Ecosystem Services from Forest Landscapes: An Overview

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1 What are Ecosystem Services?

Human beings derive direct benefit from an array of ecosystem goods as well as from the activities and products of organisms, in both wild and human-dominated ecosystems (Daily et al. 1997; Levin and Lubchenco 2008). These benefits from nature have been readily available throughout most of human history. To this day, societies take many of these natural services for granted (Daily 1997, MEA 2005), even while the support systems that provide them are being severely degraded (Vitousek et al. 1997; Levin and Lubchenco 2008; Seppelt et al. 2011). The central challenge of this century is to develop economic and social systems and supporting systems of governance from local to global scales that will achieve sustainable levels of human population and consumption while also maintaining the ecosystem life-support services that underpin human well-being (Guerry et al. 2015).

The full range of ecosystem benefits to human life is grouped under the concept "ecosystem services" (ES). Since this concept was first introduced (Ehrlich and Mooney 1983), it has evolved (Daily 1997; MEA 2005) into a global phenomenon (e.g., Kubiszewski et al. 2017). ES can be briefly defined as the benefits that humans

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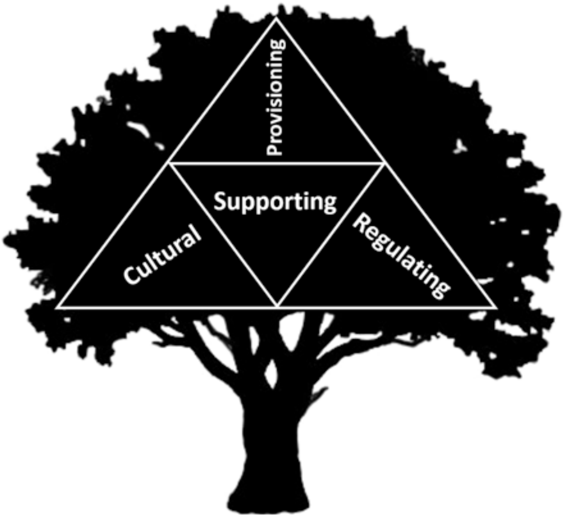

Fig. 1 Four categories of ecosystem services defined by The Millennium Ecosystem Assessment (2005)

obtain from ecological systems (Levin and Lubchenco 2008), consisting of flows of materials, energy, and information from natural capital stocks which, when combined with services derived from human capital to produce human welfare (Costanza et al. 1997). ES comprise ecosystem functions, which refer to the habitat, biological or system properties or processes of ecosystems, and also the ecosystem goods (such as food) and services (such as waste assimilation) which human populations derive, directly or indirectly, from ecosystem functions (Costanza et al. 1997, 2014).

It is possible to recognize four categories of ES (Fig. 1): (i) provisioning services or the provision of food or habitat; (ii) regulating services, such as the regulation of erosion or climate; (iii) supporting services, such as primary production or nutrient cycling; and (iv) cultural services, such as aesthetic enjoyment or recreation (MEA 2005). This classification gave rise to wider understanding of the potential uses of ES and also provided a framework for analyzing the various influences, active and passive, by which ecosystem services enhance human well-being (Boyd and Banzhaf 2007; Fisher et al. 2009). Nevertheless, most of the functions and services included under any one of the four ES categories are interdependent and support human welfare through their contribution to the joint products of the ecosystem (Costanza et al. 1997).

2 What are Forest Landscapes?

Here we define a forest landscape as either a natural or built-up area, at any scale, in which trees dominate the main ecosystems. We include in this definition all of the natural components that are present, together with their spatial heterogeneity, but also the human activities which create and affect patterns and processes within the

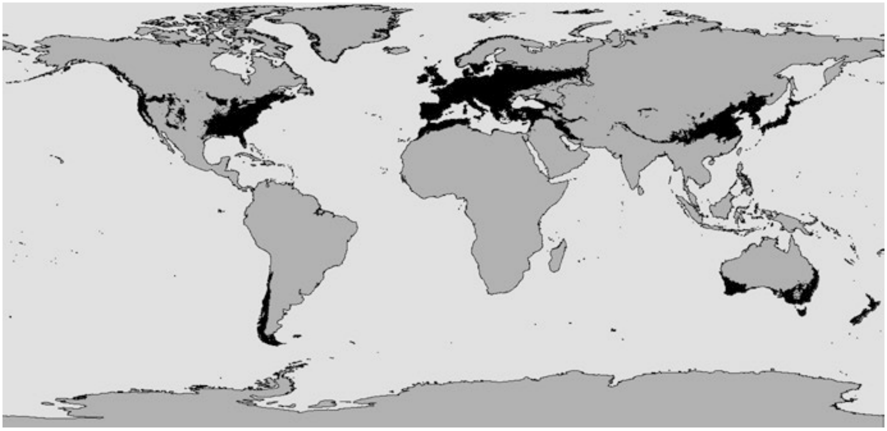

Fig. 2 Distribution of world's temperate forest biome that include broad-leaved, coniferous, and mixed forests (based on www.worldwildlife.org/biomes)

landscape. Forest landscapes cover more than four billion hectares, close to 30% of the Earth's land area, and account for 75% of terrestrial gross primary production and 80% of total plant biomass. They contain more carbon (in biomass and soils) than the total stored in the atmosphere (Beer et al. 2010; Pan et al. 2011). Forest landscapes also harbor most of the species on Earth and provide the most valuable goods and services to humanity (Costanza et al. 1997; Daily et al. 1997).

Temperate forests (Fig. 2), defined here as those forests located between 25° and 55° N and S latitudes, are highly diverse in species and soils and in the carbon pool of their ecosystems (Lal and Lorenz 2012). Temperate forest types vary among broad-leaved evergreen, broad-leaved deciduous, and coniferous, both pure or in combination. These forests are located primarily in the northern hemisphere across all continents but also in southern South America, Africa, and Oceania. Temperate regions of the world have been the most extensively altered by human activities, with significant impacts on the provision of goods and services, as well as the loss of biodiversity (Franklin 1988; Lindenmayer et al. 2012). These forests are the primary focus of our discourse because the need for improved strategies of management and conservation is particularly important there.

3 Ecosystem Services from Forests

The Millennium Ecosystem Assessment (MEA 2005) concluded that since about 1950, 60% of all ES had declined as a direct result of the growth of agriculture, forestry, fisheries, industries, and urban settlement, mainly through the increase in markets for provisioning services, but that similar declines did not occur in the other categories of benefit that ES provide (Kinzig et al. 2011). Forest ecosystems, in

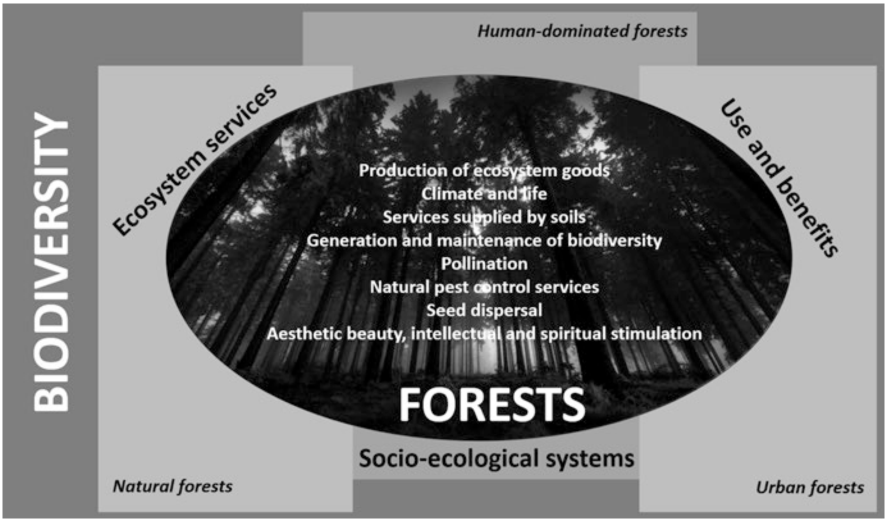

Fig. 3 Importance of forest ecosystem services in natural and anthropogenic landscapes

particular, provide critical ES to humanity (FAO 2010) and harbor most of the global terrestrial biodiversity (Gustafsson et al. 2012). Forests play a multifunctional role in which attempts are made to balance human commodity needs with the production of other goods and services, including the habitat needs of forest-dependent organisms (Thompson et al. 2011; Lindenmayer and Franklin 2002). More than 2 billion hectares of the world's forests (55%) are managed as production forests to supply ES and, at the same time, revenue from timber products to help pay for forest management (Gustafsson et al. 2012; Lindenmayer et al. 2012). When management strategies are developed, however, consideration is seldom given to the full range of ES that forest landscapes provide (Myers 1996; Daily et al. 1997; Nahuelhual et al. 2007) (Fig. 3). Some examples of ES that need to be taken into account are as follows:

- Production of ecosystem goods: The range of products obtained from forests includes food (e.g., fruits, nuts, mushrooms, honey, or spices), fuelwood, fiber, pharmaceuticals, and industrial products (Alamgir et al. 2016; Quintas-Soriano et al. 2016). In addition, animals such as cattle, goats, and sheep are raised in forests' silvopastoral systems (Peri et al. 2016), and these animals are the source of many trade products (e.g., meat, milk, wool, and leather). Hunting is also important in the forests of many countries, both for food and for sport, and can be critical to the survival of low-income people in developing countries (Golden et al. 2014).
- Climate and life: Climate plays a major role in the evolution and distribution of life over the planet, and forests are one of the main factors in the regulation of global climate. Forests help stabilize the climate, lessening extreme events (e.g., by slowing down water runoff) and removing greenhouse gases and other

pollutants from the atmosphere (Beer et al. 2010; Pan et al. 2011; Lal and Lorenz 2012).

- Services supplied by soils: Forests provide a critical role in forming soils, as well as in retaining them through reducing soil erosion. Forest soils moderate the water and carbon cycles, they retain and deliver nutrients to other organisms, and they provide a consistent and high quality source of water within forested basins (Kreye et al. 2014; Panagos et al. 2015; Sun and Vose 2016).
- Generation and maintenance of biodiversity: Forests support most of the terrestrial biological diversity, which benefits humanity through the direct delivery of goods (genetic and biochemical resources) used by humans or through the interaction of complex ecological systems (Daily and Ehrlich 1995).
- Pollination: About one-third of the human diet depends on insect-pollinated vegetables, legumes, and fruits. These pollinators, most of which live only in forested lands, allow for the successful reproduction of innumerable economic and noneconomic flowering plants (Karp et al. 2015; Martins et al. 2015; Quintas-Soriano et al. 2016).
- Natural pest control services: Several species compete with humans for goods and for other provisioning services. One approach to pest control is to use biotechnology or chemical compounds. Another option is to take advantage of biological control species that occur in nature, as many species (e.g., insects such as wasps and other species such as owls and bats) help humans live in forested landscapes (González et al. 2015; Karp et al. 2015; Quintas-Soriano et al. 2016).
- Seed dispersal: Many species of plants need animals as their dispersal agents or require passage through the gut of a bird or mammal before they can germinate. Many of these animals live only in forested lands, and several of the dispersing plant species (e.g., the fruit tree and shrubs species of temperate forests) have a long tradition of bringing goods to humans (Bregman et al. 2015; Karp et al. 2015; Peres et al. 2016).
- Aesthetic beauty, together with intellectual and spiritual stimulation: Human beings have a deep appreciation of natural ecosystems, especially forests, as evidenced by enjoyment of such pursuits as nature photography, bird watching, ecotourism, hiking, and camping. In forests, humans find an unparalleled source of wonderment and inspiration, peace and beauty, fulfillment, and rejuvenation (Daily 1997; Martínez Pastur et al. 2016).

4 Managing for Forest Ecosystem Services

The differences among human-dominated ecosystems, natural ecosystems, and ecosystems built-up through human activity have increased in recent years. Some ES provided by human-dominated ecosystems are traded on formal markets, and society tends to set a higher value on these than is actually due. The other two types of ecosystem are undervalued because their ES are not traded on formal markets, so they do not send price signals that warn of changes in their supply or condition

(Daily et al. 1997). However, the provisioning ES that flow from built-up and natural ecosystems have greatly increased. In response, it is essential to incorporate natural capital and ES into decision-making (Guerry et al. 2015). Costanza et al. (2014) estimated that ecosystems provide at least US$33 trillion dollars' worth of services annually, where about 38% of the estimated value comes from terrestrial systems, mainly from forests (US$4.7 trillion yr.$^{-1}$) and wetlands (US$4.9 trillion. yr.$^{-1}$). Our current economic, political, and social systems are not well suited to the challenge of representing the real value of ecosystems not dominated by human population and activity**.** There is a fundamental asymmetry at the heart of economic systems that rewards short-term production and consumption of marketed commodities, at the expense of stewardship of natural capital necessary for human well-being in the long term. Conservation and economic development have been considered as separate spheres for too long. Sustainable development requires explicit recognition that social and economic development are part of a stable and resilient biosphere (Guerry et al. 2015).

The Millennium Ecosystem Assessment (MEA 2005) combined both the applied and basic motives of sustainability science. It challenged the research community to synthesize what is known about sustainability science in policy-relevant ways, exposing both the strengths and the gaps in the underlying science (Carpenter et al. 2009). As human populations grow, and increasingly disconnect from nature, sustainability requires increasing focus and effort. For this, Guerry et al. (2015) proposed the following strategies to achieve sustainable development: (i) developing solid evidence linking decisions to impacts on natural capital and ES and then to human well-being; (ii) working closely with leaders in governments, businesses, and civil society to develop and make accessible the knowledge, tools, and practices necessary to integrate natural capital and ecosystem services into everyday decision-making; and (iii) reforming policies and institutions and building capacity to better align private short-term goals with societal long-term goals.

Conservation and development come from two distinct agendas: (i) conservationists who seek to increase public support for biodiversity protection by integrating economic development into protection initiatives and (ii) development agencies that seek to provide for the stewardship of nature under the mantra of sustainable development (Tallis et al. 2008). However, to achieve sustainability in ecosystem management, it is not enough to create partial reserves protecting some percentage of nature: the objectives of maintaining ES and biodiversity must be incorporated into intensively managed temperate landscapes at the landscape level (Franklin 1988; Lindenmayer et al. 2012; Gustafsson et al. 2012).

For ecosystem management, which aims to provide sustainable ES to society while also preserving and fostering biodiversity, the divergent disturbance impacts of these goals present a paradox, as they are at the same time risk factors and facilitators of management objectives (Thom and Seidl 2016). Therefore, it is necessary to develop management strategies for forestry which also incorporate broader protection and maintenance of ES and species diversity. It is probable that such new strategies will lead to reduced production of commodities but will increase the provision of ES for the whole of society.

In addition, many of the ES provided by forests are closely associated with ecosystem resilience, the ability of ecosystems to resist stresses and shocks, to absorb disturbance, and to recover from disruptive change (Myers 1996; Levin and Lubchenco 2008). If resilience declines, ES can generally be expected to decline, too. In this framework, proposals for managing forest landscapes which use ES to advance both conservation and human agendas, simultaneously, would benefit from improved scientific understanding of four key issues: sustainable use of ES, tradeoffs among different types of ES, the spatial flows of ES, and economic feedbacks in ES markets (Tallis et al. 2008). The role of the market economy in developing this new management process lies in helping to design institutions which will provide incentives for the conservation of important natural systems and will also mediate human impacts on the biosphere so that these natural systems are sustainable (Heal 2000).

MEA (2005) did not, however, deliver a fully operational method for implementing the ES concept, including tools to assist policy-makers and policy-oriented researchers in taking the provisioning of natural goods and services into account (Armsworth et al. 2007). As a result, the ES label is currently used in a range of studies with widely differing aims. This divergence presents a problem for policymakers as well as researchers because it makes it difficult to assess the credibility of assessment results and reduces the comparability of studies (Seppelt et al. 2011). Yet it is clear that, to strengthen the political relevance of the concept of ES, the scientific basis for its practical implementation must likewise be solidified (Ash et al. 2010).

5 Broader-Scale Consideration of Forest Ecosystem Services and their Sustenance

Even though much has been written on ES in forests, few examples exist in which the concept was effectively included in the planning, conservation, and management of the temperate forest ecosystems around the world. A great many of the studies and land management plans have focused on local scales, especially with respect to the types of ES addressed but also with respect to the land management policies and practices designed to sustain them.

To realize the full potential of the concept, broader-scale analyses of ES are required. We expect that the scale of focus will shift, for both the scientific community and the land managers, toward addressing broader-scale ecosystem services and design plans to sustain them. This paradigm shift to the adoption of a broader-scale consideration of forest ecosystem services will likely be made less daunting by advances in landscape ecological concepts, in remote sensing and GIS technologies and in simulation modeling methodologies.

Adoption of the concept of ES creates will create a significant change in the point of view of scientists, managers, and policy-makers, and studies on land and resource management will inevitably turn to the broader tools of ES types and landscape ecology. Landscape management with multiple objectives is a better solution for most of the urgent problems of our modern society, in which provision services cannot be divorced from either regulation or cultural services. The foundation for this shift is a better understanding of ES on a broad, even global, scale. Such a perspective is required for designing landscapes that serve human well-being while preserving the ecosystems and biodiversity on which that well-being depends.

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