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FOREST-RELATED ECOSYSTEM SERVICES

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Introduction

Forests are a crucial element not only of landscapes but also of human living conditions. Covering nearly a third of the earth's land surface (see Box 30.1), they stabilize surface soil, prevent erosion and play an essential role in water resource management at the watershed and local levels. They regulate climate and improve air quality. At the same time they are an important resource for the regional economy (wood production, recreation and tourism) and are an important cultural and social heritage of the local and regional human activities. They provide habitats for a multitude of animal and plant species and are essential for the biological diversity in forest ecosystems over large areas.

Likewise, for centuries, forests have served humans as shelter or a place for natural safety for communities during times of famine or other events that impact agricultural and food production: forests provide fruits, leaves, gum, nuts, timber and wood for fuel. Thus, throughout history, forests supported peoples' livelihoods, especially when crops failed.

Today, the world's forests are in a state of flux due to land-use and climate change, deforestation, afforestation, wildfires, insects and pathogen outbreaks. In the face of both anthropogenic and natural forces there is an increasing need to assess the value of our forests. The incorporation of the ecosystem service (ES) concept into the framework of forest management stems from a need to create a more holistic perception of forests, recognizing not only their economic value, but also their cultural and ecological values, including their regulation capability.

While timber production often dominated the way in which forests were managed in the 20th century, new challenges and increasing pressures in the 21st century have stimulated a more balanced approach, involving the delivery of multiple goods and services. Contemporary sustainable forest management seeks to meet productivity targets while still managing for biodiversity conservation and other ES. Yet integrative forest management practices at the landscape level are complex and require the understanding of patterns at different scales as well as their interrelationships through processes. This chapter sets out the importance of an integrative landscape perspective for managing forests, one which focuses on mosaics of patches and their dynamics in order to integrate ecological values (e.g., the maintenance of ecosystem health and biodiversity conservation) with economic or cultural ones (e.g., timber and recreation).

Box 30.1 Forest worldwide: an important resource

The world has just under 4 billion hectares of forest, or 30.3% of its total land area. The 10 most forest-rich countries account for two-thirds of the total forest area. In descending order of forest area they are: the Russian Federation, Brazil, Canada, the USA, China, Australia, the Democratic Republic of the Congo, Indonesia, Peru and India. The first five of these account for more than half of the world's forest area (SOFO, 2014).

Importance of forests for ecosystem service provision

Forests are important sources of timber, yet they can also provide a wide range of other ES such as habitat quality for a diverse set of species, recreation, non-timber products, water quality, carbon sequestration and landscape character. Likewise, forests, particularly tropical forests, contribute more than other terrestrial biomes to climate-relevant cycles and related biophysical processes. Forest ecosystem services, as with other nature's services, have also been claimed to be of great economic value (Costanza *et al.*, 1997; Pearce and Pearce, 2001; Pearce and Moran, 2001; de Groot *et al.*, 2012). For example, Costanza *et al.* (2014) estimated an ES value of 53,822,007$/ha/yr for tropical forests and 31,372,007$/ha/yr for temperate and boreal forests, for an overall value of over $16 trillion in annual value from ES in forests. In forest valuation studies, service components like carbon storage or hydrological protection frequently bring higher values than forest products. For example, of the bundled ES value estimated for forests mentioned above, only 6% of temperate forest and 1.6% of tropical forest valuation is from the provisioning service 'raw materials' (de Groot *et al.*, 2012).

Hence, the variety of forest landscapes and the successive forms of forest uses observed during different historical periods exemplify the diversity and intensity of multiple needs; they also demonstrate the importance of spiritual values and of social and political realities. In all, forest landscapes provide more than trees; a forested landscape provides a living society with multiple functions.

Historical importance

Forests and their derived products have played a substantial role in the development of civilization, providing humans with building materials and fuel for thousands of years. The long history of wood utilization dates back to 400,000 years ago – the age of the oldest carbon dated wood spear, found in Germany. Other man-made artefacts that have been dated to outstanding ages include a 3,000 year old staircase, a 1,300 year old building in Japan and a 1,200 year old Viking canoe (Grabner and Klein, 2014). Native peoples also relied on forests for subsistence and cultural resources, and they actively managed forests for these values. In the USA, tribal forestry is still very much alive, generating important revenues while the forest remains protected under a sustainable use scheme (*Tribal Forest Protection Act of 2004* – U.S. Public Law 108–278 108th Congress). However, despite increased awareness of the benefits of forests with respect to carbon sequestration and storage, water retention, climate regulation and the provision of habitat, deforestation rates remain disturbingly high, especially in the tropics (Hansen *et al.*, 2013; Costanza *et al.*, 2014). An integrative multifunctional forest management approach could help to maintain sustainable systems (Gramfeld *et al.*, 2013; Schindler *et al.*, 2014). But planning and implementing multifunctional forest management is challenging because of the trade-offs and synergies among ES.

Present threats to forest ecosystem services

Forest loss and its impact on people

Many of the world's remaining forests are threatened by human activities and climate change. Although the pace of deforestation has slowed globally, losses still continue. Estimates vary according to the methods used and there is disagreement on recent net changes in forest area.[1] However, most sources agree that globally, there is a continuing loss of forest cover and a higher rate of loss of forest cover in tropical areas than in temperate ones.

Without harmonized indicators and comparable figures on the impact of forest loss, policy-makers are unlikely to take decisive action to discourage policies that favour the conversion of forests to agriculture and other land uses. The FAO (SOFO, 2014) highlights the critical knowledge gaps that exist in analysing data on the socioeconomic benefits of forests. They suggest that despite international efforts, we are still lacking empirical evidence on the role and contribution of well-managed forests to sustainable development and a green economy. In addition, current data collection, which focuses on forests and trees, needs to be complemented by information about the benefits that people receive. This, they conclude, will be best done by increasing collaboration with public organizations undertaking such surveys.

Land-use change and forest degradation due to human pressures

Alteration of the earth's vegetation is perhaps the most ecologically significant impact that people have had, because of its serious implications for the maintenance of biodiversity. Since vegetation change occurs at a variety of spatial and temporal scales, it is essential that we take cross-scale effects into account. It is vital that we have the ability to measure such changes and to develop predictive models of future change at different scales to be able to plan adaptive management measures.

ES shifts and conflicts

In parts of the Amazon rainforest, rising temperatures and changing rainfall patterns are connected with increased risk of catastrophic dieback, with potentially dangerous local, regional and global consequences. In the Congo Basin, a recent analysis of deforestation trends published by the World Bank highlights the intense pressure that agricultural expansion, mineral exploitation, growing energy needs and an improved transportation network will pose for the integrity of this rainforest (Megevand *et al.*, 2013).

Another example is Ecuador, which is one of the nine most biodiverse countries. Its mega-diverse flora comprises more than 25,000 plant species, which makes it as important as Brazil in terms of species richness per unit area. However, despite Ecuador's significance as a biodiversity hotspot, information about the country is completely lacking in the 2005 Millennium Ecosystem Assessment (MA, 2005), and slash-and-burn practices have fragmented and degraded a significant portion of the original forested landscape. Conversion of natural forests into agricultural land and pastures has affected about 50% of the lower part of the southeastern tropical Andes of Ecuador, in the valley of the Rio San Francisco region (Bendix *et al.*, 2013). These changes also encompass pressures due to the dichotomy and conflicts between forest areas and adjacent pastures. An unintended consequence of this conversion is that pastures are unsustainable and are therefore abandoned after some time. This is a common process in Brazil, as well as in many other tropical and subtropical forest areas. One of the on-going challenges is to restore these degraded areas through reforestation or reconversion to pasture; but any alternative may have negative consequences for the natural system and the local populations. Scenario analysis may help trade-offs among various ES to be understood. Field observations, measurements and experiments, combined with numerical models and calibration, could also provide a foundation for deriving sustainable land use strategies based on a good understanding of the complexity of the ecological systems and the associated services in these very fragile areas.

If the world is to improve livelihoods for the people while simultaneously mitigating and adapting to climate change, it is vital that we find the balance between conserving and regenerating forest areas through economic growth for poverty reduction. In this regard, additional forest research is critical. By bringing relevant and reliable scientific information to national, regional and global policymakers, forest research can provide a positive on-site impact on livelihoods, the environment and sustainable development. To better understand the potential impacts of management on livelihoods and the forest resource base, we need to not only continue current research but also build research where forests are key to sustaining livelihoods.

Mitigation in an era of human-induced climate change

Forests are being affected by climate change, and these effects will likely intensify into the future (Iverson *et al.*, 2014). Evidence is mounting that increasing fires and drought in western North America can be tied to the changing climate (Dennison *et al.*, 2014; Peters *et al.*, 2014). The northward spread and large-area forest die-off due to the mountain pine beetle in the Rocky Mountains and the drought-related tree mortality increases in the US Southwest are well documented (e.g., Vose *et al.*, 2012; Creeden *et al.*, 2014; Williams *et al.*, 2013). In Europe, the extreme drought of 2003 (the European Heat Wave 2003, Ciais *et al.*, 2005), a series of devastating storms (e.g., Central Europe 1990, France 1999, Slovakia 2004, Sweden 2005, Central Europe 2007), and several recent severe fire seasons (e.g., Portugal 2003, Greece 2007), all point towards increasing climate variability due to human-mediated climate change (IPCC, 2014). Shifts in the altitudinal zones affected by bark beetle damages in Austria and in western North America, and latitudinal range shift of biotic disturbance agents across continents (Battisti *et al.*, 2005 (Bentz *et al.*, 2010; Dukes *et al.*, 2009)), provide additional signs of changes that may be considerably more severe in the future (Tebaldi *et al.*, 2006). Numerous other examples of the impacts of increased climate variability on forests are accumulating worldwide (e.g., Allen *et al.*, 2010). Thus, the development of adaptive forest management strategies under the increased frequency and intensity of expected extreme meteorological events is a challenge for the sustainability of forests in the future.

As climate changes, societal demands for goods and services from forests are also changing. The recent decision of European government leaders to increase the share of renewable energy in Europe to 20% by 2020 is expected to result in a much greater demand for forest biomass for bio-energy generation. This higher demand will intensify the competition for resources between forest industry, the energy sector and nature conservation/other protective functions and services (including biodiversity, protection from natural hazards, landscape aesthetics, recreation and tourism).

According to the recent US National Climate Assessment, bioenergy could also emerge as a new market for wood and, aside from some negative competitive potential mentioned above, could aid in the restoration of forests killed by drought, insects and fire (Vose *et al.*, 2012; Joyce *et al.*, 2014). Ironically, much of the restoration needed is in response to direct or indirect climate-related disturbances. Though not yet implemented at the federal level, several regional or state policies in the US also are encouraging a large step-up in energy proportion from renewables over the next decade, including from biomass. However, the rapid expansion of fossil fuel energy via hydrologic fracturing ("fracking") is slowing economic and sociological incentives for bioenergy, but with plenty of environmental negatives, including large amounts of methane leakage to the atmosphere. Methane has a much higher climate warming potential than CO_2 (Miller *et al.*, 2013).

How to adapt landscape systems to climate change is challenging scientifically. In order to support meeting targets established by forest landscape managers, we need more focus on biodiversity conservation as a proxy for the ecological dimensions of a sustainable forest management, while still improving our understanding of ecological processes to set up baselines towards future planning and scenarios. This is particularly challenging because of increasing demands and pressures to intensify wood production and timber exploitation, in addition to agriculture intensification that is increasing often at the expense of treed landscapes. Still, there are demands for improving actions in favour of safeguarding biodiversity, and in a more general way, improving the functioning of forest ecosystems. The need to optimize resource production simultaneously with improving environmental quality represents a challenge and an opportunity for the years to come. Reorganization of forest management systems are needed to find the right balance for successful management adaptation within an ecosystem services approach, while considering bundles and trade-offs at different scales. In particular, we need to consider the valorization of wood resources and production, and their vulnerabilities in relation to more intensive management practices.

A holistic landscape framework could provide a comprehensive and integrative approach from the plot level to the landscape level, considering adaptive management and an analysis of ecological thresholds (Kjellström, 2004; Andersson *et al.*, 2005; Kremer, 2007; Iverson *et al.*, 2014). We need, then, to validate concepts, methodologies and tools based on strong scientific evidence, while at the same time working in tandem with the managers charged to implement policies and actions on the ground. Adaptive management seems then a key component within the set of actions that will help balance multiple objectives under changing environmental conditions, and will improve natural resources management in a wide range of territories.

Forest management within an integrative ecosystem framework

While it has been asserted that greater biodiversity positively influences the delivery of multiple services (Mace *et al.*, 2012; Nelson *et al.*, 2009; Vihervaara *et al.*, 2015), evidence to support this from natural systems at scales relevant to management is still scarce. Sustainability of forest ecosystems affected by the use of and trade in forest-based resources requires an understanding of the links and balance between productivity and soil processes, and their interaction with natural and anthropogenic disturbances. In the past three decades, forest ecosystem models have been developed at different scales within an ecosystem framework, from the plot level to landscapes, to analyse various questions (see, for example, reviews by Chertov *et al.*, 2003; Komarov *et al.*, 2003; and applications from Mäkipää *et al.*, 1999; Morris *et al.*, 1997; Romero-Calcerrada and Luque, 2006; He *et al.*, 2008). Modelling was used to analyse the impacts of different systems of harvesting, forest disturbances, natural development of forests, climate change and carbon balance. Forest ecosystem modelling can effectively extend the classical approach where growth functions and tables are used for the prediction of forest growth and soil nutrition in the changing environment under new silvicultural regimes. The level of the basic forest unit (stand, inventory 'compartment') can now be modelled well in relation to the problems of upscaling the stand's productivity in different climatic and site conditions. Moreover, there are combined models which are able to describe the biological turnover of the elements; first of all, carbon and nitrogen, in the 'soil–vegetation' system (Chertov *et al.*, 2001; Komarov *et al.*, 2003). The models allow an estimation of the forest productivity, carbon and nitrogen dynamics, and water regime in the forest ecosystem. Models are also used to make inventories of carbon sinks and sources under the reporting requirements of the Climate Convention and Kyoto Protocol (see Liski *et al.*, 2006; Peltoniemi *et al.*, 2006; Mäkipää *et al.*, 2008). In all, forest ecosystem models, used within the ecosystem framework, are useful to test and develop our understanding of forest functioning and dynamics. They are also required to meet the demand from policymakers and managers to predict the impacts of different scenarios of use and management of forest resources and its associated services.

Multifunctional sustainable forest management (MSFM)

Management of forest stands has substantially changed in situ forest properties, mostly in terms of tree species composition and the amount of coarse woody debris. In several countries, particularly in Nordic countries that practice intensive use of their forest resources (Hanski, 2000; Luque and Vainikainen, 2008), many forest properties are carefully controlled. Regional characteristics, such as the spatial structure of forest landscapes, are also frequently changed (Luque *et al.*, 2004).

Adequate selection of nature reserves for the maintenance of biodiversity has been under extensive research over the past decades (see Cabeza and Moilanen, 2001; ReVelle *et al.*, 2002, Rodrigues and Gaston, 2002; Kallio *et al.*, 2008; Mönkkönen *et al.*, 2011). Most studies have implicitly assumed that land parcels have equal economic value. This unjustified assumption may severely undermine the efficiency of conservation. For example, using county-level data for the US, Ando *et al.* (1998) showed that accounting for heterogeneity in land prices results in a marked increase in efficiency in terms of either the cost of achieving a fixed coverage of species or the coverage attained from a fixed budget.

Gramfeld *et al.* (2013) provided evidence that diverse, mixed forests, in particular, showed higher levels of multiple ecosystem services. Importantly, the same study found that no single tree species was able to promote all services, and some services were negatively correlated with each other. The pros and cons of species mixtures for productivity and other ecosystem functions have been discussed at length since the early 19th century (see reviews in Naeem *et al.*, 2009; Pretzsch, 2005). Only recently, however, have scientists begun to explicitly investigate how species diversity might be important for the simultaneous provision of multiple functions or services (e.g., Hector and Bagchi, 2007; Paillet *et al.*, 2010; Zavaleta *et al.*, 2010; Gramfeld *et al.*, 2013). Gramfeld *et al.* (2013), working on boreal and temperate production forests, showed that the relationships between tree species richness and multiple ecosystem services were positive and that all services considered attained higher levels with five tree species than with one species.

In all, considering both economic and ecological values for site selection means that, in practice, areas are selected as part of a conservation network according to their benefit-cost ratio (Juutinen *et al.*, 2008; Juutinen *et al.*, 2014). Thus, management decisions should be a compromise among the sites that provide high benefits in terms of biodiversity value and conservation and its associated services (Kallio *et al.*, 2008). This also implies that we accept trade-offs between ecological benefits and economic costs. Another important challenge is to identify the best trades-offs among several services (Schwenk *et al.*, 2012), potentially aided by quantitative methods to evaluate management options (Carpenter *et al.*, 2009; Gramfeld *et al.*, 2013) (See Box 30.2). Multicriteria analyses can help forest owners and forest managers consider the best pathways to potential 'win-win' situations or at least good compromises.

> **Box 30.2 *Fostering ES in forests***
>
> To achieve the challenging goals of operationalization of the concepts of ecosystem services within a forest management context, we need:
>
> - *Landscape approaches*, rather than single stand or forest land approaches, in order to account for spatial interactions, bundles and connectivity networks that determine the success or failure of conservation management targets.
> - *Regionally and locally tailored management* (adapt at the scale of practice) practices (e.g., lower harvest intensities in areas of greater hydric stress).
> - *To avoid the dominance of a single management* strategy (or of the lack of any management) over large areas: diversity of species calls for a diversity of management practices.

The challenge that lies ahead

The challenge that lies ahead demands awareness of the increasing pressures on forests and forest resources, and concern about the continuous changes in climate conditions that will increase forest degradation through such things as soil erosion, desertification, droughts, pests, diseases, storms and fires. Such impacts put at risk the health, vitality and productivity of forests, which all can have adverse impacts on economies, biological diversity and the environment, as well as on the social and cultural benefits of societies. Fortunately, however, many forests are quite resilient and may be able adapt to the altered conditions (Tebaldi *et al.*, 2006; Bentz *et al.*, 2010; Thompson *et al.*, 2009), especially if assisted through active and science-based management (FAO, 2012; Park *et al.*, 2014). But for many other forests, there is an urgent need to address and take action through effective research on and implementation of sustainable forest management. Thus, societies that depend on forests will also need to adjust and adapt to new conditions and transformation adapting to changes (i.e., social-ecological resilient society).

The future will bring both challenges and opportunities. Global challenges include the demands that a growing population will make on global ecosystems, whose resilience is being tested by energy and water scarcity, continuing pollution, and a host of increasing disturbances and human demands. Based on present consumption rates, the supply of ES will fall increasingly short of demand. Forests are at present used very inequitably, and there are many people, particularly in developing countries, who have severely limited access to the benefits that forest ES can deliver. Substantial improvements in resource efficiency and management practices, as aforementioned, is essential to secure a sustainable future for all, while simultaneously tackling climate change through adaptation and mitigation measures.

A vision for the future

Future research should aim at developing and improving methods to measure and value biodiversity and ecosystem resilience (See Box 30.3). Evaluating different habitat types in terms of disturbance frequency and intensity can be imitated in the management and use of such ecosystems. This approach may help detect when ecosystems are approaching the limits of their natural functioning or productive capacity. Future efforts should also aim at improving measures on the

> **Box 30.3 Goals for better futures with forests**
>
> Forests should be conserved for the multiple benefits that they provide, but we still need to:
>
> - Improve information worldwide and communication channels on consumption of forest products for food security and health
> - Support forest management, considering multiple tree species to sustain the full range of benefits that the society obtains from forests
> - Support interdisciplinary research to provide more evidence that is needed to help re-direct policies, more effectively enhancing the socioeconomic benefits of forests
> - Coordinate management across ownership boundaries
> - Provide economic and cultural benefits to local communities; e.g., patrimonial values, identity, recreation and entertainment
> - Sustain long-term wood and biomass production
> - Promote widely non-conventional socioeconomic benefits from forests; e.g., wood products for green buildings; forests for health – medicinal plants, natural organic food; wood quality for musical instruments, boats, toys

importance of forests for society at large (See Box 30.3); we need to improve our understanding of the people who live in and around forests – in many cases depending directly on forests for their livelihoods. In all, well-managed forests have tremendous potential to contribute to sustainable development and promote food security. We need then stronger collaborative efforts to collect data and monitor trends, raise awareness and monitor progress towards an integrative sustainable forest management.

Note

1 See www.fao.org/forestry/fra/remotesensingsurvey/en/).

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