Ecosystem Changes, Biodiversity Loss and Human Well-Being

VM Proença and HM Pereira, Universidade de Lisboa, Lisbon, Portugal

Abbreviations

CBD	the Convention on Biological Diversity
IUCN	International Union for Conservation of Nature
MA	the Millennium Ecosystem Assessment
MDG	the Millennium Development Goals

Introduction

Human well-being is deeply connected with biodiversity. From subsistence communities to highly developed urban communities, everyone needs food, clean water and air, fibers, fuel, medicines, and environmental stability. Ecosystems provide these services and biodiversity sustains ecosystems and their processes.

As the world population and consumption patterns per capita increase, so do the demand for natural resources (e.g., wood and fish) and the impacts of human activities on natural habitats. Impacts might be direct (e.g., habitat destruction for urbanization) or indirect (e.g., carbon emissions that cause global warming), but they all lead to biodiversity loss and consequently threaten ecosystems balance and human well-being. Human well-being is an inclusive concept that embraces not only the physical and mental components of human health but also social well-being and freedom of choice.

There is a feedback loop between human well-being and biodiversity: human well-being is dependent on biodiversity; biodiversity and ecosystem conditions are affected by human options toward environment, and these options are influenced by the level of well-being and the socioeconomic choices of communities. This cycle will be analyzed throughout the article. The article starts with a brief overview of what is biodiversity and its distribution around the globe. Next, the value of biodiversity and ecosystem services is discussed. The link between ecosystem services and human well-being is also analyzed. The following section focuses on biodiversity loss and drivers of environmental change and the consequences on human well-being. Finally, a case study is analyzed that integrates these concepts and provides a more concrete view of the feedback loop between biodiversity and human well-being. The article concludes with some remarks about the need to find solutions that promote human well-being and also prevent biodiversity loss.

What Is Biodiversity?

Biodiversity is the variety of life on Earth. The Convention on Biological Diversity (CBD; article 2) defines biodiversity as "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems."

In other words, biodiversity includes genetic, species, and ecosystem diversity. Genetic diversity is the simplest level of diversity, including the different varieties of crops and the variation between individuals. Species diversity is basically composed of all the different species in the world, from mushrooms to mammals. Ecosystem diversity comprises the different species assemblages of each ecosystem and their relations to the environment, such as deserts, temperate forests, and coral reefs.

The diversity of species is vast and still counting with new species being described every year. So far scientists have described approximately 1.75 million species with more than half of those being invertebrates. Estimates of global species richness range from 3 million to 100 million species. This lack of precision expresses how much is still unknown about the living planet.

Biodiversity around the Globe

The distribution of species around the earth is not homogeneous. Some world regions are more diverse than others. Some regions are not only very diverse but also support a large number of endemic species (i.e., species that occur exclusively in that region). This uniqueness confers them a high level of irreplaceability making them priority areas for conservation.

The biodiversity hotspots are examples of such areas (**Figure 1**). These hotspots support a high level of plant endemism and face a severe threat of habitat loss, with at least 70% of the original vegetation already lost.

In 2000, 25 hotspots were identified around the world. Four years later, the evaluation was reviewed, with the redefinition of hotspots limits and the classification of additional areas. In total 34 regions are now classified as hotspots, containing at least 150 000 endemic plants, approximately 50% of world plant diversity, and 77% of all vertebrates. Originally these regions occupied 15.7% of earth surface, but 86% of these areas were altered by

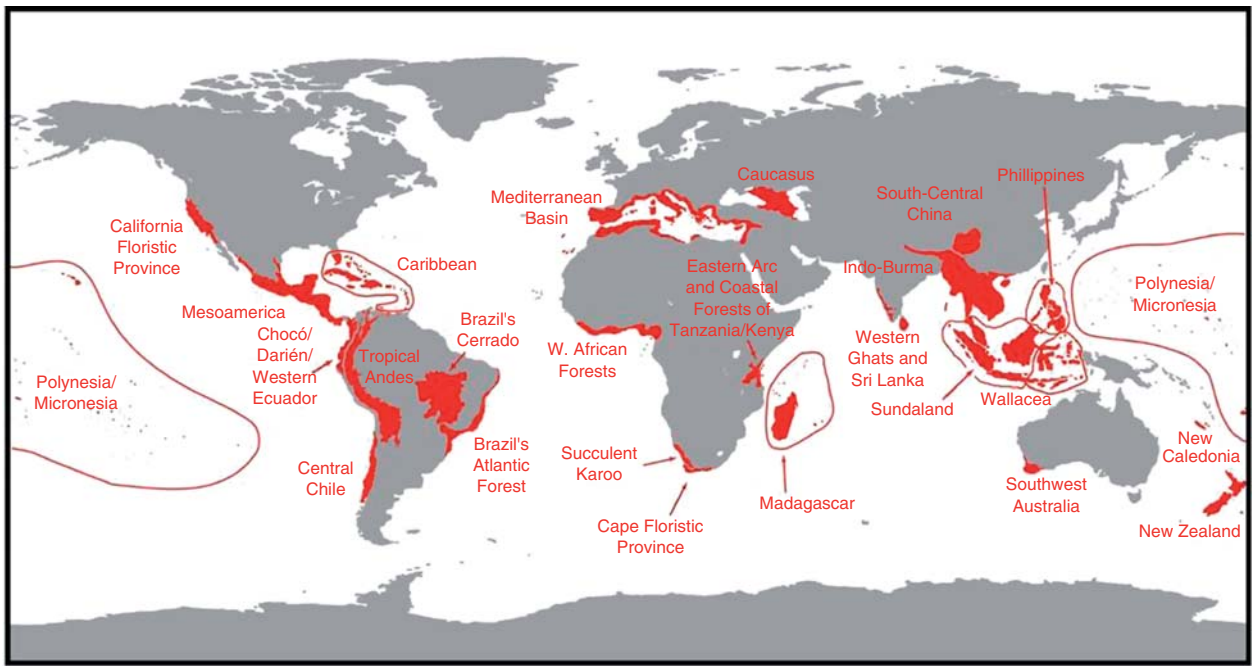

Figure 1 Biodiversity hotspots. From Myers N, Mittermeier RA, Mittermeier CG, da Fonseca GAB, and Kent J (2000) Biodiversity hotspots for conservation priorities. *Nature* 403: 853–858, with permission.

human activities and now only 2.3% remain undisturbed. Thirty-eight percent of these areas are located in the Asia-Pacific region, 24% in Africa, 15% in South America, 12% in Europe and Central Asia, and 12% in North and Central America.

While biodiversity hotspots are highly threatened and irreplaceable regions, another category of important biodiversity regions includes irreplaceable areas that are still pristine and have low anthropogenic influence. These regions are known as high-biodiversity wilderness areas, and comprise five world regions: the North American deserts and Amazonia in the American continent; the Congo forest and the Miombo-Mopane woodlands, which include the Okavango Delta, in Africa; and the New Guinea in Australasia. Endemism in these areas comprise approximately 17% of global plant diversity and 8% of global vertebrate diversity, and although these values are lower than the values found in biodiversity hotspots, these regions are still important due to the pristine condition of their ecosystems.

Biodiversity and Ecosystem Services

Ecosystems provide many services to humans, which range from commodities like food, fibers, or medical substances to indirect benefits like carbon retention, pollination, or water filtering. Ecosystem services can be classified into four categories: provisioning services, regulating services, cultural services, and supporting services. The existence and maintenance of ecosystem services is sustained by biodiversity (**Figure 2**). Provision services correspond to the goods directly obtained from ecosystems. Cultural services are nonmaterial benefits obtained from ecosystems, such as high-quality spaces for leisure or the feeling of satisfaction derived from observing a rare butterfly. Regulating services are the indirect benefits obtained from the regulation of ecological processes, such as climate regulation or soil protection from erosion. Finally, supporting services provide the basis for the production of all the other ecosystem services, and include services such as oxygen production by photosynthesis, nutrient cycling, and habitat provisioning.

Each component of biodiversity, such as species richness, species composition, or species interactions, plays a role in ecosystem services. Ecosystem functioning depends on the presence of organisms from different functional groups (i.e., that perform different roles in ecosystem processes). For example, the process of litter decomposition depends on organisms specialized on breaking down particles of different size, from earthworms to microbes. Therefore, species composition, with elements from different functional groups, is a key factor to assure the maintenance of supporting services. Species richness is central to the stability of ecosystems, a regulating service. Ecosystems with a rich and complex web of species interactions are more protected from the negative effects of environmental changes than species-poor systems. Environmental changes may affect the

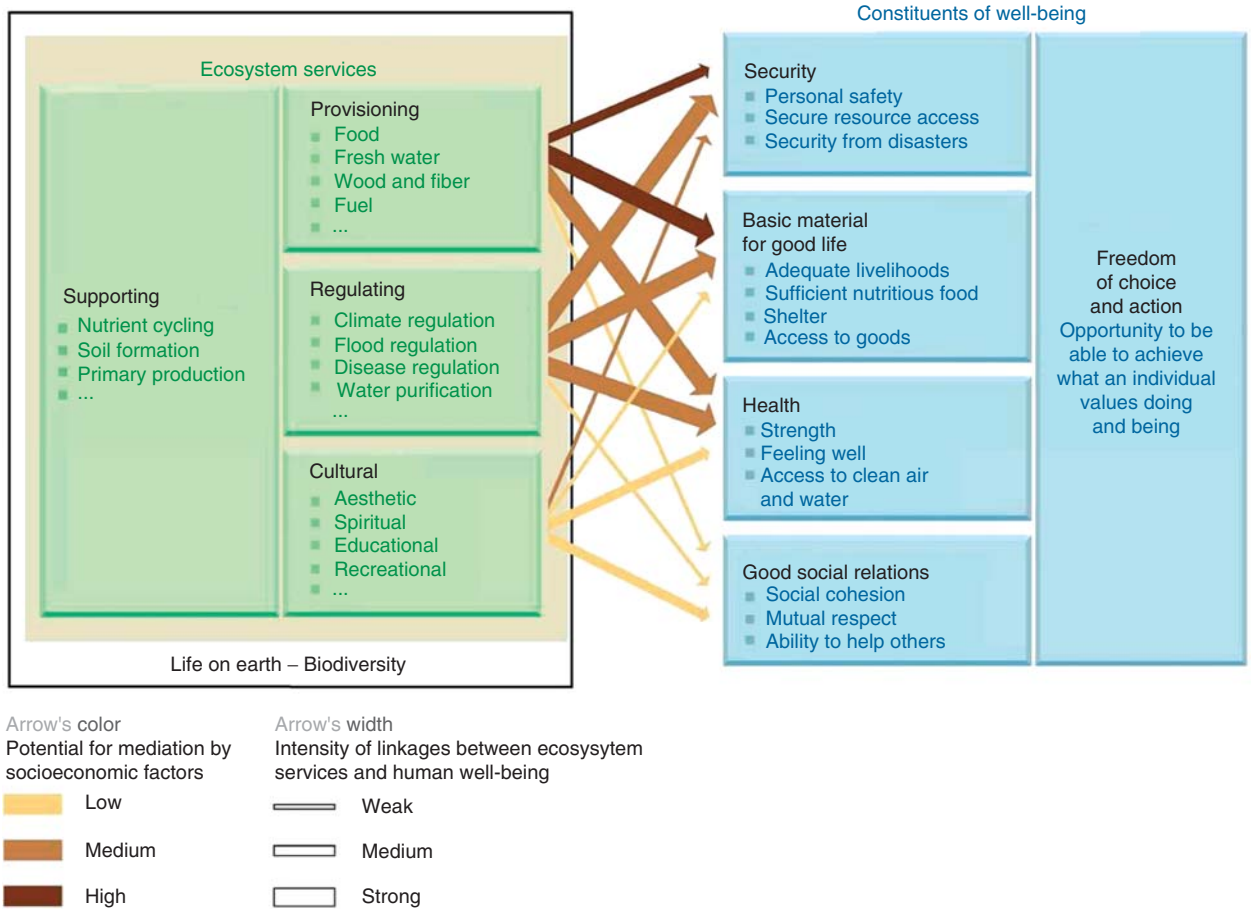

Figure 2 Linkages between biodiversity, ecosystem services, and human well-being. From Millennium Ecosystem Assessment (2005) *Ecosystems and Human Well-Being: Synthesis*. Washington, DC: Island Press, with permission.

function of certain species on ecosystem processes or eventually lead to species extinctions. Thus, if a large number of native species exist in a given area, it is more probable that some species persist and assure the maintenance of ecosystem services. Also, there is evidence that habitats maintaining the original species composition are more resistant to invasion of nonnative species.

The services provided by biodiversity and ecosystems might be valued according to a utilitarian approach (Table 1). Use values are assigned to services that have a concrete utility to humans, providing either direct use benefits or indirect use benefits, or a potential utility in the future, either for the individual or for future generations (option values). Existence value is the value that people assign to a species or ecosystem even if they do not obtain any benefit besides the satisfaction of knowing that the species or ecosystem exists. For example, people in Europe might contribute to a conservation program to save pandas in China, only because they have a philanthropic interest in assuring the species survival.

Ecosystem Services and Human Well-Being

Ecosystem services, along with other factors such as education, political systems, or available technology, contribute to human well-being. The concept of human well-being is inevitably dependent on cultural and socioeconomical settings, which influence what people consider to be most imperative for a comfortable life. Nevertheless, the elements necessary to human well-being can be classified into five components: sense of security, basic materials for a good life, health, good social relationships, and freedom of choice (Figure 2).

Sense of security exists when people feel safe about the availability of resources and the protection from eventual natural disasters and feel that their physical integrity and economic independence are safeguarded. If provisioning services fail and limit the access of people to food, water, or fuels, this will affect their sense of security. Also, if regulating or supporting services suffer from changes, communities will be in greater risk of natural disasters or diseases, and their sense of security will be weakened.

Table 1 Utilitarian value of ecosystem services, examples of ecosystem services, and general correspondence with categories of ecosystem services

Value	*Examples*	*Category*
Use value		
Direct use value		
Material benefit	Food, fuel, medicines	Provisioning services
Nonmaterial benefit	Recreational areas Sacred forests (spiritual benefit)	Cultural services
Indirect use value	Climate regulation Water purification Soil formation Oxygen production	Regulating and supporting services
Option value	Vaccines, medicines Genetic resources for investigation Key species for ecosystem functioning	Provisioning, cultural, and regulating services
Nonuse value		
Existence value	Satisfaction of knowing that a species or ecosystem exists	Cultural services

The basic materials for a good life comprise food, water, fuel, and also the earning of an income. When provisioning services are affected, access to basic materials is also affected. For example, access to food, forest materials, and clean water is seriously compromised when crops are destroyed by plagues or climate disasters, when wildfires occur, and when rivers are polluted.

Health is a central component of human well-being. Imbalances in regulating and provisioning services are the principal causes of public health problems and deficits. Contaminated water is the source of diseases such as diarrhea, cholera, and typhoid fever, leading to the death of thousands of people every year. Air pollution is a problem in urban areas where it causes lung and heart diseases. Climate change is promoting the expansion of the area affected by several diseases, such as malaria. Failure in provision services affects the access to basic materials and consequently the access to an adequate diet, potable water, or medicines, which are essential for good health conditions. Cultural services also contribute to human health, in particular mental health.

Good social relationships are dependent on the other well-being components. When basic materials or security are not assured, communities are under stress and their social relations deteriorate. The failure in provisioning or regulation services might conduce to famine or climate disasters, leading to unstable social environments. When communities are culturally connected with the environment, by faith or ancient traditions, landscape changes may affect their social stability and their emotional health.

When one of the other well-being components fails, freedom of choice and action is affected. For example, if people have to walk several kilometers to get water, if their properties are destroyed by fire, or if they need to compete for food or shelter, their range of life options will be much reduced. Freedom of choice is transversal to the achievement of the other components of well-being. When people live a good life, they are in condition to make better options about ecosystem use and management. This influences the state of ecosystem services and consequently the condition of the other components of well-being.

Poor communities are more vulnerable to the degradation of ecosystems and to the effects of changes in ecosystems services; in particular, if they depend directly on local ecosystems. Wealthy societies, however, are on a safer position because they have the economical power to minimize the consequences of natural disasters, can afford medicines to combat diseases, and if local ecosystems fail, products may always be imported from other locations. This economical advantage of wealthy societies is sometimes mischievous, because it allows the transfer of production demands to poorer regions, causing the exploitation of ecosystems in those regions with little benefits to local people.

Human Activity, Biodiversity Loss, and Implications for Human Well-Being

World population has increased exponentially over the past decades: 2.5 billion people in 1950, 6.5 billion in 2005, and projections say 9 billion by 2050. Furthermore, per capita consumption has also been increasing. A direct consequence of this trend is the increase in the demand for natural resources, often above sustainable levels. Native forests are being logged and replaced by

agricultural fields or production forests, world fisheries are in imminent risk of collapsing, and about two-thirds of the world's available freshwater is polluted. During the past centuries, human activity has raised species extinction rates up to 1000 times the values found in the fossil record. According to 'The International Union for Convervation of Nature (IUCN) Red List of Threatened Species,' a world report on species conservation status, there are presently more than 5000 endangered species of vertebrates and 8000 of vascular plants.

Biodiversity loss encompasses loss at the genetic, species, and ecosystem levels. The loss of genetic diversity increases species vulnerability to ecosystem changes. This is especially alarming in the case of crops. The intensification of agricultural practices has led to a decline in the genetic diversity of cultivated species. The decline in agrobiodiversity reduces resilience of our crops to ecosystem changes, threatening the stability of food production. Losses of species diversity comprise either the extinction of species and populations at local scales or changes in community composition. A current trend is the simplification of biotic communities due to the increasing dominance of species better adapted to human-modified ecosystems (species that are more tolerant to perturbation, that benefit from nutrient loadings, etc.). An identical result is observed in the case of invasive species that, in the absence of predators, pathogens, or competitors, become dominant, leading to the reduction or even extinction of native populations. As a consequence, biotic communities around the world are becoming less distinct, and there is a loss of diversity from local to global levels. Finally, biodiversity loss at the ecosystem level is transversal to most terrestrial biomes (e.g., temperate forests, grasslands, and tropical forests), mainly due to conversion into cultivated land.

The main drivers of ecosystem change and biodiversity loss are land-use changes, pollution, overexploitation of resources, spread of invasive species, and climate change. These drivers have a direct effect on ecosystems, but their dynamics are influenced by indirect drivers such as sociopolitical context, economic activity, demographic changes, cultural practices, and scientific and technologic advances. For example, the adoption of environmental practices that conduce to sustainable use of resources is more likely in sociopolitical regimes that encourage the dialogue between different sectors of the society.

The importance of each driver is not the same across ecosystems. Terrestrial ecosystems (e.g., forests and grasslands) are especially affected by land-use changes, particularly the conversion of natural habitat into agricultural land. The main driver affecting marine ecosystems is overexploitation of fish stocks, whereas pollution and invasive species are currently the major threats to freshwater ecosystems.

Ecosystem changes are a result of synergistic combinations of the interactions between drivers. Moreover, drivers also interact across spatial and time scales and ecosystem changes might be caused by events that occurred somewhere in the past. For example, isolated events as deforestation of tropical forests, fires in Mediterranean ecosystems, and global emissions of greenhouse gases from fossil fuel combustion will all contribute to climate change. Climate change affects local communities worldwide by causing storms, floods, sea level rise, and droughts.

Reports of natural catastrophes (e.g., floods, storms, and tornados) costs are quite demonstrative of the effects of ecosystem changes and biodiversity loss on human well-being. Global costs of natural disasters between 1980 and 2004 reached values more than $1800 billion. In 2002 alone economic losses were evaluated to be $70 billion. The effects of natural disasters go beyond economic losses: more than a million deaths between 1980 and 2004, destruction of public infrastructures, and social instability. Part of these economic and human losses can be attributed to the deterioration of regulating services and poor land planning. Poorer communities, unable to react to disasters, are more affected by these events and might face subsequent epidemics, famine, and social conflicts.

Human pressure on ecosystems usually intends to intensify the production of ecosystem goods, but frequently disregards the degradation of other services, often regulating services. For instance, the use of pesticides and fertilizers in agriculture enhances production levels but negatively affects the quality of groundwater. Commodities have a market value and their economic benefits are easily accessed, therefore they are considered in management options. In contrast, there are no markets for regulating and supporting ecosystem services, and as a consequence theose services lack economic value and are often disregarded. However, the costs of losing these services are sometimes higher than the economic benefits obtained from marketed goods, and the final balance can be critical to human well-being.

Some studies have compared the economic benefits from preserving natural ecosystems versus the economic profits obtained from converted land (**Figure 3**). In Canada, freshwater marshes are drained and used for agriculture due to their high fertility. Preserved habitats offer high-quality areas for outdoor activities, such as hunting and fishing, and provide higher economic benefits than converted wetlands. In Cameroon, forests are also converted into farming land. Benefits from maintaining forests include protection against soil erosion, carbon retention, and also biodiversity option values and existence values. In Thailand, mangroves are converted into aquacultures for shrimp farming. Non-converted mangroves supply several goods, such as timber, charcoal, and fish, and provide coastal protection

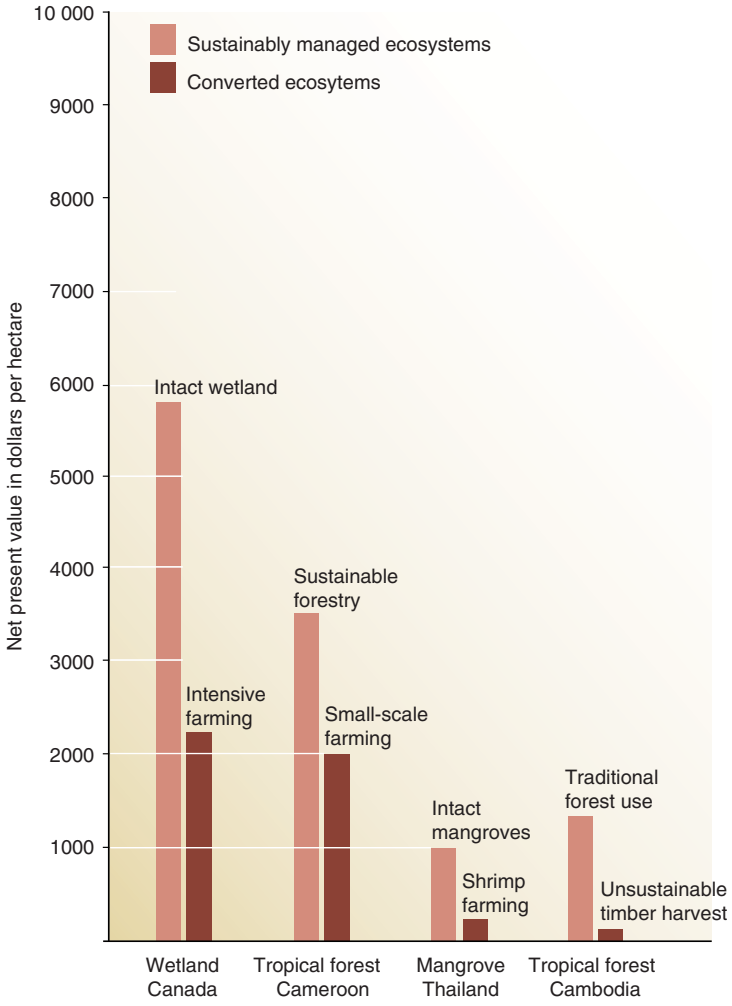

Figure 3 Economic benefits from preserving natural ecosystems versus the profits obtained from converted land. From Millennium Ecosystem Assessment (2005) *Ecosystems and Human Well-Being: Synthesis*. Washington, DC: Island Press, with permission.

from storms. Traditional forest use in Cambodia includes the practice of swidden agriculture (agriculture made in short-term fields created from cutting and burning forest patches) and extraction of forest products (timber, food, medicines). Provisioning services from traditional use provide fewer profits than unsustainable logging. However, if other ecosystem services are considered, such as carbon retention, water retention, and biodiversity, unsustainable use of forests becomes less profitable than traditional use.

In all these cases, the gains from the production of goods are large for private owners, but for the country economy the final balance is not lucrative, either due to the costs of converting land (e.g., cost of draining marshes) or due to the loss of the services obtained from sustainable managed ecosystems. A last example (not represented in Figure 3) comes from New York City. The city watershed had been under pressure for development with negative consequences for water quality. The city faced two options: build water treatment facilities to deal with decreasing water quality or protect the watershed ecosystems. The cost of building water treatment facilities was estimated at $8 billion, plus $300 million per year for maintenance. The cost of having that service provided by ecosystems was $1 billion, corresponding to the ecological restoration of the watershed that supplies the city with water and to economic compensations to land owners to preserve the habitat. As a result of this valuation, New York City has decided to protect the watershed ecosystem.

Forest Ecosystem Services and Human Well-Being

Forests constitute ubiquitous ecosystems vital for the biosphere equilibrium. Forests are central to the biogeochemical cycles (e.g., carbon cycle), support much

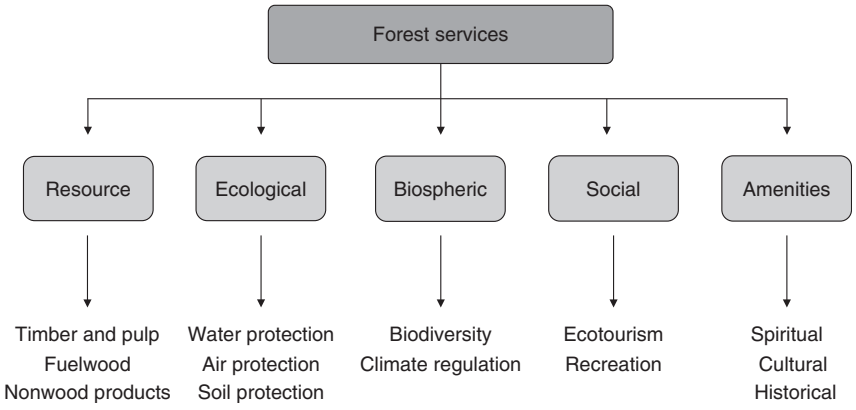

Figure 4 Forest ecosystem services. Adapted from Millennium Ecosystem Assessment (2005) *Ecosystems and Human Well-Being: Current State and Trends*. Washington, DC: Island Press.

biodiversity, and provide many ecosystem services (Figure 4). Humans benefit from forest services at all spatial scales, for example, fuelwood at the local scale, water purification at the regional scale, and climate regulation at the global scale. Owing to historical human action, approximately 40% of the original world's forests have been destroyed and much of the remaining forest is fragmented or perturbed.

This section examines in more detail the feedback loop between forest biodiversity, ecosystem condition, and human well-being. The evolution of the Portuguese forest is used as a case study for this analysis.

The Portuguese landscape was dominated by oak forests (*Quercus* spp.) in the beginning of the Holocene. Evergreen oaks, such as the cork oak (*Quercus suber*) and holm oak (*Quercus ilex*), were dominant in the south and deciduous oaks, such as the common oak (*Quercus robur*) and pyrenean oak (*Quercus pyrenaica*), in the north. Land-use changes started with human settlement in the Neolithic and gradually continued until today. Forests were first cleared due to the need of land for pastures and agriculture and then due to the increasing need for fuelwood and industrial wood, in particular for naval construction during the maritime discoveries (fifteenth to sixteenth centuries). Records dating from the seventeenth century report the occurrence of severe floods. Deforestation of mountains led to soil erosion and sedimentation of soil particles into riverbeds. The changes in the riverbeds and the increased surface runoff caused the floods. Agriculture was by that time the main land use in the country and existing forest had already changed in composition, with pine becoming the dominant species.

Since the late nineteenth century several major forestation programs took place and forest is nowadays the main land-cover class. Forestation programs were first developed by the government and later by private organizations. Since 1986, when Portugal became a member of the European Community, there were also subsidies from the community. The first motivation for these programs was the need of restoring forested area and forest ecosystem services including soil protection and flood regulation. Later there was commercial demand for wood and wood pulp due to the growth of forest industry. The species used for forestation were mainly pine (*Pinus pinaster*) and eucalypt (*Eucalyptus globulus*), both fast-growing species and with a high commercial value.

The state of degradation of ecosystems after centuries of unsustainable use conditioned the selection of trees species to those that were able to cope with poor environmental conditions and simultaneously halt land erosion. Pine was chosen due to its ecologic properties and commercial value. It is a fast-growing species with pioneer abilities (i.e., it is able to colonize poor environments and create the conditions for the establishment of richer and complex ecosystems) and also provides important economic benefits from timber, resin, and other forest products. Pine was intensively planted in the first half of the twentieth century, and its area of distribution reached a maximum in the 1980s. Although it is an autochthonous species, its actual distribution is unnatural and much expanded.

The plantation of eucalypt was motivated only by interests in direct economic benefits (wood pulp). Plantation started after 1950 and was more intense in the 1980s. The growth of the wood pulp industry was the principal driver of eucalypt forest plantation.

Pine and eucalypt are now the dominant species in the northern half of the country. Broadleaf deciduous oaks have a very limited distribution, being dominant only in some mountain areas. In the southern half of the country, perennial oaks are still dominant, due to their commercial value for the production of cork and their production of acorns for cattle.

Recent statistics indicate that Portugal is in the top 10 countries with the largest annual gain of forest (production forest plantations), an annual net gain of

40 000 ha per year (2000–05). The Portuguese forestry sector is a source of income to approximately half million people. This shows the importance of planted forests for human well-being. Pine and eucalypt forests are the principal sources of wood products, namely, timber and pulp. Planted forests also provide nontimber forest products, such as pine nuts and resin, and if properly managed they also provide other ecosystem services such as soil fixation (some pine forests were planted to protect coastal dunes) and carbon retention. Although planted forests generally support less biodiversity than native forests, they may promote biodiversity when placed in formerly degraded habitats.

Nevertheless, failures in the planning and management of planted forests facilitated the occurrence of wildfires, which is now one of the main environmental and economic problems affecting Portugal (in 2003, approximately 300 000 ha of forest was burnt, which corresponds to approximately 3% of the country area). Indeed, most of the planted forests were not planned to be structurally diverse. Instead they are monospecific and occupy large continuous areas. Moreover, the intense migration of people from rural areas to urban centers during the past decades left forests abandoned and without management. Therefore, fuel loads have accumulated and the landscape is currently much less compartmentalized, leading to large-scale fires. This situation is especially difficult to control because most forest belongs to small private owners and only their organized action would have effective results on forests condition.

The problem is aggravated by the fact that both pine and eucalypt trees contain flammable substances that intensify fire and even the litter, either fallen needles or leafs, is very flammable, thus contributing to fire progression. In fact, both species have evolved in fire-prone ecosystems and have traits to cope with fire damage and to persist after fire occurrence. The consequence of all these factors (bad planning, lack of management, and flammability of planted species) is the occurrence of severe fires every year, in particular during summer months, when temperatures are high and precipitation is low.

Forest fires have severe effects on human well-being. First, there are direct effects on the economy, affecting several sectors of the society, from industries to small owners, and also public administration. Besides the destruction of forests, fires also affect public infrastructures and destroy private property, such as houses, cars, and cattle. There are also health costs associated with these fires, such as injuries and deaths and respiratory problems caused by particle emissions. Furthermore, fire combat operations are very expensive, with a single hour of air operations costing over €2000.

Indirect effects on human well-being are mediated by the consequences of wildfires for ecosystem services. Wildfires have negative impacts on air purification services (during the process of photosynthesis, oxygen is produced and carbon dioxide and polluting particles are removed from the atmosphere) and water cycle regulation. Soil quality also is affected after fire. During the combustion of forest materials, minerals are released and stay on the soil surface. However, due to the absence of vegetation, the soil erodes, losing minerals and the remaining organic material. The lack of vegetation also increases the probability of burnt areas to suffer landslides and floods. Fires affect climate regulation as well, at both the local and the global scale. Climate is affected at the local scale when forest cover disappears, as forests have a vital role in the water cycle, which regulates air humidity and temperatures. Fires also affect climate at the global scale as the release of carbon into the atmosphere contributes to global warming.

After a long history of forest destruction and the reversion of the pattern with the plantation of new forests, the Portuguese forest now faces new threats. Forested area is increasing but forest plantations present several barriers to attain sustainability. They support less biodiversity than native forests and are wildfire prone. As a consequence forest habitats are facing a progressive degradation and are being replaced by scrublands, an early successional habitat. This tendency has serious implications for people who lose the benefits of forest ecosystems.

The need for new forest management strategies is evident. Future actions have to consider the promotion of biodiversity and ecosystem services. Oak forests are climax forests, that is, they represent the last stage of succession. Oak forest communities are biodiverse and adapt to local environmental conditions, which confers them resistance and resilience to perturbation. In the case of fire, and considering the present fire regimes, oak forests are more resistant to fire perturbation than pine or eucalypt forests. This is partially due to their high water content (water is retained in soil, litter, and vegetation), which raises moisture levels and diminishes flammability. This resistance to fire also assures the maintenance of forest processes and forest services, reducing the risks of soil erosion, soil nutrient loss, floods, and so on.

Oak forest provides important regulating services, such as water protection, climate regulation, and soil formation. The water protection service is especially important because the remaining oak forests are mostly found in mountain environments where precipitation is usually greater. Because oak forests usually have a highly permeable soil, the amount of rain water lost by runoff is reduced. Some water stays retained in the superficial soil layers and the remaining percolates deeper and deeper, being purified in the process and finally reaching groundwater and, in due course, joining streams and rivers. With respect to climate regulation, oak forests

have an important role as carbon sinks owing to their stability.

Owing to their past destruction and actual distribution, the larger stands of oak are located in protected areas and their management is focused in nature conservation targets. Therefore, the most profitable provisioning service, timber provisioning, is currently marginal. Nevertheless, oak wood has a high quality, being resistant and durable, and with a significant commercial value. The extant forests might have a good economical potential as productive forests if correctly managed, and investment in new plantations of oak for timber production can be economically attractive. Finally, native forests also provide important cultural services. For example, their natural spaces present a high potential for ecotourism and outdoor activities, which also have a use value for local communities as important sources of income.

All summed, and although there are no economic estimations of the value of services provided by native forests in Portugal, it is quite probable that their total benefits might surpass the actual profits of pine and eucalypt forest, when the cost of wildfires is accounted for. Moreover, native forests support much biodiversity and should also be promoted by their option and existence values.

Finding the Way to Sustainability

The overexploitation of resources has led to the present biodiversity crisis. The need to halt biodiversity loss is unquestionable. The CBD was opened for signature in 1992. Since then, 195 countries committed to the challenge of halting biodiversity loss. More recently, the Conference of the Parties, the governing body of the Convention, has decided "to achieve by 2010 a significant reduction of the current rate of biodiversity loss at the global, regional and national level as a contribution to poverty alleviation and to the benefit of all life on earth." The large number of countries involved in the '2010 target' is a sign of the international community awareness about the urgent need of actions toward the protection of ecosystems and their services. Additionally making progress toward the 2010 target will contribute to the Millennium Development Goals (MDG) of the United Nations. The MDG determine, among other things, the reduction in poverty and child mortality, the investment in education, and the integration of the principles of environmental sustainability in political decisions.

Human well-being and ecosystem protection have been sometimes at odds at the local scale because of the spatial disconnection between where ecosystem services are provided and where people benefit from them. This is further aggravated because many of these services are nonmarket services, being often disregarded in economic decisions. Nevertheless, the value of the benefits of nonmarket services is considerable and should be included in management strategies and development policies. For instance, much of the remaining natural areas are located in developing regions, where essential components of well-being have not yet been achieved. If nonmarket ecosystem services are valued, these populations will be in possession of tradable goods. The populations in these regions can be paid to maintain their natural habitats and use this new source of income for development. The commerce of carbon credits is an example. Polluters, from countries to industries or common citizens, compensate their carbon emissions by paying for the maintenance of forests that will sequester and retain carbon. Some states have also recognized the importance of ecosystem services of certain habitats by passing legislation directed at protecting those habitats. For instance, wetlands, which are important for water purification and flood regulation, are currently protected by laws in many countries.

An alternative is to find win-win solutions at the local scale, that is, options that favor both ecosystem condition and socioeconomic development locally. This approach has been followed in some projects aiming at the sustainable management of forests by commercializing a wider range of forest products, including timber, edible products such as mushrooms, fodder for domestic animals, medicines, and exudates such as gums.

Probably, a combination of both local and global approaches will be the key to the best sustainability strategies. And, at the consumer end, the adoption of a behavioral conduct of saving energy and other resources, such as food and water, is also essential. Ecosystems would be preserved from unnecessary pressure demands and as a consequence human well-being would be improved.

Finally, it is necessary to promote studies, from local to global scales, to obtain information about the state of ecosystems and their linkages with human well-being, and make the results available to the broadest spectra of people – from general public to politicians, teachers, and scientists. Recently one such study was conducted, the Millennium Ecosystem Assessment (MA). The MA involved more than 1300 scientists from 95 countries. The result was a comprehensive set of reports, freely available, on the state of ecosystems, their services and the linkages to human well-being, at different spatial scales. An MA2 is now being planned to start somewhere around 2010, but other studies looking at successful management strategies using local and global approaches are needed.

In summary, human well-being and biodiversity are intimately related. The consequences of biodiversity loss to human well-being are diverse and difficult to predict with exactitude. They might reach unexpected severity and affect people anywhere in the world. To assure the

long-term improvement of human well-being worldwide, sustainable strategies for managing ecosystem services must be developed.

See also: Climate Change and Health, Climate Change and Health: Risks and Adaptive Strategies, Climate Change, Environmental Health, and Human Rights, Ecosystems Services, Overview of How Ecosystem Changes Can Affect Human Health.

Further Reading

Balmford A, Bruner A, Cooper P, et al. (2002) Economic reasons for conserving wild nature. *Science* 297: 950–953.

Brooks TM, Mittermeier RA, da Fonseca GAB, et al. (2006) Global biodiversity conservation priorities. *Science* 313: 58–61.

Costanza R, d'Arge R, de Groot R, et al. (1997) The value of the world's ecosystem services and natural capital. *Nature* 387: 253–260.

Daily GC, Söderqvist T, Aniyar S, et al. (2000) The value of nature and the nature of value. *Science* 289: 395–396.

Díaz S, Fargione J, Chapin FS, and Timan D (2006) Biodiversity loss threatens human well-being. *PLoS Biology* 4: 1300–1305.

FAO (2006) *Global Forests Resources Assessment 2005: Progress towards Sustainable Forest Management*. Rome: FAO.

Loreau MS, Naeem S, Inchausti P, et al. (2001) Biodiversity and ecosystem functioning: Current knowledge and future challenges. *Nature* 294: 804–808.

Millennium Ecosystem Assessment (2005) *Ecosystems and Human Well-Being: Biodiversity Synthesis*. Washington, DC: World Resources Institute.

Millennium Ecosystem Assessment (2005) *Ecosystems and Human Well-Being: Current State and Trends*. Washington, DC: Island Press.

Millennium Ecosystem Assessment (2005) *Ecosystems and Human Well-Being: Health Synthesis*. Geneva: World Health Organization.

Millennium Ecosystem Assessment (2005) *Ecosystems and Human Well-Being: Synthesis*. Washington, DC: Island Press.

Myers N, Mittermeier RA, Mittermeier CG, da Fonseca GAB, and Kent J (2000) Biodiversity hotspots for conservation priorities. *Nature* 403: 853–858.

Pereira HM and Cooper DH (2006) Towards the global monitoring of biodiversity change. *Trends in Ecology & Evolution* 21: 123–129.

Relevant Websites

http://www.conservation.org
Conservation International.

http://www.biodiv.org
Convention on Biological Diversity (CBD).

http://www.millenniumassessment.org
Millennium Ecosystem Assessment (MA).

http://www.unep.org
United Nations Environment Programme (UNEP).