Chapter 13

# Forests as social–ecological systems

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## Introduction: ecosystem services as a framework for linking people and forests

The state of forests is intricately linked to the lives of the people dependent on them. This chapter examines the social impacts related to changes in climate and forests using diverse case studies from around the world. It treats forests as social–ecological systems, recognizing the interconnected influences of forest health and human welfare. It focuses on the socioeconomic systems already being impacted by climate change, how social forces mitigate or amplify those impacts, and possible adaptation options. It pays special attention to vulnerable populations, including rural communities dependent on natural resources for their livelihoods and likely disproportionately affected by climate change.

According to the United Nation's *State of the World's Forests* (Food and Agriculture Organization of the United Nations, 2020), more than 800 million people live in tropical forests and savannas in developing countries, rely on agroforestry farming systems, use wood-based energy for cooking, or spend part of their time collecting fuelwood or producing charcoal. These benefits people get from forests, including direct, indirect, and nonuse benefits, are collectively called ecosystem services. Ecosystem services span the physical objects that humans use or consume (provisioning services, such as food, drinking water, and wood), ecological processes that make life possible on Earth (regulating services, such as flood regulation), and recreational and spiritual connections to nature (cultural services) (Millennium Ecosystem Assessment Program, 2005). In addition, a fourth category, supporting services, is often included, which makes the other ecosystem services possible. For example, biodiversity is a supporting service that enhances the provisioning service of agricultural production.

Maintaining sufficient natural capital stocks is essential for maintaining resilient economic and social systems. In addition, many services provided by nature are more efficient than their human-built equivalent, and few substitutes exist for many supporting ecosystem services (Fitter, 2013). For example, water from forests is generally of higher quality than water from other land uses due to the natural filtration processes of forest vegetation and soils, allowing lower-cost methods of water treatment (Melo et al., 2021; Seidl et al., 2017; Vincent et al., 2016; Warziniack, Sham, Morgan, & Feferholtz, 2017). Protected forests also provide a buffer from other more polluting land uses, limiting the development and agriculture within a watershed.

The value of provisioning services has been studied for centuries, dating back to at least 1849 and Faustmann's research on the optimal timing of forest harvests. Because provisioning services are often traded in markets and represent key links in supply chains, they have long been tracked and measured through domestic market transactions, imports, and exports.

Most forest benefits, however, are not exchanged in markets, making it difficult to estimate their value. In such cases, alternative economic valuation techniques can be used. Nonmarket values for recreation, scenic beauty, and wildlife have been widely studied in economic research. In a 1949 letter to the U.S. National Park Service, Harold Hotelling described how demand curves and nonmarket values for recreation could be derived from the relationship between visitation rates and the distance visitors live from a particular site (Hotelling, 1949). Hotelling observed that the cost to travel to the site is a price visitors incur, and people that live closer and therefore have lower costs to visit, have higher visitation rates. Over 70 years later, Hotelling's ideas still form the basis of many economic valuation studies.

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**FIGURE 13.1** A Peruvian guide points out the biodiversity on the Inca Trail, including 425 registered species of orchids along the Inca Trail and in Machu Picchu. *Photo: Nikoma Thompson.*

In contrast to these well-studied uses of nature, the concept of ecosystem services arose from concerns that a wide range of nature's benefits was being ignored. Missing from the discussion was nature's role in cultural celebrations, spiritual identity, mental and physical health, regulating global climate, and sustaining everyday life. In addition, non-timber forest products (NTFPs), essential to the livelihoods of people throughout the world, had been essentially ignored (Ticktin, 2004). The early ecosystem services literature highlighted the differences between traditionally valued parts of nature and these neglected services by distinguishing between ecosystem goods (tangible products of nature) and ecosystem services (intangible benefits from nature) (Brown, Bergstrom, & Loomis, 2007). It was hoped that highlighting the value of intangible services would provide incentives for better management.

Today, the line between ecosystem goods and services has blurred, partly for simplicity and partly to follow conventions in several landmark reports. For example, the Millennium Ecosystem Assessment (Millennium Ecosystem Assessment Program, 2005) lumped ecosystem goods and ecosystem services together, and for better or worse, that has largely become the convention in the literature. A byproduct of combining goods and services is the ability, if not the preference for, addressing multiple ecosystem services provided by a landscape. Forests that provide clean drinking water also tend to be biodiversity hotspots, which in turn support rich natural resource-based cultures and tourism.

Peru, for example, is one of the most biologically diverse countries on the planet. The country's diversity of landscape leads to a wide range of plants and animals earning it the designation of megadiverse by the Center for Monitoring the Conservation of the Environment. In 2019, tourism revenues in Peru reached $4.7 billion. Two of the country's top attractions are Machu Pichu and the Inca Trail. Visitors to Machu Pichu bring in about $6 million every year, and the Inca Trail brings another $3 million. Direct spending on tourism and the industries that support tourism are important to the guides and communities in the region (Fig. 13.1).

## Sustainable development goals and drivers of change

In 2020, the United Nations Environment Program released its 6th Global Environmental Outlook (GEO-6) under the theme "Healthy Planet, Healthy People." It called attention to the ties between environmental conditions and the health and wealth of the world's people. It also provided an update on progress toward meeting many of the goals set out in the 2030 Agenda for Sustainable Development (the sustainable development goals or SDGs). In short, the world is not on track to meet many of them, particularly those related to the environment and human health.

The GEO-6 identified five drivers of environmental change that determine the ability to meet environmental and human health goals: population, urbanization, development (i.e., industrialization and increasing regional incomes), technology, and climate change. The underlying causes of excessive forest conversion and degradation can also be traced to the market and policy failures affecting the forest land use decisions that affect these five drivers. Meeting many of the SDGs will depend on how countries react to the climate crisis and how well they address those drivers.

**FIGURE 13.2** Neighborhood gardens (left) and trees (right) not only provide food and shade, they also provide a sense of connection to nature and wildness for city residents. *Photo: Travis Warziniack.*

## Population and urbanization

In 2020, the world's population was estimated at 7.8 billion people. By 2050, the population is expected to reach nearly 10 billion people.[1] Over half of those people live in cities, resulting from a shift from a majority rural world population to a majority urban population that occurred in 2010.

Demands for forest products by urban populations and land clearing associated with urban diets (mainly meat consumption) are the leading causes of deforestation in much of the world (DeFries, Rudel, Uriarte, & Hansen, 2010). Despite their smaller residential footprint, urban residents, on average, use more natural resources per capita, use more electricity, eat more meat, and purchase more consumer goods than their rural counterparts (Kennedy, Nantel, & Shetty, 2004; Mendez & Popkin, 2004; Rudel, 2007). In addition, a meta-analysis on the causes of deforestation found that forests are more likely to be cleared when the economic returns to doing so are high, either because the forest product or alternate land use is profitable or because the cost of clearing the land is low. For example, roads allow easy forest access (Busch & Ferretti-Gallon, 2020).

Due to their dependence on forests and natural resources, the rural poor bear a disproportionate share of the burden of these consumption habits (Vedeld, Angelsen, Sjaastad, & Kobugabe, 2004). About 28% of household income in developing countries comes from forests and wildlands (Angelsen et al., 2014), and 70% of the world's poor depend on local natural resources to supplement consumption and income, with higher rates among women and minorities (Barbier & Hochard, 2018; TEEB, 2010). The rural poor are expected to see the highest population growth rates, closely linked to unequal access to education, lack of women empowerment, and lack of access to sexual and reproductive services (Malhotra, Schuler, & Boender, 2002). These social forces lock in sustained poverty and susceptibility to both climate change and land degradation (Jaka & Shava, 2018; Yadav & Lal, 2018).

Urbanization can also increase socioeconomic status, quality of life, and overall human health, but these benefits differ by city. In the Global South, people are becoming more hesitant to move to larger cities, like Johannesburg, South Africa, due to crime and low-quality housing. This change results in urbanization in previously designated rural areas and the growth of small and medium cities (McHale, Pickett, Bunn, & Twine, 2013). These secondary cities may provide key socioeconomic benefits and ecosystem services to a larger population (Laituri, Davis, Sternlieb, & Galvin, 2021). There is also evidence that people are growing forests in these places and caring for biodiversity that had once been overharvested elsewhere (McHale et al., 2018). A more urbanized population highlights the importance of nature in cities and studying cities as human−ecological systems. For millions of urban residents, backyard trees and community gardens are their primary exposure to nature. Pocket parks can serve as places of wildness and exploration (Fig. 13.2).

# Development

The past few decades have seen remarkable progress in empowering forest-dependent communities to steward the lands on which they live, but most remain in poverty, subject to government policies that range from benevolent to corrupt (Rahman, 2018; Sommer, 2018). Moreover, in places with poorly defined property rights, forest-dependent communities

1. https://population.un.org/wup/.

are among the most vulnerable in the world and will be among the most impacted by climate change (Badini, Hajjar, & Kozak, 2018; Sommer, 2018).

For much of history, economic growth proceeded through the extraction of natural resources on the sparsely populated frontier (Chomitz & Gray, 1996; Nepstad, Stickler, & Almeida, 2006; Rudel, 2005). As a result, governments actively promoted the clearing of forests for agriculture, ranching, and logging in the name of growth and progress. However, evidence suggests that economic development centered on natural resource extraction can slow growth through two primary mechanisms.

First, through what Sachs and Warner (2001) describe as the natural resource curse, human and financial capital invested in extracting natural resources can crowd out investments in faster-growing manufacturing or technology industries. This allocation can lead to windfalls for the elite in control of the natural resources but can set the country on a long-term growth path marked with stagnation. Competition for resource rents can lead to corruption and violence, perpetuating a country's economic woes even further. While generally considered a developing country issue, studies in the U.S. south also show that economic incentives to recruit pulp and paper companies to rural communities can lead to reductions in investments in public education and human capital (Joshi, Bliss, Bailey, Teeter, & Ward, 2000).

The second mechanism is the so-called "Dutch disease," used initially to describe the decline of manufacturing in the Netherlands following the discovery of extensive natural gas resources in 1959 (Corden & Neary, 1982). The large-scale extraction of a valuable natural resource during a boom can potentially drive up the value of a country's currency. Such extraction not only directs capital away from other sectors but also makes the country's exports less competitive on the international market. Such investments are particularly troublesome when natural resource prices are volatile, exposing resource-dependent countries to large swings in international markets.

Economists have also observed an inverted-U-shaped relationship between income and a wide range of environmental conditions, known as the Environmental Kuznets Curve or EKC.[2] Low-income households and countries tend to have low environmental impacts, almost by definition, because they consume less. During the early stages of growth, however, countries are more likely to rely on natural resource extraction and less likely to employ pollution controls. Households transitioning from fuelwood to cook and heat their homes may switch to modern and more polluting fuels (e.g., gas and electricity). Comparatively, wealthier countries have access to cleaner technologies and demand better environmental quality (Antle & Heidebrink, 1995; Goklany, 1999).

The EKC relationship has mainly been observed for environmental damages that have a local and immediate impact on economic welfare, for example, pollution such as sulfur dioxide emissions. Evidence for an EKC is mixed for tropical forests (Barbier & Burgess, 2001). Some evidence for an EKC for forests was found by Bhattarai and Hammig (2001), who looked at deforestation rates across 66 countries in tropical regions of Latin America, Africa, and Asia. They find deforestation rates increase to annual incomes of around US$4000−6000 per capita and decline thereafter. Forests, however, take decades to recover from overextraction, and most tropical countries are decades away from achieving the US$4000 per capita mark. Simply "waiting out" transitions via EKC would lead to widespread deforestation and biodiversity loss. Furthermore, wealthier countries may be shifting their environmental impacts to poorer countries. This change raises the question, as more countries go through the income transition, where will environmental impacts be displaced?

Some of the original EKC logic continues to underpin major diplomatic disagreements between countries like India and the United States, most notably in the 2021 COP 26 conference. India's refusal to allow wording in the final COP 26 Glasgow agreement that refers to the end of coal energy reliance speaks to perceived tensions in the Global South between environmental controls and increased economic wealth. Unfortunately, EKC arguments are also used to justify massive and accelerating forest clearance for increased agricultural production, sovereign autonomy over natural resources, and accelerating access to a fair share of the global economy. Economic options for reducing deforestation include removing distortionary policies like subsidies on extraction and conversion activities and correcting market failures related to open access and public goods provision such as greenhouse gas sequestration and the provision of biodiversity.

Of course, not even the most conservative economists would argue that an EKC development path is inevitable. Much of the recent debate around forest transitions centers on trying to find alternatives: developed nations, it is argued (Culas, 2012), reached a peak of deforestation a century ago, and most deforestation is now concentrated in tropical developing nations (Mather, 1992) that will eventually achieve an EKC "forest transition." What is needed, it is argued,

2. Simon Kuznets first described an inverted u-shaped relationship between per capita income and income inequality in the 1950s. This relationship was widely known as the Kuznets curves. The environmental literature adapted the Environmental Kuznets Curve name to show the relationship between per capita income and environmental quality.

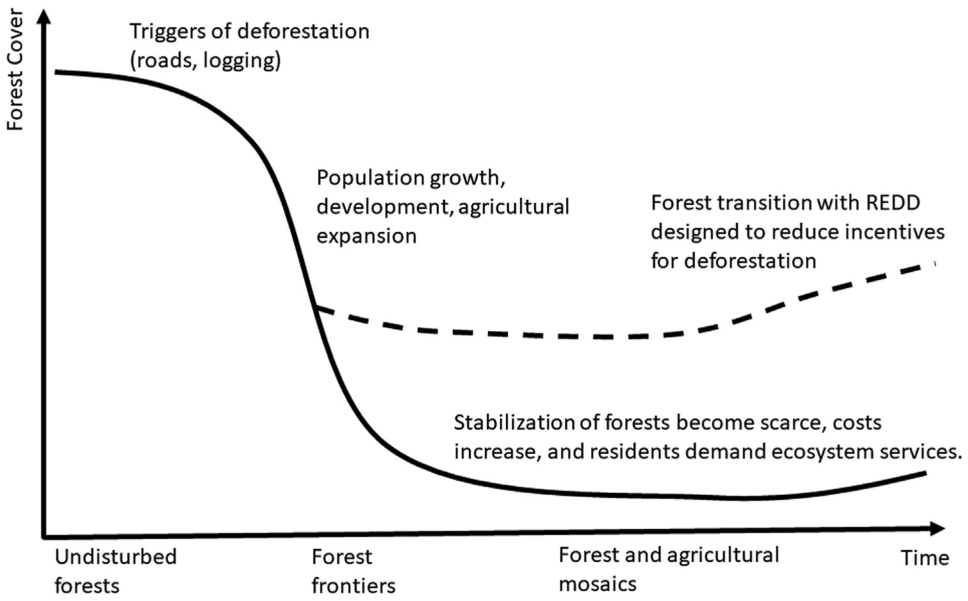


**FIGURE 13.3** Environmental Kuznets curve. The building of roads and expansion of logging opens the forest up to development and easier extraction. Population growth causes a feedback loop—more people need more forest resources which opens up more land for development. Eventually, forested land becomes scarce, increasing the costs of extraction, and wealthier residents demand ecosystem services that forests provide. REDD + is designed to tunnel through the development path and provide incentives to conserve forests. *Based on Culas, R. J. (2012). REDD and forest transition: Tunneling through the environmental Kuznets curve.* Ecological Economics, 79*, 44–51.*

is a "tunneling through" of the Kuznets Curve, avoiding the necessity of increasing per capita income to diminish environmental damage (Munasinghe, 1995, 1999). For economists like Culas (2012) and others, policies like the UNFCCC's Reducing Emissions from Deforestation and Forest Degradation in Developing Countries (REDD + , https://redd.unfccc.int/) are precisely the kind of intervention at a national level that will allow for this tunneling effect, providing incentives for countries to achieve a forest transition to reduced deforestation, ahead of the development curve (Fig. 13.3).

In contrast to resource-centered economic development, investments in human capital might be the best way to improve environmental quality and reduce the vulnerability of poor households to climate shocks. As we shall see, arguments around the disjuncture between development, increased GDP, and reduced deforestation are especially important for poor households in the African savanna woodland biome.

## Technology

Global human wealth and health saw dramatic improvements in the 20th century. Improvements were seen in consumption, life expectancy, and mortality rates. These improvements are due to advances in healthcare, public infrastructure to provide clean water and sewage, and the introduction of modern crop varieties and irrigation methods worldwide (von der Goltz et al., 2020).

The expansion of agriculture has increased pressure on forested lands, especially in the Middle East and tropical regions (Barbier, Burgess, & Grainger, 2010). In the 1980s and 1990s, the agricultural area increased by 629 million ha in developing countries and fell by 335 million ha in developed countries (Gibbs, Ruesch, Achard, & Foley, 2010). Much of this occurred in tropical forests. By some estimates, another 10 billion ha of new agricultural land will be needed to meet the demands of a larger, wealthier population by 2050—more than doubling the agricultural land base (Alexandratos, 1999; Food and Agriculture Organization of the United Nations, 2009; Tilman et al., 2001). Whether or not it is possible to allocate that much land to agriculture is an open question. Instead, changes in consumer habits may be needed, including shifts toward diets with less meat and food waste (Bijl et al., 2017).

Some countries with increasing land scarcity have attempted to decouple agricultural production from land use. For example, the high-density city-state of Singapore aims to produce 30% of its food by 2030, up from about 10% in 2020. With only 1% of its land use in agriculture, the Singaporean government relies on urban farming, hydroponics, and rooftop farms to meet much of that goal. Other cities are taking similar steps, with urban farming growing in Chicago, Vancouver, and throughout European cities (Diehl et al., 2020). Agroforestry, the integration of trees and shrubs into crop and livestock farming, has also been promoted as a solution to forest loss and land degradation. Comingling of forests and agriculture has the potential to aid in carbon sequestration, maintain biodiversity, and provide sustainable livelihoods to farmers and ranchers (Jose, 2009) (Box 13.1).

**BOX 13.1 Combating deforestation in the Amazon with remote sensing and smart policies.**

Deforestation makes up a significant portion of anthropogenic carbon emissions, with estimates ranging from 6% to 17% (Baccini et al., 2012). The Amazon Rainforest is one of the largest victims of deforestation, losing over 1 million ha of forest in 2019—lower than the 2.8 million ha lost in 2004 but worse than the 457,000 ha lost in 2012 (Pacheco et al., 2021).

There was a marked decrease in deforestation beginning in the early 2000s due to a handful of factors: new government policies, financial incentives provided by other countries, and pressure exerted on the government and industries administered by the Brazilian people (Boucher, Roquemore, & Fitzhugh, 2013). In Brazil, deforestation rates have rocketed, reaching their highest values in 16 years in 2021 (Mataveli et al., 2022). Converging evidence also suggests that deforestation has disrupted hydrological balances in the Amazon to the extent that it may now have passed a global tipping point, that extensive dieback is inevitable, and that the world's largest tropical forest is now inexorably moving towards becoming a savanna system (Boulton, Lenton, & Boers, 2022; Xu et al., 2022).

Deforestation has been reduced by over two-thirds from its average level in the decade from 1996 to 2005 and by nearly three-fourths from its high point in the mid-2000s (Boucher et al., 2013). One key to that success was implementing a data collection system called PRODES that used Landsat imagery to calculate and track deforestation in the Amazon (Voiland, n.d.). Landsat allowed annual high-resolution calculations of deforestation. In 2004, forest monitors began using MODIS satellite imagery, which has a lower resolution than Landsat but is available daily. MODIS and the DETER system allow near real-time deforestation monitoring as the fires are often used to clear the logs after cutting. These systems provide daily reports to enforcement officers. Fig. 13.4 shows MODIS images for 2000 and 2017 along the Caguan River in Colombia. In much of the Amazon, deforestation occurs along river corridors that provide access to remote parts of the forest.

While a significant improvement, MODIS's resolution generally only allows the detection of large deforestation events. Cloud cover can also significantly hinder the ability to capture deforestation when it occurs. As a result, loggers and ranchers have adapted. Illegal logging in Brazil has shifted from large-scale to small-scale clearings and occurs mainly on cloudy days, forcing scientists to seek higher resolution monitoring options that can penetrate through the cover (Boucher et al., 2013; Charles, 2021).

New remote sensing techniques use radar and microwaves to monitor deforestation and illegal logging in real time. Because radio waves can penetrate through mist and rain, this new monitoring technique allows environmentalists to be notified of deforestation in all kinds of weather. This information is accessible to everyone around the globe (Charles, 2021; Weisse, 2021). In addition, this new technology alerts stakeholders faster than ever, and captures change with much higher resolution, detecting the removal of a single tree (Charles, 2021; Weisse, 2021).

Further, studies have shown that equipping indigenous forest residents with monitoring technologies can decrease deforestation in a given territory by 52% in the first year of implementation (Slough, Kopas, & Urpelainen, 2021). In one case, a team of indigenous residents of the Peruvian Amazon confronted the perpetrators who were committing illegal activities. The mere knowledge that they were being monitored was convincing enough to make them leave (Bewick, 2020).

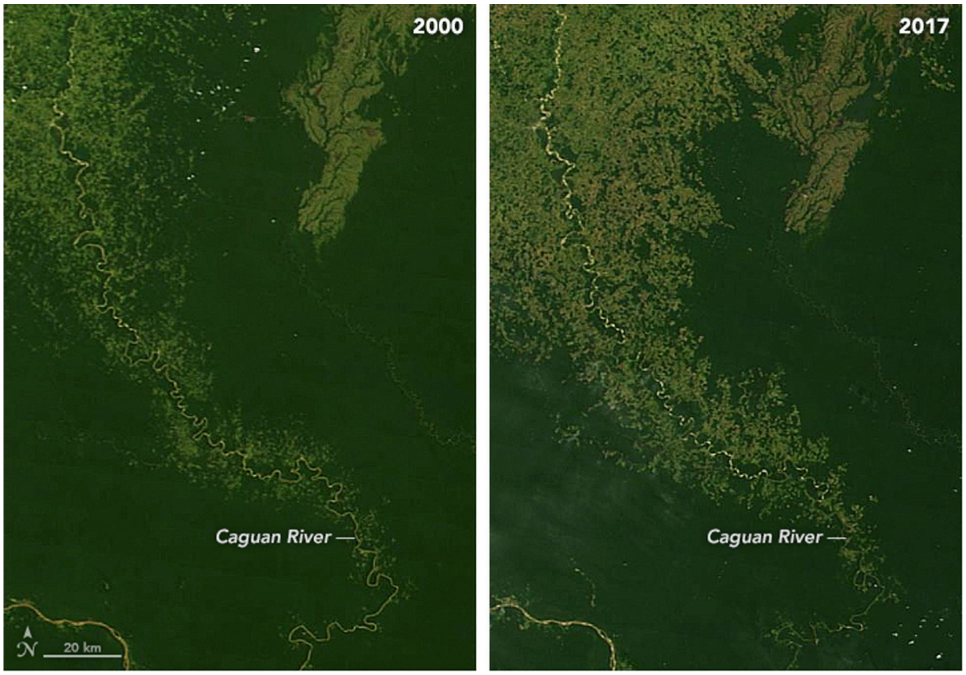


**FIGURE 13.4** NASA Earth Observatory images by Lauren Dauphin, using MODIS data from NASA EOSDIS/LANCE and GIBS/Worldview. Story by Adam Voiland. *From Mapping the Amazon by Voiland, A. (n.d.).* Tracking Amazon deforestation from above. *Earth Observatory, NASA. Available from https://earthobservatory.nasa.gov/images/145988/tracking-amazon-deforestation-from-above.*

## Spatial scale (structure/extent/balance)

The ecosystem services concept has been so effective at communicating the value of nature to people that it is now also being used to influence management and policy. The application of ecosystem services as a management tool requires moving from resource-focused policies (e.g., water, timber) to landscape-scale policies like land use (e.g., forests) and management of natural capital (the resource base from which ecosystem services flow). A natural capital framework recognizes natural limits to use and extraction and captures the environmental heterogeneity in human-dominated landscapes (McHale et al., 2018).

Accounting for the spatial scale of deforestation drivers matters. Many socioeconomic and ecological drivers are clustered in space, so disentangling their relative importance in any one location is difficult. For example, population pressures and land suitability for agriculture stand as a driving force across all spatial scales, from global to national to local (Ferrer Velasco, Köthke, Lippe, & Günter, 2020). Generalizing the effects of demographics, institutions, and ecosystem characteristics to smaller community-level outcomes, however, is more complicated. Local variation in these variables, combined with the context of culture and policy, is more likely to determine deforestation patterns and the success of interventions to stop deforestation (De Koning et al., 2011; Ferrer Velasco et al., 2020).

At a global scale, Rockström et al. (2009) identify nine planetary boundaries to keep the Earth within the "safe operating space" capable of supporting modern human societies. These planetary boundaries include limits on climate change, ocean acidification, chemical pollution, nitrogen and phosphorus loading, freshwater withdrawals, land conversion, biodiversity loss, air pollution, and ozone layer depletion. The Earth has already exceeded the safe limits for nitrogen and phosphorus loading and biodiversity loss and has crossed into the "increasing risk" category for climate change and land conversion (Steffen et al., 2015).

Combining planetary boundaries with metrics based on the U.N. Sustainable Development Goals, Raworth (2017) develops a "doughnut" model of economic sustainability. Raworth argues that goals like gross domestic product have emphasized aggregate growth over equity, justice, and environmental quality. As a result, while the wealthy have largely prospered, societies have failed to meet even the minimum needs of the most vulnerable. Therefore communities should instead strive to live in the middle band of the doughnut, taking care not to exceed planetary boundaries while striving to provide basic needs like food, water, and security for all.

While a global scale analysis is useful to communicate the urgency and extent of the environmental challenges we face on this planet, implementable solutions require a smaller-scale approach. Ecosystem service and natural capital accounting are increasingly applied to specific, local management actions. As technology develops, it might be possible to address ecosystem services at even smaller scales than land use like forests or agriculture, including the ability to monitor at the 1-m resolution, under and through tree canopies, and with short time intervals (see Box 13.2).

At local and individual levels, ascribing actions to global impacts occurs through a footprinting process. The Ecological Footprint from the Global Footprint Network transforms individuals' consumption into the number of Earths needed to sustain that level of consumption globally (Kelly, Burns, & Wackernagel, 2015). It calculates the resources individuals or communities consume in relation to the local resources available. By this measure, the United States accounts for 12% of the total global ecological footprint but only contains 4.25% of the global population. The United States uses twice the resources available within its border. The top 10% of global income earners represent 25%–43% of global consumption and ecological footprint. The bottom 10% represents a mere 3%–5% of the global ecological footprint (Teixidó-Figueras et al., 2016).

While footprinting captures the flows of natural resource use, it does little to address stocks of natural capital. Spatially explicit footprinting, however, is meant to capture resource provisioning and waste generation at multiple scales, allowing management of land use practices for the provisioning of ecosystem services (Luck, Jenerette, Wu, & Grimm, 2001). Specifically, mapping the many linkages between human behaviors and actions to impacts and effects on the ground will be necessary for designing landscapes in human-dominated ecosystems that maximize the benefits to people and nature.

**BOX 13.2 Three types of forest-dependent poor (Sunderlin et al., 2005).**

- Traditional/indigenous minorities in ancestral lands—for example, the Kayapo in the Brazilian Amazon, Batwa in southeastern Cameroon, and the Punan in Indonesia.
- People that have lived for a long time in forests but are not considered indigenous—for example, the Kinh people in Vietnam.
- People that have been displaced by rapid social change and have migrated to forests—for example, *ladino* migrants in Latin America, war refugees in the Democratic Republic of Congo, and migrants from Java and Bali to outer islands in Indonesia.

## Land tenure

Deforestation increased by 53% between 2001 and 2012 (Hansen et al., 2013), with 80% of that deforestation occurring in Brazil, Indonesia, the Democratic Republic of Congo, and Malaysia. The primary reason for deforestation is clearing land for other economic purposes, primarily agriculture. Much of this is illegal or off the books, rarely showing up in official statistics. For example, between 2009 and 2013, Indonesia lost an estimated $4 billion per year in government revenue from illegal logging (Blundell, Harwell, Niesten, & Wolosin, 2018). Illegal logging deprives countries of tax and royalty revenues, destroys natural capital, causes forest degradation, and can displace rural communities (Kissinger, Herold, & De Sy, 2012).

The poorest of the poor often rely on NTFPs for sustenance and as employment of last resort (Angelsen & Wunder, 2003; Neumann & Hirsh, 2000; Pandit & Thapa, 2004). Increased reliance on NTFPs, some argue, can lead to more sustainable forest management compared to timber production or clearing of the forest for other purposed because prosperity from NFTP relies, in part, on having a functioning ecosystem. In sparsely populated areas, this seems to be the case. However, much like any other public good, population pressures and the opportunity for commercial profit can lead to the overharvesting of high-valued NTFPs (Arnold & Ruiz-Pérez, 2001; Neumann & Hirsh, 2000) (Fig. 13.5).

Legacies of colonization throughout the world have displaced native populations or limited their power to prosper from forest resources. Today, hundreds of millions of people live in public forests (White & Martin, 2002) (Fig. 13.6), forests that are more likely to be turned over to private companies for logging and agricultural use and are often linked to corruption and rent-seeking. In many countries, forests are declared property of the national government by definition—there is no private ownership of forests. In addition to not giving an incentive to invest in or protect the forests for future use, de facto government ownership of forests creates a perverse incentive to deforest; after the forest is

**FIGURE 13.5** Village women carrying fuelwood back to their homes Sonati village, Pratapgarh, Rajasthan. Golf Monitor. *Licensed under Creative Commons CC BY-SA 2.0.*

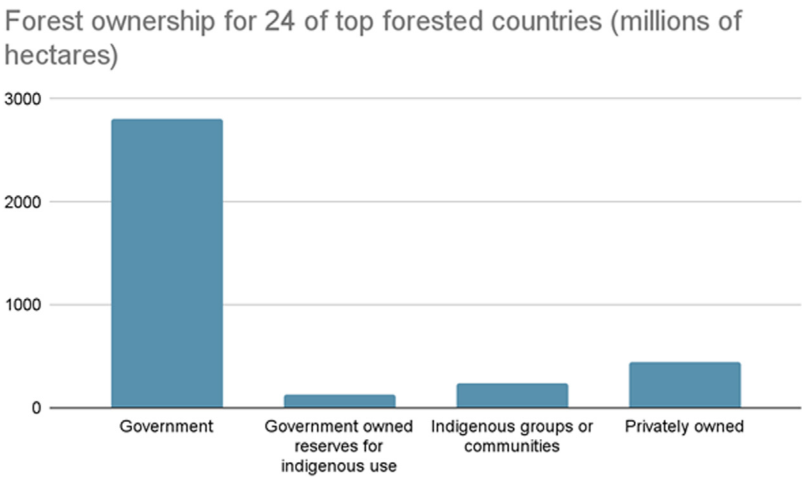


**FIGURE 13.6** Forest ownership. Data availability and reliability vary among countries, but best estimates for 24 of the top forested countries show 77% of the world's forests are owned and managed by governments, 4% is reserved for communities, communities own 7%, and 12% is privately owned. In developing countries, community reserves and ownership might be as high as 22% of all forested land. At the extremes, Sweden and Finland are 70% and 80% privately owned. Argentina is 80% private. Mexico and Papua New Guinea are 80% and 90% indigenous or other community owned. *Based on data from White, A., & Martin, A. (2002).* Who owns the world's forests?: Forest tenure and public forests in transition*. Forest Trends.*

gone, it can be claimed as private land. Where communities or rural families technically own the land, ownership is often contested or not enforced.

Legal ownership of the land has been shown to significantly impact deforestation more than governance. If property rights are not well-defined, there is no incentive or legal power to invest in and sustainably manage forests as a common good or appropriated by the wealthy (Dove, 1993). Forest outcomes are significantly improved when community members and stakeholders actively engage in management. Outcomes depend more on empowerment than the legal title (Agrawal, Chhatre, & Hardin, 2008).

Elinor Ostrom, Nobel laureate, proposed eight principles for managing common pool resources such as forests. The principles have held up in a wide range of cultures and circumstances. They rely on the active participation of those who benefit from the resource, transparent behavior monitoring, and agreed-upon consequences for rule violations.

Ostrom's eight principles for managing a commons:

1. Define clear group boundaries.
2. Match rules governing the use of common goods to local needs and conditions.
3. Ensure that those affected by the rules can participate in modifying the rules.
4. Make sure the rule-making rights of community members are respected by outside authorities.
5. Develop a system, carried out by community members, for monitoring members' behavior.
6. Use graduated sanctions for rule violators.
7. Provide accessible, low-cost means for dispute resolution.
8. Build responsibility for governing the common resource in nested tiers from the lowest level up to the entire interconnected system.

## Adaptation to climate change

Forest conversion, especially of peatlands contained in tropical forests, makes a significant contribution to greenhouse gas emissions and global warming (Barbier & Burgess, 2021). Evidence suggests that human welfare and environmental health can be effectively sustained by empowering the people that live in and depend on forests. More and more studies show that local management of local forests combined with strong institutions can increase forest health, carbon storage, and biodiversity (Chhatre & Agrawal, 2009; Schleicher, Peres, Amano, Llactayo, & Leader-Williams, 2017).

Frameworks like that proposed by Ostrom and those addressing the SDGs require a systems approach to development and conservation. Neither social nor ecological issues can be tackled without recognizing that the two are inherently linked. For example, deforestation affects soil nutrients and a forest's ability to sequester carbon as much as it affects the incomes and safety of the people dependent on the forest. Likewise, the best way to fight deforestation is often to empower forest-dependent communities and ensure their basic needs like safety, nutrition, and education are met.

Recent work has focused on whether development goals like the SDGs are synergistic or require trade-offs between important objectives (Barbier & Burgess, 2017). Expanding access to electricity, for example, is likely to decrease infant mortality but increase carbon emissions. Meanwhile, Nilsson, Griggs, and Visbeck (2016) found that providing affordable and clean energy (SDG 7) can come at the expense of reducing hunger rates (SDG 2) in sub-Saharan Africa, but also that a hunger-reduction strategy might also conflict with a forest conservation goal.

In many places, the goal is not just to limit deforestation but to actively engage in reforestation and restoration of forests (Alexander, Aronson, Whaley, & Lamb, 2016). In recognition of restoration's role in future ecosystem health, the United Nations declared 2021–30 the United Nations Decade on Ecosystem Restoration. The U.N. efforts include a synthesis of restoration work, which was then used to identify the principle of ecosystem restoration. These principles focus on the role of local people in stewarding their natural resources and how to effectively use monitoring and broad spectrums of knowledge to guide policy.[3]

### Knowledge gaps and research needs

While the research community is coming to understand the benefits of physical processes provided by forests and how those are affected by development and climate change, we are just beginning to understand the role of forests and nature on human health and well-being and how those might be affected by rapid change in landscapes. For example,

3. https://www.fao.org/3/cb6591en/cb6591en.pdf.

there is growing evidence that green areas, open spaces, and tree cover directly impact people's physical and mental health (Wolf et al., 2020). However, with climate change, land use change, and urbanization, unexpected outcomes may challenge our current ways of thinking. Scholars have gone as far as to suggest we have entered a new geological epoch called the Anthropocene, where Earth's systems are dominated by human actions more than natural forces (Lewis & Maslin, 2015).

Research is needed on the financial models to achieve effective conservation, mitigation, and adaptation. The concept of risk in ecological models is entirely different from the financial models of risk. As conservation finance grows as a tool for policy, more sophisticated measures of benefits and variance will be needed. For example, how do investments in one ecosystem service vary with investments in another or the market in general? A global database of costs and benefits of restoration could support research on the underlying causes of deforestation, like market and policy failures, and support new innovative economic policies that create incentives to reduce carbon emissions and deforestation (Barbier, Lozano, Rodríguez, & Sebastian, 2020).

In large metropolitan areas in the United States, forest fragmentation may be associated with positive human health outcomes (Tsai, Floyd, Leung, McHale, & Reich, 2016), even though fragmented landscapes have been notoriously used to describe the negative impacts of human development. Whether such results apply globally is an open question. Discussion on humans and nature usually leads to generalized conclusions that human development is the antithesis of conservation, yet there are times when fragmented or human-dominated landscapes could serve as sanctuaries for biodiversity (Aronson et al., 2014; Ives et al., 2016; Lepczyk et al., 2017; McHale et al., 2013).

Most long-term research projects on fragmentation have been centered on tropical rainforests, which has limited our understanding of forest patchiness (Laurance et al., 2012; Newbold et al., 2016). For most of these studies, extensive contiguous forest areas are the best guarantee of resilience against climate change and adverse edge effects. However, landscape ecology is now beginning to advance a very different understanding of forest fragments (Fahrig, 2013). There is recognition of the independent effects of habitat loss on the one hand and fragmentation on the other (Rios, Benchimol, Dodonov, De Vleeschouwer, & Cazetta, 2021). A radically distinct and increasingly influential hypothesis, the Habitat Amount Hypothesis (HAH), has undermined many of the most significant predictors of the older island biogeography theory. Proponents argue that managers should be less concerned with patch size, protected area shape, and relative isolation. Instead, they suggest focusing on the relationship between species richness (alpha biodiversity) and the total habitat amount in a landscape. Influential (though contested) proofs of the HAH principles are now beginning to emerge (Melo, Sponchiado, Cáceres, & Fahrig, 2017; Saura, 2021).

Moreover, the ecosystem services literature has been dominated by generalized linkages between land use and ecosystem services that assume, for instance, that forested ecosystems, agricultural lands, and urban areas each provide a different set and number of benefits. The management of forests and other ecosystems for increased ecosystem service provisioning will require measuring forest ecosystem structure and function, how these ecosystems change with climate change and urbanization, and how these changes directly influence the provisioning of a multitude of services and disservices (McHale et al., 2018). Also, important to consider are perceptions of ecosystem services and disservices and how well perceptions align with the measurement of ecosystem service provisioning.

A pluralistic understanding of the benefits and costs of nature will lead to more nuanced and equitable management of natural resources, as there is often a disconnect between those who are on the receiving end of services and disservices, with more vulnerable populations experiencing the costs of conservation (McHale et al., 2018). Furthermore, a sense of place is integral to personal and cultural identity. The pace of change may be happening at scales that are not easy to cope with, especially at cultural sites and indigenous lands. Comanagement and inclusive decision-making will be central to managing forests and other valuable ecosystems, as will comanagement and inclusive decision-making, the return of aboriginal lands, and full stewardship by indigenous communities (Fa et al., 2020; Garnett et al., 2018).

Scientific discourse has shifted significantly in the past five years and has begun to acknowledge the critical role indigenous communities play in the conservation of forests. Increasing numbers of influential studies are now acknowledging that intact forest systems are, in fact, better conserved under indigenous management systems than as formally protected areas (Ban et al., 2018; Fa et al., 2020; Garnett et al., 2018; Schuster, Germain, Bennett, Reo, & Arcese, 2019). By some estimates, indigenous people "manage or have tenure rights over at least 38 million km... [and] about 40% of all terrestrial protected areas and ecologically intact landscapes" (Garnett et al., 2018). There is, however, a significant proviso: incentives for the indigenous preservation of forests, and the slowing of deforestation, depend strongly on land tenure agreements. Granting full title rights to forests for indigenous peoples is thus one of the most consequential mechanisms for protecting forest ecosystem functioning globally (Blackman, Corral, Lima, & Asner, 2017; Fa et al., 2020; Robinson, Holland, & Naughton-Treves, 2014).

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