peace and beauty, and fulfillment and rejuvenation it provides (Kellert and Wilson 1993, as cited in Daily et al. 1997a). In addition to valuing the existence of nature generally, people may have specific attachments to particular places, landscapes, or experiences. This is true of places that are aesthetically, culturally, or historically significant, as well as other places that are not seemingly significant to the observer (Farnum et al. 2005). Social interactions with friends and family and experiences with features of a place define visitors' and residents' sense of place, attachment to place, and the feeling that a community attributes to a specific landscape (Eisenhauer at al. 2000, Kruger and Jakes 2003). The draw of these places and experiences can influence where people live, work, and recreate.

Tom Iraci

Figure 8—The recreational, spiritual, and aesthetic values of the Deschutes National Forest attract millions of visitors each year.

Recreation—The Deschutes National Forest (NF) is one of the Pacific Northwest's most highly used national forests for recreation. Data regarding recreational use can be difficult to capture, particularly at the forest scale. However, findings from the FY08 USDA National Visitor Use Monitoring (NVUM) survey and other regional assessments have helped illustrate the Deschutes NF's recreational value.[2]

Annually, there are 1.9 million recreation visits to the Deschutes NF. Like other national forests, the majority (46 percent) of these visits are day trips by local visitors who live within 50 miles of the recreation site. About 10 percent of Deschutes NF visits are associated with nonlocals who are camping on the forest and another 10 percent with nonlocals who recreate on the forest and stay overnight in local hotels, resorts, or private campgrounds. The Deschutes NF offers a number of convenient opportunities to view natural scenery and features; each year the forest attracts more than 200,000 "side trip" visits from individuals who travel to the central Oregon area for business, to visit friends or relatives, or for other reasons unrelated to the national forest. The primary recreational uses on the Deschutes are hiking/walking (16 percent), downhill skiing/snowboarding (16 percent), and viewing natural features (15 percent). About 15 percent of visits are for fishing, hunting, or viewing wildlife.

Visitors were asked about their visit-related spending, including lodging, restaurants, groceries, gas and oil, and admission fees. Dollars spent per trip ranged from an average of about $33 per party for locals on day trips to about $788 per party for nonlocals paying for downhill skiing and overnight lodging (White and Stynes 2010). In a typical year, recreation visitors on the Deschutes spend about $111 million in nearby communities during their trips. This visitor spending generates about $80 million in sales at local businesses after accounting for some spending that immediately leaves the region. When local business sell goods and services to recreation visitors, these businesses make purchases from other local companies. This "secondary" economic activity stemming from recreation visitor spending amounts to an additional $25 million in sales at local businesses.

In addition to visitor use and spending, another source of economic value is spending by outfitters and guides. Outfitters who served Deschutes NF visitors in 2008 paid more than $113,000 in permit fees to access the Bend-Fort Rock District alone, which experiences the highest recreation use of any district on the forest. Gross annual income to permittees as a result of these activities was nearly $3.5 million. Finally, national forest personnel and concessionaires also spend money locally as they purchase services and goods to provide recreation opportunities.

[2] Visitor use and spending data were provided by Eric White, Oregon State University.

Aesthetics, sense of place, and cultural heritage values—The aesthetic characteristics of the Deschutes NF are among its most valued ecosystem services. The NVUM survey collects data about the quality of a visitor's experience by elements of importance. In the forest's FY02 survey, scenery ranked first or second for element importance and first for satisfaction at developed day use areas, overnight sites, and general forest areas (Kocis et al. 2003).

The attachment that visitors have to specific sites or locations also contributes to the forest's social value. These include locations that are historically and culturally significant, like food gathering sites, sacred places, and features associated with important events. The Deschutes NF contains over 4,000 archeological and historic sites. A notable example is the Santiam Wagon Road, which was used by settlers to reach central Oregon from the Willamette Valley, and which has been nominated to the National Register of Historic Places.

The Deschutes NF archeology staff collaborates with the Klamath Tribe, Burns Paiute Tribe, and Confederated Tribes of Warm Springs to protect sites that have cultural and spiritual value, including those that are used for harvesting of traditional foods. Many of these features, such as the Three Sisters mountain range and the Metolius Basin, are valuable to diverse constituencies and draw visitors from across the country. For some families, specific fishing sites, summer cabins, and lakes in the high Cascade Range have been visited for generations. These direct social, cultural, and historic experiences help people form attachments to places (Eisenhauer et al. 2000). Engaging with the public to inventory and monitor sociocultural meanings of places could enhance land managers' connections with the public and strengthen the public's connections with the land (Kruger and Jakes 2003).

Community economic development—The Deschutes NF is a defining feature of central Oregon. Proximity to the forest has been a major factor in the region's economic growth over the past few decades. Central Oregon accounts for only 5.6 percent of the state's total population, but attracts 20 percent of newcomers. Deschutes County experienced a 283-percent increase in population from 1970 to 2000 (USDC Census Bureau 2000). Much of the draw for new residents has been the outdoor recreation opportunities offered by state and federal lands in the region, including the national forest. The region somewhat epitomizes the "New West" in Oregon in that recent declines in natural-resource-extractive industries have been countered by increased tourism, outdoor recreation, and amenity-based inmigration (Judson et al. 1999). The cities

of Bend and Sisters, for example, are noted as desirable travel destinations in national media, offering some of the Nation's best mountain biking (Laskin 2004, Preusch 2004). Access to the forest is marketed by real estate developers as well as by destination resorts such as Black Butte Ranch and Sunriver Resort. Association with the Deschutes NF enhances the value of these properties and is a draw to the region as a whole.

Biodiversity—

Biodiversity is characterized by the MEA as an essential underpinning of ecosystem health and function with subsequent effects on ecosystem services provided by ecological systems (MEA 2005). As stated by Mace et al. (2005), "direct benefits such as food crops, clean water, clean air, and aesthetic pleasures all depend on biodiversity, as does the persistence, stability and productivity of natural systems." The diversity of the plant, animal, and microbial species living within a community influence critical processes including plant productivity, soil fertility, water quality, nutrient cycling, pollution and waste reduction, biomass accumulation, resistance to disease and disturbance, and other environmental conditions that affect human welfare (Naeem et al. 1999, Tilman 1997). Biodiversity can also be valued for its intrinsic worth, or existence value, and may provide potential future benefits that are yet unknown or unrecognized (Tilman 1997).

The Deschutes NF is situated across climatic and geologic gradients that give rise to high genetic diversity. The forest contains both cool wet subalpine environments and warm semiarid plateaus. Precipitation ranges from 145 inches per year at the summit of South Sister to 12 inches in Bend. This range of conditions may provide sites for rare and common species to persist and adapt to climate change.

The wide variety of vegetation and habitat types on the Deschutes NF supports hundreds of significant fish and wildlife species. These include several sensitive, threatened and endangered species, such as the northern spotted owl, the Oregon spotted frog (*Rana pretiosa*), Pacific fisher (*Martes pennanti*), greater sage grouse (*Centrocercus urophasianus*), white-headed woodpecker (*Picoides albolarvatus*), bull trout and steelhead (*Oncorhynchus mykiss*), as well as game species including mule deer, Rocky Mountain elk (*Cervus elaphus*), western pronghorn (*Antilocapra americana*), cougar (*Puma concolor*), bears, and game birds (fig. 9). These species have cultural and recreational value, and provide provisioning services to communities.

Frank Vanni

U.S. Fish and Wildlife Service

Figure 9—The Deschutes National Forest provides habitat for more than 350 species of fish and wildlife, including the northern spotted owl, mule deer, Rocky Mountain elk, bull trout, and steelhead salmon.

Management Activities and Ecosystem Services

Shifts in language and perspective can illustrate and identify the ecosystem service outcomes of agency activities and encourage collaboration across resource areas to manage these outcomes, with an emphasis on integrated stewardship of ecological processes and functions.

Forest Service management activities have the potential to increase, decrease or maintain ecosystem services provided by national forest lands. Understanding these relationships can help staff with planning, priority-setting, and decisionmaking, and could strengthen communication and collaboration with the public. Shifts in language and perspective can illustrate and identify the ecosystem service outcomes of agency activities and encourage collaboration across resource areas to manage these outcomes, with an emphasis on integrated stewardship of ecological processes and functions. This section provides background about projects that have been or could be implemented on the Deschutes NF, includes examples of metrics currently used to measure program accomplishments, and illustrates the potential of describing these activities in terms of ecosystem service outcomes.

Sample Management Activities

The following summaries are intended to provide examples of some agency projects, although they are not complete or fully representative of all programs. Sidebars provide a greater level of detail to better illustrate the relation between selected project types and ecosystem services.

Water and soils—

The quantity and quality of water on the Deschutes NF is influenced by a wide range of project types and involves collaboration across several staff areas including hydrology, fisheries, engineering, and soil science. Activities include:

- Planting of vegetation in riparian areas to avoid high water temperatures, sedimentation, and turbidity in rivers and streams.
- Restoration of stream channel shape and function in areas previously drained for agriculture.
- Monitoring of water quality and temperature.
- Restoration of slopes, meadows, and channels to improve ground water storage and sustain late-season flows (USDA FS 2000).
- Setting limits on soil compaction and erosion caused by logging operations and fuel treatments.
- Tillage treatments to restore soil porosity; promote the movement of water, air, and heat in the soil; and improve seedling survival in reforestation sites.[3]
- Design of road drainage systems and road closures to prevent runoff and diversion of ground water to surface flows.

[3] Craigg, T. 2000. Subsoiling to restore compacted soils. Transcript from 21st annual forest vegetation management conference. On file with: Deschutes National Forest, 1001 SW Emkay Drive, Bend, OR 97702.

- Collaboration with the Oregon Water Resources Department, Deschutes River Conservancy, and irrigation districts to manage piping volumes and sustain ground water recharge.

Fish and wildlife—

- Restoration of aspen, meadows, and marshes, and protection of rock outcrops to support wildlife.
- Rebuilding connections between fragmented forest landscapes by closing roads and planting native vegetation.
- Addition of wood to streams to provide spawning and rearing habitat.
- Improvements to fish passage, including culvert replacement.

Vegetation—

- Selected reforestation following wildfire, road rehabilitation, and stream restoration.
- Maintenance of seed banks to protect genetic resources.
- Removal of invasive species.
- Harvest of timber to produce economic benefits for local communities.
- Silvicultural activities to restore forest structure and composition in areas subject to fire suppression and logging of old-growth pine trees.

Fisheries Program Involvement on Private Lands

Deschutes National Forest staff are involved with stream restoration and habitat improvements on private lands. These efforts include partnerships with the Upper Deschutes and Crooked River Watershed Councils, Deschutes Land Trust, and Three Sisters Irrigation District to restore flood plains, improve fish passage, and restore channels. The forest is also involved in mitigation of impacts from the Pelton Round Butte hydroelectric project located on the Deschutes River. Since 2005, $13 million has been invested in projects on federal, tribal, and private lands, including stream restoration, culvert replacement, diversion removal, fish passage improvements, and environmental education. Approximately $14 million in additional funds will be distributed by 2020. Investments have also been made to improve irrigation infrastructure and management, with an expected total of $11.5 million by 2013.

Invasive Species Impacts on Ecosystem Services

Many invasive species have negative impacts on ecosystem services by causing declines in populations of native plant species that contribute to healthy ecosystems. Invasive plants can increase soil erosion, deplete nutrients and water, and quickly outcompete native vegetation. This often results in declining habitat and forage for livestock; loss of threatened, endangered and sensitive species; and reduced soil productivity (USDA FS 2009).

Invasive plants also affect the quantity and quality of recreational activities such as fishing, hunting, hiking, wildlife viewing, and water-based recreation. They can impede access, interfere with watercraft, lower water quality, and reduce the abundance and diversity of fish and wildlife (Eiswerth et al. 2005). Reduction of recreation use can have significant economic implications for both national forest lands and surrounding communities.

Fire and fuels—

- Thinning to reduce drought stress and vulnerability to insect attacks.
- Prescribed burning to remove surface fuels and reduce fire intensity.
- Reduction of fire risk in forests that border communities.

Recreation—

- Planning and management of trails that provide a sustainable level of access to forests and waterways.
- Design and development of interpretive sites to increase understanding of and appreciation for natural and cultural resources and management issues on national forest lands.
- Development of campgrounds and other facilities.
- Monitoring use of wildernesses, wild and scenic rivers, national scenic and historic trails, and other Congressionally designated areas.

Effectiveness of Hazardous Fuel Treatments

Active management of fuels can help prevent catastrophic loss of forest cover and protect the ecosystem services forests provide (Stephens et al. 2009). Thinning can improve forest health, increase forest resilience to disturbance, and enhance critical habitat (Hayes et al. 1997, Stephens et al. 2009). An additional benefit of these treatments is protection of homes that border forests. On average, approximately 60 percent of fuel treatments on the Deschutes NF occur in the wildland-urban interface. This results in protection of millions of dollars of real estate and increases the safety of communities.

In fiscal year 2008, 25,000 acres were treated on the Deschutes NF with the goal of contributing to the reduction of fire risk. In 2007, three wildfires in the Pacific Northwest were assessed to determine whether fuel reduction treatments had an impact on fire behavior (USDA FS 2007a). The most notable and recent example was the GW Fire, which affected a fuel-treatment area located between the fire and a high-value wildland-urban interface area. Lightning ignited the GW Fire on August 31 in the Mount Washington Wilderness west of Sisters, Oregon. The fire burned 5,887 acres of the Deschutes NF. Twenty-five percent of the Forest Service lands that burned had received prior fuel or other vegetation treatments. In areas with favorable weather conditions and a mosaic of fuel treatments, fire behavior was modified, thus allowing effective suppression activities, which slowed fire spread. This increased the forest's resilience to fire, retained vegetation cover, and protected nearby communities.

Performance Measures

The Forest Service currently reports its program accomplishments in metrics required by Congress (acres treated, miles of stream restored, board feet sold, etc.). However, these categories and targets do not fully capture the outcomes of management activities from an ecosystem service perspective. For example, projects that reduce fuel with the intent of decreasing fire risk and improving forest health are currently reported as "fuel treatments" and are described in terms of acres treated, which focuses on spatial units of activity rather than the outcomes that result. These projects could also be described in terms of improving vegetation function and increasing forest resilience, with subsequent ecosystem service benefits. The following tabulations provide examples of management activities by category as they are currently defined and reported, and compare these output-based metrics to examples of potential ecosystem service outcomes that could result from the projects or actions listed. These lists are not complete or fully representative, but are intended to illustrate the potential of ecosystem service language to enhance communication about program delivery.

Recreation—

Activity	Target/metric	FY08 accomplishment	Examples of ecosystem service outcomes
Trail construction or reconstruction	Miles	9.0	• Recreational experiences (hiking, biking, skiing, hunting, motorized vehicle use, etc.) • Aesthetic and spiritual experiences • Sense of place • Cultural heritage values • Protection of fragile ecosystems (wetlands, streams, alpine areas)
Visitor use `	Number of visits	1.9 million (FY08 National Visitor Use Monitoring survey)	• Recreational experiences (hiking, biking, skiing, hunting, motorized vehicle use, etc.) • Aesthetic and spiritual experiences • Sense of place • Cultural heritage values • Community economic development and higher real estate values

Fuel treatment—

Activity	Target/metric	FY08 accomplishment	Examples of ecosystem service outcomes
Fuel reduction	Acres	25,000	• Increased forest resilience to disturbance, resulting in sustained vegetation cover and subsequent provisioning, regulating, supporting, and cultural services • Enhancement of wildlife habitat • Community safety • Economic benefits (property protection)

Forest products—

Resource	Target/metric	FY08 accomplishment	Examples of ecosystem service outcomes
Timber	Million board feet	55.34 (lumber and chipable material)	• Wood and nontimber forest products • Reduced fuel loading, which increases forest resilience to drought stress and insect attacks, resulting in sustained vegetation cover, thereby providing regulating, supporting, and cultural services • Enhancement of wildlife habitat • Community economic benefits
Biomass	Bone dry tons	80,000 (approx.)	• Wood products • Alternative fuel source • Enhancement of wildlife habitat • Economic benefits for local communities and industries

Watershed restoration—

Resource/activity	Target/metric	FY08 accomplishment	Examples of ecosystem service outcomes
Watershed restoration	Acres	44	• Fresh water • Climate, water, and erosion regulation • Fish and wildlife habitat • Recreational opportunities • Aesthetic and spiritual experiences • Economic benefits from irrigation • Water quality improvements • Enhanced nutrient cycling
Soil restoration	Acres	1,966	• Improved plant growth, resulting in provisioning, regulating, supporting, and cultural services • Regulation of waterflow • Filtration of nutrients and pollutants resulting in improved water quality
Noxious weed removal	Acres	3,156 (manual) 1,361 (herbicide)	• Improvements in site productivity, supporting vegetation growth and subsequent provisioning, regulating, and supporting services • Wildlife habitat and forage • Recreation opportunities (hunting, hiking, water-based recreation)—see "Invasive Species" sidebar on page 23 • Aesthetic experiences • Water quality improvements

Addressing Relationships Among Ecosystem Services in Management Decisionmaking

> "Where once we tended to compartmentalize, managing for a particular good or service—timber here, forage there, recreation over here, urban forest over there—today we tend to focus more on restoring a whole range of goods and services across entire landscapes. We do that by restoring the functions and processes characteristic of healthy, resilient forest ecosystems—ecosystems capable of delivering clean air and water, wildlife habitat, carbon sequestration, and all the other benefits that Americans want and need."
>
> —*Forest Service Chief Tom Tidwell*

Articulating Forest Service management objectives and accomplishments in terms of ecosystem services marks a shift in perspective and could provide staff with more opportunities to manage ecological functions and processes in addition to outputs.

Articulating Forest Service management objectives and accomplishments in terms of ecosystem services marks a shift in perspective and could provide staff with more opportunities to manage ecological functions and processes in addition to outputs. As illustrated above, ecosystem service objectives can be addressed by activities across program areas. Rather than meeting an individual resource target, program staffs could work collectively toward shared outcome-related goals that support healthy, resilient forests and the ecosystem services they provide. Understanding the relationship between the quality and quantity of services provided, and the conditions of the ecosystems that provide them (Daily 1997b), can also help managers set priorities, identify restoration needs, establish management goals, and illustrate the rationale for their decisionmaking.

Critical to this analysis is consideration of how a particular management activity or series of activities could affect ecosystem function and the suite of services provided on a given site or across a landscape. **Although ecosystem services can be described individually by type, the sections above illustrate that they are inherently interactive and interdependent as part of a natural system**. Forest managers recognize this; several on the Deschutes NF have expressed a desire to work collectively to address these relationships in management decisionmaking. Fire risk, for example, is a primary concern for staff and the public, and fuel management is critical to sustaining a resilient landscape. Fuel treatment decisions affect nearly all other ecosystem services, including the forest's water quality, wildlife habitat, and recreation opportunities. Deciding where, when, and to what extent to treat fuel should ideally involve consideration of these other services.

The complexity of management issues, and the goal of sustainably managing flows of ecosystem services over time, also lends itself to collaborative decisionmaking with stakeholders outside the agency. Maintaining the health of forest

ecosystems often demands a landscape-scale approach across ownerships. Involving other agencies, private landowners, tribes, civic leaders, business owners, conservationists, and others in discussions about forest management contributes to more informed planning that reflects ecological and public priorities. Working collectively in project development can also reduce conflict and litigation, which often delay project implementation.

Sustaining Ecosystem Services Through Partnerships

> "The key is collaboration. No one of us can do it alone—the challenges are just too great. Landscape-scale conservation brings people together to collaborate across ownerships, to address shared issues and common concerns, and to pursue common goals based on mutual respect."
>
> —*Forest Service Chief Tom Tidwell*

The language of ecosystem services potentially offers a means for identifying mutual interests and building or strengthening collaborations that enhance the goods and services provided by Forest Service lands.

The Deschutes NF has achieved some of its most impressive restoration work through partnerships. The Soil and Water Program alone has achieved a 5:1 ratio of partner to Forest Service investment in management activity. Collaboration with external organizations has enabled the forest to fund and implement projects that are unlikely to have happened otherwise. The language of ecosystem services potentially offers a means for identifying mutual interests and building or strengthening collaborations that enhance the goods and services provided by Forest Service lands. Examples of two such existing partnerships are highlighted below, followed by descriptions of potential partnerships that could be explored based on shared interests in ecosystem services.

Examples of Existing Partnerships

National Forest Foundation: Whychus Creek restoration—
Whychus Creek once provided habitat for one of the biggest populations of steelhead salmon (commonly known as trout) in the Deschutes River Basin. In the early 1900s, its channels were straightened for agricultural purposes and nearly 90 percent of its water was diverted for irrigation. This destroyed pools and critical spawning areas. To address this loss, the Forest Service is engaging in a collaborative effort supported by several stakeholders, including a $1.7 million contribution from the National Forest Foundation (NFF). The Deschutes River Conservancy, the Deschutes Land Trust, and Deschutes NF staff are working together to restore the original creek channel, replant native vegetation, and remove obstacles to fish passage. Irrigation districts are involved to maintain flow in the creek to recover habitat and watershed health. In addition to improving conditions for steelhead, this restoration effort will result in such important co-benefits as a higher water

table and enhancements in bird forage and water quality. Working collaboratively has enabled Deschutes NF staff to address multiple causes of the creek's degradation and implement a long-lasting and successful restoration effort.

Reforestation funded by American Forests and Arbor Day Foundation— The Deschutes NF has received funding for reforestation from organizations that recognize the importance of maintaining healthy forests for ecosystem service provision, including reducing erosion and providing a sustainable supply of clean water. American Forests and Arbor Day Foundation have provided a total of $245,800 for reforestation of over 4,000 acres of the forest following wildfire between 2005 and 2008 (fig. 10).

Tom Iraci

Figure 10— Reforestation funded by Deschutes National Forest partners has helped sustain ecosystem services provided by healthy watersheds.

Potential Ecosystem-Service-Based Partnerships

National Forest Foundation: Carbon Capital Fund—
In addition to funding restoration, the NFF provides financial support for carbon sequestration demonstration projects on national forest lands. The NFF has expressed interest in funding reforestation projects on the Deschutes NF that meet Voluntary Carbon Standard guidelines. Potential sites would be those in recent fires, blowdowns, or other disturbance areas that would not otherwise be planted because of high projected costs or inadequate funding. Sites would also need to sequester more carbon through planting than through natural regeneration processes. National

forest lands would not directly enter private carbon markets as offset sites—rather, projects would be developed in accordance with standards and guidelines in the forest plan, and would be managed for multiple objectives in addition to carbon sequestration, including habitat and water quality improvements. Projects would also need to incorporate analysis of the financial and ecological costs of planting as compared to natural regeneration processes, which provide critical supporting ecosystem services. These services include restoration of nitrogen in soils prior to revegetation by trees, and increases in plant and wildlife diversity.

Environmental and conservation organizations—
The Deschutes NF has been very successful at establishing relationships with environmental organizations, land trusts, and watershed councils, particularly through the restoration of Whychus Creek and the Metolius River, and landscape restoration efforts through Community Wildfire Protection Plans. Many of these partnerships are based on common interests in ecosystem services, including restoration of critical habitats and watersheds. Describing the ecosystem service benefits of ongoing management actions, such as road decommissioning, tillage practices that mitigate soil compaction, and invasive species removal, could attract new investment in typical Forest Service projects that do not currently garner as much attention from funders.

Recreation groups—
Hunting organizations like the National Wild Turkey Federation, Rocky Mountain Elk Foundation, and Ducks Unlimited fund habitat restoration to further their recreation objectives and support the forest's wildlife management goals. By planning projects collaboratively in areas that are of high priority for both managers and hunters, funds can be leveraged to support restoration. A similar approach could be taken with mountain bikers, hikers, off-highway vehicle users, and cross-country skiers, whose user groups already donate volunteer hours in areas of mutual interest. The forest currently has a Trail Users Advisory Group and is developing a forestwide recreation advisory collective managed by its Provincial Advisory Committee, which facilitates communication between federal and nonfederal entities to help implement the Northwest Forest Plan. As the economic benefits of recreation to the Bend community are more clearly defined, related industries like equipment suppliers and lodging providers may be motivated to become engaged in recreation development on the forest. This could include funding or collaboratively planning projects that create new user opportunities and enhance visitor satisfaction.

Community and economic development organizations—
Management of national forest lands is affected by the social and economic conditions of surrounding communities. Ideally, the Deschutes NF and local economies could derive mutual benefit from the development of industries for innovative and sustainable wood products like biomass. Organizations such as the Central Oregon Intergovernmental Council and Sustainable Northwest are supporting the growth of conservation-based industries through collaborations with public officials, professionals, entrepreneurs, and potential investors. Through partnerships with these stakeholders, the Deschutes NF could develop its role in nascent wood product markets and take steps to facilitate their growth.

A viable biomass economy could serve both economic and ecological objectives. Thinning, for example, can improve watershed values by reducing water stress, increasing resilience to fire and disease, and enhancing critical habitat, while providing inputs for biomass markets. Many national forests have identified a greater forest restoration need than can be addressed by the agency budget allocated by Congress. Favorable market conditions for biomass can support sustainable wood products industries while providing revenue for restoration.

Timber production—
Timber continues to be an important ecosystem service provided by national forest lands. Understanding the relationship between timber harvests and other ecosystem services will inform decisionmaking about where and to what extent logging is sustainable or beneficial to forest health by improving habitat and watershed values or reducing fire risk. Gains and losses to other services, like recreation and aesthetic values, must be considered. Organizations such as the American Forest Resource Council, which represents forest product manufacturers and forest landowners, may be interested in supporting the development of tools that increase public confidence in the planning and implementation of logging operations. A viable forest industry also provides capacity to undertake forest restoration activities that require a trained workforce and mills to process resulting wood products (Oliver 2009).

Private landowners—
The type and quality of ecosystem services provided by the Deschutes NF are affected by the management of lands beyond its borders. Instream flow for migratory fish, for example, is affected by management throughout a watershed. Because private lands account for almost 60 percent of the Nation's forests, their stewardship is critical to sustaining supplies of ecosystem services across the landscape (Collins and Larry 2008). Over 11 percent, or 17.9 million acres, of private forests is likely to see dramatic increases in housing development by 2030 (Stein et al. 2005 as cited

By partnering with private landowners, the Forest Service can protect the provision of ecosystem services, enhance their quality, and in some cases avoid the need for costly management actions on public lands.

by Collins and Larry 2008). This loss of forest land will affect water quality, fish and wildlife habitat, forest health, and recreational access, and could increase pressure on services provided by national forests (Collins and Larry 2008).

By partnering with private landowners, the Forest Service can protect the provision of these services, enhance their quality, and in some cases avoid the need for costly management actions on public lands. By testing metrics and sharing methodologies for managing ecosystem services on national forests, the agency could support the development of ecosystem service markets in the private sector, which present financial opportunities for working forests that extend beyond traditional forest products (Collins and Larry 2008). Conceptually, markets compensate landowners who engage in restoration activities that provide ecosystem services, such as carbon sequestration, water quality improvements, or enhanced fish and wildlife habitat. Buyers of these services include agencies, developers, utilities, industries, and others who are required to offset or mitigate their impacts on regulated ecosystem services as mandated by legislation such as the Endangered Species Act, the Clean Water Act, or greenhouse gas emissions standards. Other ecosystem service buyers are motivated by a desire to protect the quality of a resource that they value or rely on, such as biodiversity or clean water. This additional source of revenue for private landowners could increase investment in restoration and help them confront increasing pressure to convert their forests to other uses. By developing ecosystem service metrics on national forest lands, and providing technical assistance to private landowners who would like to engage in these markets through the State and Private Forestry branch of the agency, the Forest Service can help protect the benefits provided by a mixed-ownership forest landscape.

In addition to facilitating the involvement of landowners in markets, the Forest Service can work collaboratively to improve the management of forests beyond its borders. The Deschutes NF is authorized by the Wyden Amendment (Public Law 109-54, Section 433) to enter into cooperative agreements to conduct management activities on private lands for the protection, restoration, and enhancement of habitat or reduction of fire risk. This amendment was included by Congress in the FY 2009 Omnibus Appropriations Act, and later extended through the end of FY 2011, to authorize use of Forest Service funds for watershed restoration and enhancement agreements on private or public lands that benefit the resources of national forest lands. An ecosystem service approach can help the Deschutes NF identify areas of concern and target investments that will enhance the services provided across ownerships.

Municipal watersheds—
The city of Bend derives half of its water supply from Bridge and Tumalo Creeks, which flow from the Deschutes NF. Forest Service management activities that maintain water quality, including riparian management and prevention of surface runoff and erosion, result in water treatment cost savings for the city. Several other municipalities, including Portland, have developed relationships with the Forest Service to manage and protect watersheds for drinking water. The Portland Water Bureau has signed an agreement with the Mount Hood NF to cooperatively manage the Bull Run watershed, a primary municipal water source. This includes joint stewardship activities to maintain roads, control invasive weeds, protect streams, and monitor water quality. Similar investments by Bend could result in water treatment savings for the city and generate co-benefits like habitat restoration.

Ongoing Research and Future Needs

At the outset, we outlined four potential uses of the ecosystem services concept to the Forest Service: (1) describing the various benefits that national forests provide to the American public, (2) helping the agency to approach decisionmaking from the perspective of ecosystem service outcomes, (3) assessing whether ecosystem service flows are in decline and developing strategies for sustaining them while conserving resources over time, and (4) facilitating collaborative work with stakeholders, including communities, tribes, and nongovernmental organizations. If we are to further pursue these potential uses, we must examine in greater detail how the ecosystem service concept can serve each of these purposes.

This report provides a foundation for this investigation by (1) characterizing the concept of ecosystem services as it could apply to national forests, (2) using the Deschutes NF as a case study to describe the value of an ecosystem services approach, (3) providing examples of how management actions and performance measures can be characterized in terms of ecosystem services, and (4) identifying partners with potential to collaboratively plan, fund, or implement projects.

A related purpose of this report is to identify steps that are necessary before ecosystem service concepts can be implemented in a management setting. Existing Forest Service data and reporting systems do not completely capture the full suite of services that national forests provide to the public. Land managers also face a paucity of quantified, scale-specific information about ecosystem service use, users, and user options that help provide context for the benefits a national forest provides. The MEA classification was a useful tool to define ecosystem services generally, but a place-based typology is needed that more directly reflects the Deschutes NF context. The Pacific Northwest Research Station is in the process of helping define

this typology and develop an ecosystem service-approach to planning and decisionmaking (fig. 11). These efforts are described below, followed by suggestions for future research.

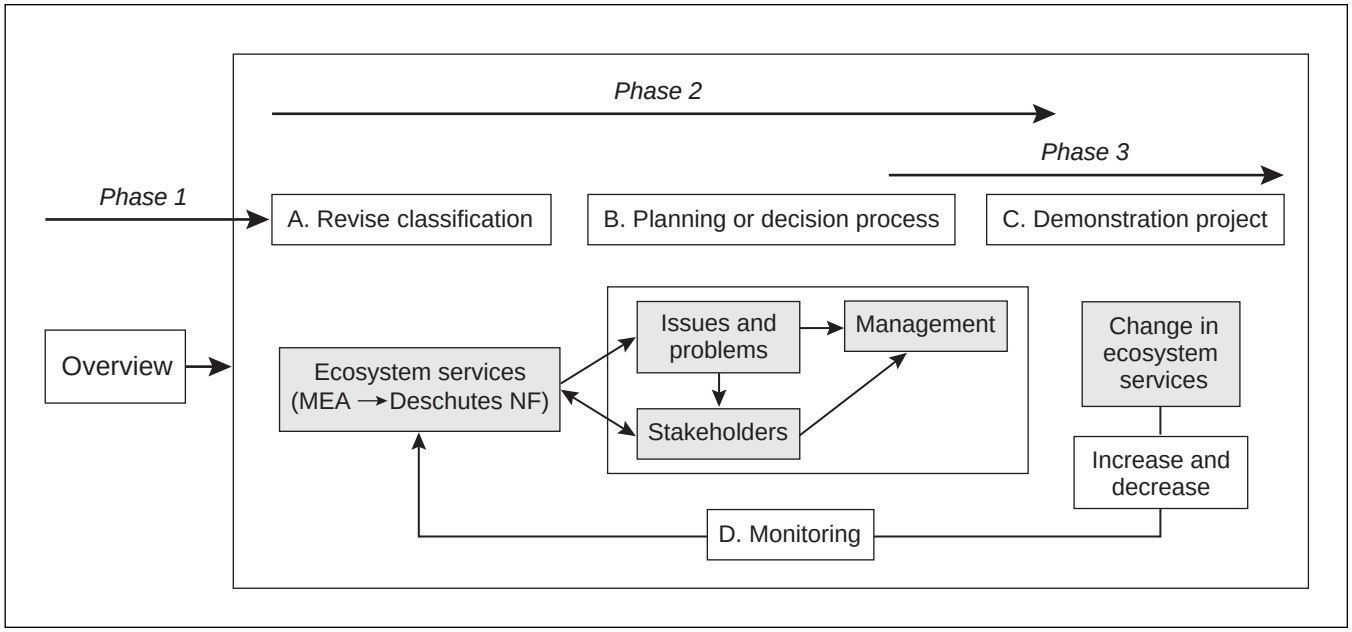

Figure 11—Illustration of the ecosystem service framework research progression from the current phase to (A) development of a classification and framework that builds upon the Millennium Ecosystem Assessment (MEA) to more accurately reflect the Deschutes National Forest specifically, (B) integration of stakeholder expectations and place-based management needs for planning and decisionmaking purposes, and (C) application of the framework to a demonstration project.

Research Overview

Managing for ecosystem services involves understanding the suite of benefits a forest provides, clarifying relationships between the quantity and quality of services provided and the condition of ecosystems that provide them, recognizing how these services are valued by diverse constituencies, and collaborating with stakeholders to sustain ecosystem functions and processes across landscapes (Daily 1997b, Kline 2006). It also involves an assessment of demands or uses of ecosystem services, and an analysis of the driving factors that may lead to declines in ecosystem service flows over time (Beier et al. 2009; Patterson and Coelho 2008, 2009). Rather than focusing on an extensive quantification of ecosystem services provided by national forests, which would be very difficult to accurately define for some benefits and may not serve management objectives, the emphasis of this effort is to explore how ecosystem service concepts can be applied operationally in a management context to serve the Forest Service mission. A goal of initial research is to collaboratively define ecosystem service benefit categories and investigate how they might be addressed or used (depending on scale, issue, etc.). Research will help identify

which services can be quantified and which may need to be described and considered in different ways, such as ordinal methodologies for indicating stakeholder priorities, or specifying how management activities lead to increases and decreases in services, as well as methods for using this type of information in project design and prioritization. Most importantly, research will explore:

- How management activities can be planned and communicated in terms of ecosystem service outcomes.
- Whether an ecosystem service approach strengthens collaborative decision-making internally and with stakeholders.

Ongoing Research

1. Designing an ecosystem service classification for the Deschutes NF

A particular problem that is being addressed in ongoing research is to understand public perceptions of ecosystem services, especially the wide array and sometimes intangible nature of cultural ecosystem services. Developing this understanding is useful for acknowledging cultural values in decisionmaking, and for articulating the range of benefits beyond provisioning services that national forests provide to the American public. The MEA identifies a few coarse-filter categories of ecosystem services, and a few cultural services, such as historic/heritage, educational, and aesthetic services. Likewise, past ecosystem service analyses have focused primarily on a few, relatively quantifiable services, such as recreation visitor days and scenic values. **Yet the Deschutes NF clearly contributes and even helps to create many other important offsite and sometimes intangible values, such as community character and well-being, outdoor lifestyles, and a sense of place for residents of central Oregon.** How these services are identified and weighed or valued along with more traditional and tangible values of services "coming off" the forest (like timber, salmon fishing, and clean water) is an important question being investigated.

Ongoing research is:

- Exploring public and agency staff perceptions of ecosystem services.
- Developing a typology for using and measuring cultural ecosystem services.
- Identifying management challenges, knowledge gaps, and research needs that are pertinent to the ecosystem services provided by the Deschutes NF.

The typology will provide a starting point for applying the ecosystem service framework described below. The results will help managers identify the types of ecosystem services that are most relevant for particular decisions or restoration projects, and will facilitate the involvement of partners in project-level planning

and implementation. The results may also highlight areas of agreement as well as points of potential conflict. We will address how to communicate ecosystem service concepts to the public and among Forest Service staff in a manner that serves the agency's mission and addresses management challenges. Critical to this investigation is understanding whether ecosystem service terminology resonates with people as a reflection of what they value and thereby strengthens collaborative decision-making. But the primary purpose of this classification process is to develop a typology that is useful for measuring cultural services, and to identify management needs, knowledge gaps, and data deficiencies related to cultural services of the Deschutes NF.

A principal goal of this research effort is to develop the Deschutes National Forest's capacity to articulate management decisionmaking and activities from the perspective of outcomes in addition to outputs.

2. Development of an outcomes-based ecosystem service framework for landscape planning and decision support

A principal goal of this research effort is to develop the Deschutes NF's capacity to articulate management decisionmaking and activities from the perspective of outcomes (healthy forests, clean air and water) in addition to outputs (miles of roads decommissioned, numbers of acres treated). Implicit in this approach is accounting for tradeoffs that may result from particular actions, such as soil compaction that occurs during intensive logging operations, as well as potential complementary and beneficial outcomes, such as fuel reduction projects that both improve forest health and enhance critical habitat. This integrated analysis could help managers contend with particularly challenging management decisions. For example, "controversial" or sensitive areas like existing owl habitat tend to be avoided for fuel treatment because of fear of litigation and uncertainty about how to restore forest resilience while safeguarding habitat of protected species. As a result, many of these areas remain at elevated risk to high-severity fire. An integrated ecosystem service assessment could help managers identify fuel reduction treatments that both reduce fire risk and sustain spotted owls in critical areas. A more fire-resilient landscape might also protect recreation opportunities and maintain vegetation cover that reduces runoff into rivers and streams. Road management is similarly complex; roads are one of the greatest sources of erosion on the forest but are used for recreation. Analyzing the costs and benefits of a road on a given site from the perspective of a suite of ecosystem services could provide a rationale for its decommissioning or continued use.

This approach to planning could support National Environmental Policy Act requirements by providing managers and the public with a new way of comparing possible action alternatives. An ecosystem service framework can help clarify the relationship between the nature of public benefits provided by forests (water quality, recreation opportunities) and the condition of the landscape that provides

them, with an emphasis on ecosystem functions and processes. Ecosystem services could help define desired conditions, strengthen a purpose and need statement, and justify the rationale for a project design. Describing management outcomes in terms of ecosystem services provided can help build trust with the public and illustrate the intention of a project. At the agency level, articulating accomplishments and performance in terms of ecosystem service benefits can also demonstrate the value of national forests to Congress and to the American public more generally.

Ongoing research will provide a starting point for implementing a practical application of the ecosystem service concept based on minimal primary data collection and modeling. Our focus is on helping forest managers explain the beneficial outcomes of management actions using a framework that people can understand. We will:

- Produce an annotated bibliography of research literature describing ecosystem service conceptual frameworks and related concepts.
- Describe, in nontechnical language, an intuitive conceptual framework for describing the ecosystem services or benefits provided by forest landscapes and their influence on human welfare.
- Outline key steps involved in using the framework as a basis for landscape analysis, including data and analytical requirements.
- Consider different ways of approaching national forest decisionmaking that draw on the ecosystem service concept, but may not necessarily involve estimating dollar values.

Future Research

1. Understanding supply and demand for ecosystem services—
Much is known about ecosystem services provided by national forests, but awareness of ecosystem services used by people is often less clear. Understanding the demand side of ecosystem services becomes more complex when the picture incorporates multiple services and multiple scales in time and space, and when we consider all of the ecosystem services that are used indirectly to create and transport forest products, or assimilate their wastes. In some cases, those who benefit from services provided by the Deschutes NF can be clearly identified and quantified, such as the number of visitors, hunters, or outfitter guides who use the forest annually. In other cases, beneficiaries might only be known in more general terms such as the city of Bend, the forest products industry, or recreation equipment suppliers. Understanding the importance of ecosystem services from the Deschutes NF also requires a sense of where these ecosystem services might otherwise originate. For example, what percentage of wood products sold in the Bend area are sourced from the Deschutes NF or from elsewhere in the Pacific Northwest,

or are imported from other countries? To what extent does Bend benefit directly from ecosystem services provided by the forest, and how do consumer choices reflect demand for ecosystem goods and services imported from elsewhere? Is the Deschutes NF carbon neutral? To what extent are forests surrounding Bend able to sequester citizen emissions? Questions posed in this way open a valuable discussion with the public about the use and value of local, regional, and global ecosystem services. The objective of this future study element is to summarize the status and trends of a few case ecosystem services used by people and communities, according to proximity to a forest landscape, while assessing available options for their conservation. This information can help us to identify the optimal mix of supply and demand side interventions that can sustain ecosystem service flows over time for the least public cost.

2. Demonstration project—

One goal of future research is to determine at what scale and at which point in the management decisionmaking process an ecosystem service analysis should occur. This could be applied early in the process to establish management priorities. An assessment of ecosystem service outcomes following management activity can also determine whether objectives were met and inform adaptive management. To improve understanding of how ecosystem services on national forest lands interact, scientists and managers will seek ways to measure and understand the outcomes of a range of possible management actions on a demonstration site (fig.11). The final structure for the demonstration project is still being developed. It may entail modeling of alternative futures and assessment of how, (1) a suite of ecosystem services will be affected by several proposed activities, (2) tradeoffs among services might occur, (3) services might change with time and spatial scale, (4) the rate at which services are supplied and demanded may be affected, and (5) service flows may degrade or diminish over time. We will also consider ways to address the valuation of ecosystem services that elude easy monetization and how to incorporate their consideration into management.

This demonstration project will also integrate stakeholder interests into evaluation of possible management outcomes. We will explore how effectively the ecosystem service framework and terminology addresses public concerns, supports a collaborative process, and garners trust in agency decisionmaking. If possible, we will also conduct a demonstration project on the Willamette NF to explore how valuation of ecosystem services by stakeholders might vary in different locations. This forest is located on the western slope of the Cascade Range and has very different ecological characteristics. Perceptions of ecosystem services provided by national forests can be shaped by site-specific environmental, demographic, cultural, economic, and political factors. This place-based comparison will help

illustrate how public involvement in an ecosystem service approach to forest management might be affected by local conditions. Testing of this concept at more than one site can also strengthen its potential application on other national forests and on other forest ownerships.

3. Collaborative development of metrics—
Future research will address how to measure or describe ecosystem services in a management setting, either qualitatively or quantitatively. Nongovernmental organizations in the region, including the Willamette Partnership and Defenders of Wildlife, are also working to support a more integrated, functions-based approach to land management, including measurement of the benefits provided by healthy landscapes. The Willamette Partnership's Counting on the Environment project aims to develop a multi-credit ecosystem marketplace that provides financial incentives for restoration activities that deliver multiple ecosystem services provided by highly functioning salmonid habitat, wetlands, and prairie as well as water temperature improvements in rivers and streams (Willamette Partnership 2009). They have developed a protocol to measure the benefits that result from management activities on private lands, but currently lack a metric for measuring the suite of ecosystem services provided by forests. Defenders of Wildlife is also interested in creating metrics that measure the value of forest habitats including oak woodlands and flood plains. In support of these mutual objectives, the Forest Service Pacific Northwest Region, Pacific Northwest Research Station, and the Deschutes and Willamette NFs are working with these partners to develop and pilot forest and habitat metrics on national forest lands. The resulting products can be used as analytical tools for public land managers to assess the ecosystem service outcomes of management activities, and can also be applied to ecosystem service markets that are developing in the private sector.

Conclusion

The efforts described in this report will enable scientists and managers to explore how ecosystem service concepts can be applied operationally to guide stewardship of national forests and support the restoration of functions and processes characteristic of healthy and resilient forest ecosystems. Place-based application brings the ecosystem service framework to a new level. This approach highlights the connection between public benefits and ecosystem condition, and addresses management challenges by considering the range of services that are affected by projects, as well as the tradeoffs that result from particular actions. Framing the benefits of projects in terms of ecosystem service outcomes provides the Forest Service with a new way to approach forest management and articulate benefits provided to the public. This could enhance the ability of the agency to build collaborative relationships with

partners and stakeholders. These partnerships, together with the perspective that ecosystem services brings to decisionmaking, are innovative tools for enhancing forest stewardship and sustainably managing flows of ecosystem services over time.

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Metric Equivalents

When you know:	Multiply by:	To find:
Inches (in)	2.5400	Centimeters (cm)
Miles (mi)	1.6090	Kilometers (km)
Acres (ac)	0.4050	Hectares (ha)
Gallons (gal.)	3.7854	Liters (l)

Literature Cited

Apple, D.D. 2000. Evolution of the Forest Service toward a learning organization. Washington, DC: U.S. Department of Agriculture, Forest Service. http://www.fs.fed.us/publications/policy-analysis/fs_learning.html. (January 2011).

Beier, C.M.; Patterson, T.M.; Chapin, F.S., III. 2009. Ecosystem services and emergent vulnerability in managed ecosystems: a geospatial decision-support tool. Ecosystems. 11(6): 923–938.

Bowes, M.D.; Krutilla, J.V. 1989. Multiple-use management: the economics of public forestlands. Washington, DC: Resources for the Future. 357 p.

Brown, T.C.; Bergstrom, J.C.; Loomis, J.B. 2007. Defining, valuing, and providing ecosystem goods and services. Natural Resources Journal. 47: 329–376.

Carroll, N.; Fox, J.; Bayon, R., eds. 2008. Conservation and biodiversity banking. London: Earthscan. 298 p.

Collins, S. 2007 (7 May). Ecosystem services: a new perspective on forestry. Speech. National silviculture workshop. Ketchikan, AK. http://www.fs.fed.us/news/2007/speeches/05/ecosystem-services.shtml. (January 2011).

Collins, S.; Larry, B. 2008. Caring for our natural assets: an ecosystem services perspective. In: Deal, R.L., ed. Integrated restoration of forested ecosystems to achieve multi-resource benefits: proceedings of the 2007 national silviculture workshop. Gen. Tech. Rep. PNW-GTR-733. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 1–11.

Costanza, R.; d'Arge, R.; de Groot, R.; Farber, S.; Grasso, M.; Hannon, B.; Naeem, S.; Limburg, K.; Paruelo, J.; O'Neill, R.V.; Raskin, R.; Sutton, P.; van den Belt, M. 1997. The value of the world's ecosystem services and natural capital. Nature. 387: 253–260.

Daily, G.C., ed. 1997a. Nature's services: societal dependence on natural ecosystems. Washington, DC: Island Press. 392 p.

Daily, G.C. 1997b. Valuing and safeguarding earth's life-support systems. In: Daily, G., ed. Nature's services: societal dependence on natural ecosystems. Washington, DC: Island Press: 365–374.

Daily, G.C.; Alexander, S.; Ehrlich, P.R.; Goulder, L.; Lubchenco, J.; Matson, P.A.; Mooney, H.A.; Postel, S.; Schneider, S.H.; Tilman, D.; Woodwell, G.M. 1997a. Ecosystem services: benefits supplied to human societies by natural ecosystems. Issues in Ecology. 1: 1–18.

Daily, G.C.; Matson, P.A.; Vitousek, P.M. 1997b. Ecosystem services supplied by soil. In: Daily, G., ed. Nature's services: societal dependence on natural ecosystems. Washington, DC: Island Press: 113–132.

Deal, R.L.; Raymond, C.; Peterson, D.L.; Glick, C. 2010. Ecosystem services and climate change: understanding the differences and identifying opportunities for forest carbon. In: Integrated management of carbon sequestration and biomass utilization opportunities in changing climate: proceedings of the 2009 national silviculture workshop. RMRS-P-61. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 9–25.

Díaz, S.; Tilman D.; Fargione, J.; Chapin, F.S.; Dirzo, R.; Kitzberger, T.; Gemmill, B.; Zobel, M.; Vilá, M.; Mitchell, C.; Wilby, A.; Daily, G.C.; Galetti, M.; Laurance, W.F.; Pretty, J.; Naylor, R.L.; Power, A.; Harvell, D. 2005. Biodiversity regulation of ecosystem services. In: Hassan, R.; Scholes, R.; Ash, N., eds. Ecosystems and human well-being: current state and trends—findings of the condition and trends working group of the Millennium Ecosystem Assessment. Washington, DC: Island Press: 297–329.

Eisenhauer, B.W.; Krannich, R.S.; Blahna, D.J. 2000. Attachments to special places on public lands: an analysis of activities, meanings, and community connections. Society and Natural Resources. 13(5): 421–441.

Eiswerth, M.E.; Darden, T.D.; Johnson, W.S.; Agapoff, J.; Harris, T.R. 2005. Input-output modeling, outdoor recreation, and the economic impacts of weeds. Weed Science. 53: 130–137.

Farnum, J.; Hall, T.; Kruger, L.E. 2005. Sense of place in natural resources recreation and tourism: an evaluation and assessment of research findings. Gen. Tech. Rep. PNW-GTR-660. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 59 p.

Hayes, J.P.; Chan, S.S.; Emmingham, W.H.; Tappeiner, J.C.; Kellogg, L.D.; Bailey, J.D. 1997. Wildlife response to thinning young forests in the Pacific Northwest. Journal of Forestry. 95(8): 28–33.

Intergovernmental Panel on Climate Change [IPCC]. 2007. Climate change 2007: synthesis report. Contribution of Working Groups I, II and III to the fourth assessment report of the Intergovernmental Panel on Climate Change. IPCC, Geneva, Switzerland: IPCC Secretariat. 104 p.

Judson, D.H.; Reynolds-Scanlon, S.; Popoff, C.L. 1999. Migrants to Oregon in the 1990s: working age, near-retirees, and retirees make different destination choices. Rural Development Perspectives. 14: 24–31.

Kline, J. 2006. Defining an economics research program to describe and evaluate ecosystem services. Gen. Tech. Rep. PNW-GTR-700. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 46 p.

Kocis, S.; English, D.B.; Zarnock, S.J.; Arnold, R.; Warren, L. 2003. National Visitor Use Monitoring results: Deschutes National Forest. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region. 21 p.

Kruger, L.E.; Jakes, P.J. 2003. The importance of place: advances in science and application. Forest Science. 49(6): 819–821.

Laskin, D. 2004. A town that's more than a pretty face. New York Times. March 7.

Mace, G.; Masundire, H.; Baillie, J. , coord. authors. 2005. Biodiversity. In: Hassan, R, Scholes, R., Ash, N., eds. Ecosystems and human well-being: current state and trends—findings of the condition and trends working group of the Millennium Ecosystem Assessment. Washington, DC: Island Press: 77–122.

Maleki, S. 2008. Counting all that matters: recognizing the value of ecosystem services. Science Update 16. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 12 p.

McKenzie, D.; Gedalof, Z.M.; Peterson, D.L.; Mote, P. 2004. Climatic change, wildfire, and conservation. Conservation Biology. 18: 890–902.

Millennium Ecosystem Assessment [MEA]. 2005. Ecosystems and human well-being: synthesis. Washington, DC: Island Press. 137 p.

Myers, N. 1997. The world's forests and their ecosystem services. In: Daily, G., ed. Nature's services: societal dependence on natural ecosystems. Washington, DC: Island Press: 215–235.

Naeem, S.; Chapin, F.S., III; Constanza, R.; Ehrlich, P.R.; Golley, F.B.; Hooper, D.U.; Lawton, J.H.; O'Neill, R.V.; Mooney, H.A.; Sala, O.E.; Symstad, A.J.; Tilman, D. 1999. Biodiversity and ecosystem functioning: maintaining natural life support processes. Issues in Ecology, Number 4. 11 p.

Neary, D.G.; Ice, G.G.; Jackson, C.R. 2009. Linkages between forest soils and water quality and quantity. Forest Ecology and Management. 258: 2269–2281.

Nielsen, J.; Innis, S.; Pollock, L.K.; Rhoads-Weaver, H.; Shutak, A. 2006. Renewable energy atlas of the West: a guide to the region's resource potential. Boulder, CO: Land and Water Fund of the Rockies. 82 p.

Oliver, M. 2009. Old growth revisited: integrating social, economic and ecological perspectives. Science Findings 110. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 6 p.

Osmond, D.L.; Line, D.E.; Gale, J.A.; Gannon, R.W.; Knott, C.B.; Bartenhagen, K.A.; Turner, M.H.; Coffey, S.W.; Spooner, J.; Wells, J.; Walker, J.C.; Hargrove, L.L.; Foster, M.A.; Robillard, P.D.; Lehning, D.W. 1995. WATERSHEDSS: Water, soil and hydro-environmental decision support system. http://www.water.ncsu.edu/watershedss/info/wetlands/manage.html. (January 2011).

Patterson, T.; Coelho, D. 2008. Missing feedback in payments for ecosystem services: a systems perspective. In: Chapman, R.L., ed. Creating sustainability within our midst: challenges for the 21st century. New York: Pace University Press: 61–72.

Patterson, T.M.; Coelho, D.I. 2009. Ecosystem services: foundations, opportunities, and challenges for the forest products sector. Forest Ecology and Management. 257: 1637–1646.

Postel, S.; Carpenter, S. 1997. Freshwater ecosystem services. In: Daily, G., ed. Nature's services: societal dependence on natural ecosystems. Washington, DC: Island Press: 195–214.

Preusch, M. 2004. Journeys: 36 hours: Bend, Ore. New York Times, October 15.

Smithwick, E.A.H.; Harmon, M.E.; Remillard, S.M.; Acker, S.A.; Franklin, J.F. 2002. Potential upper bounds of carbon stores in the Pacific Northwest. Ecological Applications. 12: 1303–1317.

Stein, S.M.; McRoberts, R.E.; Alig, R.J.; Nelson, M.D.; Theobald, D.M.; Eley, M.; Dechter, M.; Carr, M. 2005. Forests on the edge: housing development on America's private forests. Gen. Tech. Rep. PNW-GTR-636. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 16 p.

Stephens, S.L.; Moghaddas, J.J.; Edminster, E.; Fiedler, C.E.; Haase, S.; Harrington, M.; Keeley, J.E.; Knapp, E.E.; McIver, J.D.; Metlen, K.; Skinner, C.N.; Youngblood, A. 2009. Fire treatment effects on vegetation structure, fuels and potential fire severity in western U.S. forests. Ecological Applications. 19(2): 305–320.

Tilman, D. 1997. Biodiversity and ecosystem functioning. In: Daily, G., ed. Nature's services: societal dependence on natural ecosystems. Washington, DC: Island Press: 93–112.

U.S. Department of Commerce [USDC], Census Bureau. 2000. Population estimates for states, counties, places, and minor civil divisions: annual time series. Washington, DC.

U.S. Department of Agriculture, Forest Service [USDA FS]. 1990. Deschutes National Forest Land and Resource Management Plan. Bend, OR: Deschutes National Forest. 202 p.

U.S. Department of Agriculture, Forest Service [USDA FS]. 1993. Viability assessments and management considerations for species associated with late-successional and old-growth forests of the Pacific Northwest—report of the scientific analysis team. Washington, DC. 530 p.

U.S. Department of Agriculture, Forest Service [USDA FS]. 2000. Water and the Forest Service. FS-660. Washington, DC. 40 p.

U.S. Department of Agriculture, Forest Service [USDA FS]. 2005. 100 years of conservation… for the greatest good. FS-819. Washington, DC. 9 p.

U.S. Department of Agriculture, Forest Service [USDA FS]. 2007a. An assessment of fuel treatments on three large 2007 Pacific Northwest fires. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region. 51 p.

U.S. Department of Agriculture, Forest Service [USDA FS]. 2007b. USDA Forest Service strategic plan for fiscal years 2007–12. FS-880. Washington, DC. 32 p.

U.S. Department of Agriculture, Forest Service; U.S. Department of the Interior, Bureau of Land Management [USDA and USDI]. 1994. Record of decision for amendments to Forest Service and Bureau of Land Management planning documents within the range of the northern spotted owl. [Place of publication unknown]. 74 p. [plus attachment A: standards and guidelines].

White, E.M.; Stynes D.J. 2010. Spending profiles for national forest visitors, NVUM round 2 update. Report for USDA FS and OSU Joint Venture Agreement No. 10-JV-11261955018. 68 p. http://www.fsl.orst.edu/lulcd/Publicationsalpha_files/White_Stynes_NVUM2010a.pdf. (March 2011).

Willamette Partnership. 2009. Ecosystem credit accounting: pilot general crediting protocol: Willamette Basin Version 1.1. http://willamettepartnership.org/tools-templates/general-crediting protocol-1. (March 2011).

Woodward, F.I. 1987. Climate and plant distribution. London: Cambridge University Press. 188 p.

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