There is a new level of awareness of the global importance of forests and sustainable forest management. *Credit: Rowland Williams*

Emerging Perspectives on Forest Biodiversity

Forests are the focus of renewed global attention because of their role in climate change mitigation. However, biodiversity loss continues to put forests at risk, diminishing their capacity to adapt to pressures, including climate change. New approaches to biodiversity conservation are promising, but they need to be matched by more effective governance and greater financial investments.

The world's forests play an important role in maintaining fundamental ecological processes, such as water regulation and carbon storage, as well as in providing livelihoods and supporting economic growth (UNEP 2007, FAO 2009a). About 1.6 billion people depend in some way on forests for their livelihoods, and wood and other goods removed from forests were valued at US$122 billion in 2005 (World Bank 2004, FAO 2010). As the home of two-thirds of all plants and animals living on land, forests are the most biodiverse terrestrial ecosystems (Schmitt et al. 2009, FAO 2010, IUCN 2010). Many of the essential benefits we derive from forests are underpinned by forest biodiversity, as is the capacity of forests to adapt to pressures, including climate change (MA 2005a, Seppala et al. 2009).

There is a new level of awareness of the global importance of forests and sustainable forest management. Reducing greenhouse gas emissions from deforestation—and reducing forest degradation—are recognized as central to achieving the objectives of the UN Framework Convention on Climate Change (UNFCCC) (**Box 1**). Investing in sustainable forest management can also create millions of new 'green jobs' (FAO 2009b). For more than 20 years, the international community has demonstrated its concern about deforestation, forest degradation, and the consequent loss of forest biodiversity (FAO 2009a, Rayner et al. 2010). Progress at the international level has included adoption of the Convention on Biological Diversity, and has been complemented by efforts at the national and sub-national levels. Thirteen per cent of the world's total forest area is under formal protection, and almost 75 per cent of forests are covered by a national forest programme. There is also an upsurge in sustainable forest management initiatives and the strengthening of local rights with regard to forest management at the local level (FAO 2007, Agrawal et al. 2008, CBD 2010, FAO 2010).

Despite this progress, and net gains in forest area in Europe and Asia, total loss of forest cover during the last decade still averaged around 13 million hectares per year (FAO 2010) (**Figure 1**). Most deforestation is occurring in tropical forests, which are especially

What is forest biodiversity?

Forests are defined as land with tree crown cover (or equivalent stocking level) of more than 10 per cent and an area of more than 0.5 hectares (FAO 2000).

Forest biodiversity is the variability among living organisms in forest ecosystems. It comprises diversity within and among species, and within and between each of the terrestrial and aquatic components of forest ecosystems (CBD 1992).

Box 1: Forest biodiversity and climate change mitigation

Trees sequester and store carbon from the atmosphere. Although the link between biodiversity and carbon cycling is not well understood, one-quarter of the carbon emitted by human activities, such as burning of fossil fuels, is thought to be fixed by forests and other land ecosystems (Midgley et al. 2010). Forests therefore play an important role in addressing climate change. **REDD+** is an international policy mechanism whose purpose is to mitigate climate change by **R**educing **E**missions from **D**eforestation and forest **D**egradation in developing countries, and to enhance forest carbon stocks through activities such as forest conservation and sustainable forest management (Angelsen 2009). Paying developing countries to conserve forests highlights the economic importance of ecosystems and biodiversity. With the UN Development Programme and the UN's Food and Agricultural Organization, UNEP is assisting countries to participate in REDD+.

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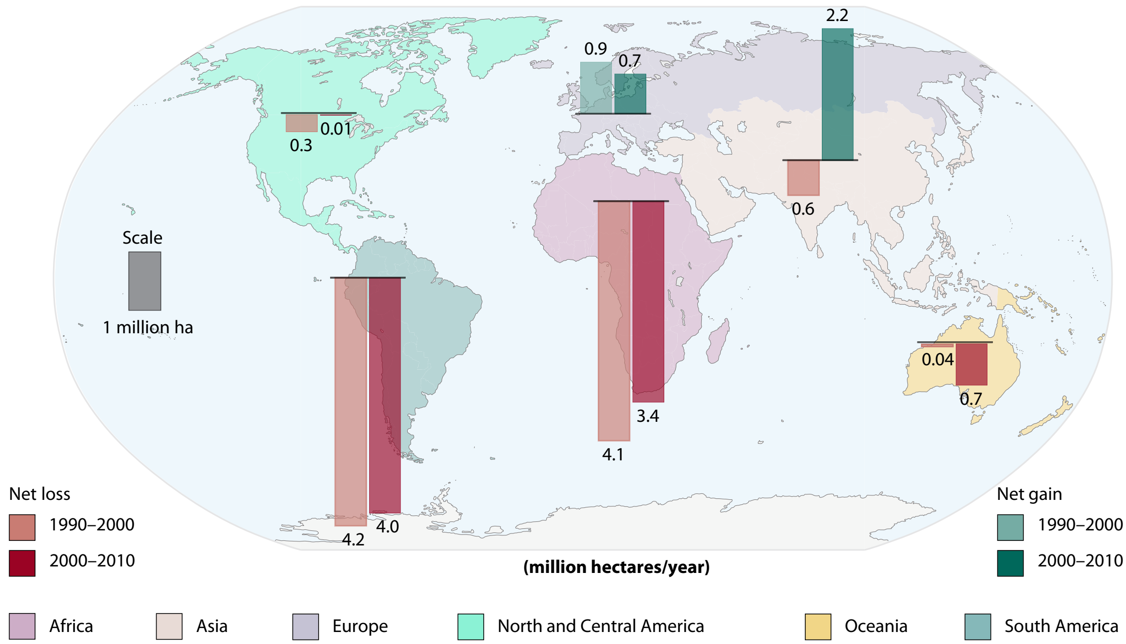
Figure 1: Annual change in forest area by region in millions of hectares per year, 1990-2010. There is a continued trend towards expansion in Europe, while large-scale afforestation in China of between 2 and 3 million hectares per year is contributing to net gains in Asia. The rate of deforestation is decreasing in some countries, such as Brazil and Indonesia. However, net losses remain significant in South America and Africa despite this reduction. Severe drought and forest fires have exacerbated forest losses in Australia since 2000. *Source: FAO (2010)*



rich in biodiversity (CBD 2010). Although the global rate of net forest cover loss has slowed, partly due to the expansion of plantations and to natural forest restoration, forest biodiversity loss continues to occur disproportionately since the highest levels of deforestation and of forest degradation are reported for biodiversity-rich natural forests in developing countries (Schulze et al. 2004, CBD 2010).

The greater scientific, management and political focus on forest biodiversity conservation is offering new understanding, insights and opportunities for responding more effectively to forest biodiversity loss (MA 2005a, Cashore et al. 2006, Gardner et al. 2010, Maris and Béchet 2010, Pfund 2010).

Drivers and consequences of forest biodiversity loss

Globally, the key drivers of forest biodiversity loss are: population and consumption growth; increasing trade in food and agricultural products; growing demand for forest products, including biomass for energy generation; expansion of human settlements and infrastructure; and climate change (FAO 2009, Slingenberg et al. 2009, DeFries et al. 2010, IUCN 2010). At the landscape scale, these drivers are manifested in biodiversity loss resulting from pressures such as deforestation for agriculture and development, fragmentation of forest habitats, forest degradation associated with unsustainable harvesting of forest products for industrial use and livelihood needs, changed fire regimes, an increase in invasive species, and proliferation of pests and diseases (Asner et al. 2005, FAO 2007, UNEP 2007, Nellemann and Corcoran 2010).

If current global trends in habitat loss, resource exploitation and climate change continue, rates of species extinction will accelerate, biodiversity-rich habitats will be lost or degraded, especially in the tropics, and the distribution and abundance of species and ecosystems will change dramatically (Lindenmayer et al. 2008, Leadley et al. 2010). **Figure 2** shows the outcome of a scenario for human impacts on biodiversity to 2050 (Alkemade et al. 2009).

Loss of forest biodiversity diminishes forest ecosystems' resilience, that is, their ability to adapt to and recover from natural and human-induced disturbance. This can adversely affect both local livelihoods and national economies (MA 2005b). Societal changes, such as those associated with increasing wealth and consumption, may further intensify pressures on forests (Haines-Young and Potschin 2009). Many pressures are expected to be amplified by climate change (Malhi et al. 2009). For example, there is growing concern that changes in climate could occur so rapidly that many forest species will not be able to adapt and migrate (Menéndez et al. 2006). The capacity of individual species to migrate and colonize new environments depends on the characteristics of both species and landscapes. Landscape fragmentation, which results in less connectivity of habitat to allow natural migration, limits the adaptive capacity of species and the viability of ecosystems (Vos et al. 2008).

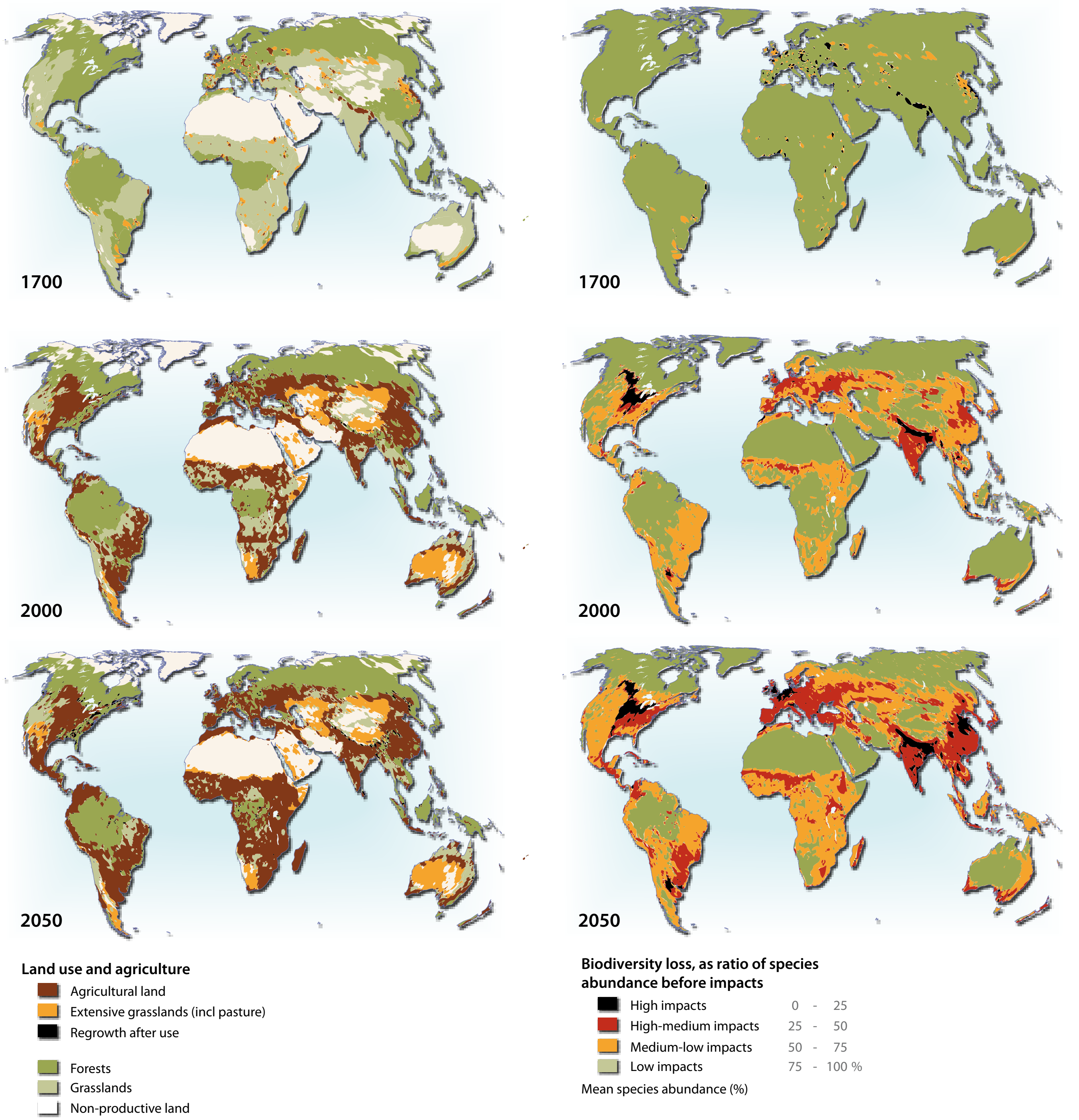


Figure 2: Projected land use changes (left) and loss of biodiversity (right) between 1700 and 2050. These maps, developed using the IMAGE and GLOBIO3 models, show increasing impacts on forest biodiversity driven by land-use intensity, land cover change, fragmentation, infrastructure development, atmospheric nitrogen deposition and climate change. *Sources: IMAGE, GLOBIO3 and Alkemade et al. (2009), reproduced in Nellemann et al. (2010) Credit: Hugo Ahlenius, Nordpil*

Aerial view showing extensive tree mortality of mature lodgepole pine in British Columbia, Canada, as a result of mountain pine beetle attack. *Credit: L. Maclauchlan, British Columbia Ministry of Forests and Range. Credit moutain pine beetle: Dion Manastyrski*

Box 2: Pest outbreaks in boreal forests

The mountain pine beetle (*Dendroctonus ponderosae*) is endemic to North American pine forests, where it persists in small populations that can only survive in wounded or otherwise weakened host pines. When there are enough beetles to overcome the resistance of healthy, mature pines during a mass-attack, a population eruption of the insect becomes possible. If subsequent generations of beetles successfully mass-attack additional mature pines, the population eruption can spread through the stand. The potential for such eruptions increases with the beetles' winter survival and the proportion of suitable host trees within the stand. A regional outbreak can develop if the eruption then spreads from its stand of origin outwards to the broader landscape. This becomes more likely with increasing connectedness and prevalence of suitable host stands in the landscape.

Since 2000, the mountain pine beetle outbreak in North America has killed over 14 million hectares of mature pines in Canada and 4 million hectares in the United States (Alfaro et al. 2010). Among the factors contributing to the outbreak are decades of forest management, including fire suppression and planting, that favoured mature lodgepole pine. The area occupied by these pines had more than tripled at the start of the outbreak (Taylor and Carroll 2004). The unprecedented extensiveness of mature pine—the preferred host tree—combined with unusually high beetle survival during a series of mild winters allowed the current outbreak to become much more severe and extensive than any previously recorded (Carroll et al. 2004, Safranyik and Carroll 2006, Taylor et al. 2006) (**Figure 3**). The mountain pine beetle was unable to spread across the landscape to the same extent during earlier outbreaks because the connectedness and contiguity of suitable host stands were broken up by younger pines and greater diversity of tree species (Taylor et al. 2006, Raffa et al. 2008).

The mountain pine beetle outbreak was a factor contributing to the collapse of timber industries, leaving many forestry industry-based towns in British Columbia with depressed economies, failed small businesses, high unemployment and dwindling populations as people started to look for jobs elsewhere.

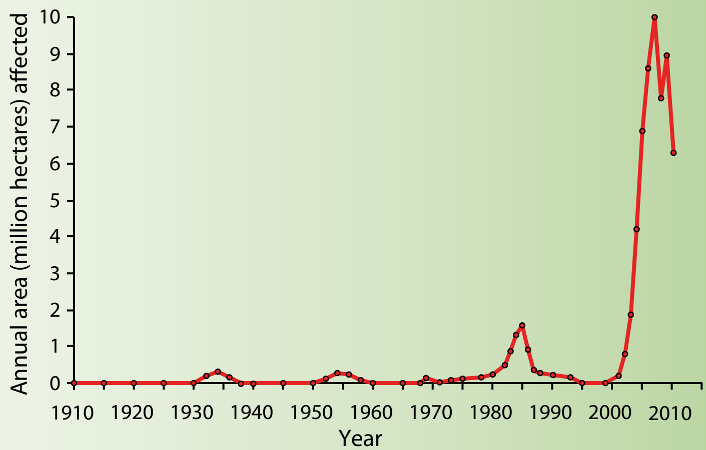


Figure 3: Millions of hectares of pine forest affected by mountain pine beetle outbreaks in British Columbia since 1910. Reduction of the area affected after the 2007 peak is due to a lack of available host trees and a harsher winter. *Sources: Alfaro et al. (2010), Canadian Forest Service Forest Insect and Disease Survey, British Columbia Ministry of Forests and Range*

The combination of biodiversity loss, climate change and habitat degradation can lead to the proliferation of forest fires, pests and disease. Forests are naturally dynamic systems, but their loss and degradation on a scale unprecedented in human history could exceed ecological thresholds. An ecological threshold is the point at which an abrupt change can occur in an ecosystem (Groffman et al. 2006). Such a change could bring about substantial degradation or even collapse of a (forest) ecosystem, with significant loss of biodiversity and the services it provides (Rockström et al. 2009, Thompson et al. 2009, Leadley et al. 2010, Vergara and Scholz 2010).

Predicting ecological thresholds is very difficult, as processes of change are influenced by multiple variables. However, new scientific evidence is emerging about signals that can help identify different thresholds in forest ecosystems (Biggs et al. 2009, Rockström et al. 2009). For example, reduced diversity among tree species and in stand age has made forests in western North America particularly vulnerable to pest outbreaks on mature pine. As warmer winters improved the over-wintering survival of the mountain pine beetle, an extraordinary pest outbreak occurred during the last decade with major ecological and economic consequences (**Box 2**).

Changes in the resilience of forest ecosystems can also threaten forest-based climate mitigation strategies (Thompson et al. 2009). For example, forests' climate mitigation benefits may be at risk if projects designed to sequester atmospheric carbon are affected by severe fires or pest outbreaks. Single-species carbon stocks with low biodiversity could be particularly vulnerable to stresses, as demonstrated by the mountain pine beetle outbreak. The ecological impact of this outbreak changed the net carbon balance of Canada's forests, which became a carbon source instead of a carbon sink, affecting the country's total carbon budget (Kurz et al. 2008). In the peak year, the direct impact of the mountain pine beetle outbreak in terms of CO_2 emissions was 20 megatonnes of carbon from the decay of dead trees and net changes in sequestration. These emissions were equivalent to 75 per cent of average annual direct forest fire emissions from all of Canada between 1959 and 1999 (Kurz et al. 2008). To mitigate such threats to forest-based climate mitigation strategies, forest management needs to be improved by promoting greater diversity in tree species and age class and by considering the possible impacts of climate change.

Approaches to biodiversity conservation

Common insights and principles that can improve forest biodiversity conservation in a variety of landscapes and land uses are emerging from research and practice (Brokerhoff et al. 2008, Gardner et al. 2009, Anand et al. 2010, Gilbert-Norton et al. 2010, Lindenmayer and Hunter 2010). They include better understanding the importance of landscape mosaics and forest remnants; connectivity across landscape gradients and between remnants; the variable responses of individual species to disturbances; and the roles of various forms of planted forests, including plantation forests, in biodiversity conservation. Better approaches to conceiving, planning and managing land use change are also envisaged or being implemented (Kanowski and Murray 2008, Franklin and Lindenmayer 2009, Pfund 2010). These approaches look beyond a narrow concentration on individual species and particular land uses to recognize interdependencies between landscape elements, and between ecosystems and human populations (Bond and Parr 2010). More integrated management approaches, adapted to both social and ecological processes, are being explored with regard to long-term biodiversity conservation (Grantham et al. 2009, Gardner et al. 2010). For example, many forest management strategies aimed at biodiversity conservation are consistent with strategies for climate change mitigation and adaptation, as well as with the objectives and practice of sustainable forestry more generally (Bauhus et al. 2009, Innes et al. 2009, Klenner et al. 2009, Thompson et al. 2009).

Ecosystem-based management considers the full array of interactions within an ecosystem, including human activity. Rather than managing a single forest in isolation, it accounts for these interactions across the landscape mosaic of multiple land uses (Gardner et al. 2009). Ecosystem-based management can therefore enhance biodiversity conservation in the context of broad-scale land-use change (Pfund 2010). It includes the maintenance of natural forests and of ecological functions and processes across multiple land uses (Gardner et al. 2009). The extent of natural forest maintained in a human-modified landscape primarily determines species richness (Anand et al. 2010). This is because these remnant forests—given adequate size and appropriate configuration—are refuges for highly sensitive species and play an important role in forming ecological corridors that facilitate species movement across fragmented landscapes (Crooks and Sanjayan 2006, Gilbert-Norton et al. 2010). For example, biodiversity conservation in Brazil's highly fragmented Mata Atlântica rainforest has been enhanced by improving its connectivity with biodiversity-friendly land uses such as agroforestry and secondary forests (Ribeiro et al. 2009, Tabarelli et al. 2010). Ecosystem-based management approaches have also been successfully applied to plantations (**Box 3**).

In addition, maintaining and restoring habitat and connectivity in the landscape matrix between protected forest areas is of fundamental importance to biodiversity conservation (Lamb

Mosaic of rainforest and plantations at the Veracel pulp mill and tree plantation in the state of Bahia, Brazil. *Credit: Lasse Arvidson, Stora Enso*

Box 3: New generation plantations

Intensively managed planted forests are highly productive plantations primarily intended to produce wood and fibre. There are around 25 million hectares of intensively managed planted forests worldwide, representing one-quarter of plantation forests and almost 0.2 per cent of global land area. They generally comprise tropical 'fastwood' plantations of acacia and eucalyptus, as well as temperate conifers. Many of the issues relevant to these forests also apply to the even larger area of tropical tree crops grown for non-wood products—coconut, oil palm and rubber (Kanowski and Murray 2008).

The New Generation Plantations Project led by WWF collects information and experience from tree plantations in a range of forest landscapes that are compatible with biodiversity conservation and human needs (NGPP 2010). This project is exploring how forest and plantation management can maintain and enhance ecosystem integrity and forest biodiversity (Neves Silva 2009). New approaches to plantation management can also enhance biodiversity at the stand level (Paquette and Messier 2010).

During the 1960s and 1970s, Brazil's Atlantic rainforest, Mata Atlântica, was deforested at an accelerated rate due to logging of valuable tree species for sawmilling and subsequent land clearance for cattle grazing. Management of a local pulp mill and tree plantation, which owns around 210 000 hectares in the region, has planted close to 91 000 hectares with eucalyptus on land previously used for cattle grazing, while more than 100 000 hectares are set aside for conservation. Eucalyptus is planted on plateaus, leaving valleys, river banks, steep slopes, and other areas with special characteristics reserved for environmental preservation. The area reserved for the rainforest is mainly regenerating naturally, but the most degraded parts are being restored through active planting of some 400 hectares of native species per year. The creation of forest corridors has enhanced connectivity between isolated remnants of the rainforest. At the end of 2009, over 3 500 hectares of rainforest had been restored (NGPP 2010).

At the landscape level, the plantations have had positive effects by stabilizing land use and reversing gradual forest degradation caused by cattle grazing. They have also made a significant contribution to biodiversity conservation by creating conditions for the protection and regeneration of the Atlantic rainforest.

et al. 2005, Franklin and Lindenmayer 2009). A meta-analysis of 89 restoration assessments, covering a wide range of ecosystem types, indicated that restoration increased biodiversity and the provision of ecosystem services such as regulation of water flow, particularly in the biodiversity-rich tropics (Benayas et al. 2009). However, it also highlighted the challenges involved in restoring degraded ecosystems and the decadal or greater timescales required. Such analyses have repeatedly demonstrated that it is preferable to avoid degradation and conserve forest biodiversity before restoration measures become necessary (TEEB 2009).

Adaptive management, too, has emerged as essential to forest biodiversity conservation, in part because it can enhance ecosystem resilience (Walker and Salt 2006, Nitschke and Innes 2008, Thompson et al. 2009). It uses a flexible, step-based approach to learn from experience, experimentation and monitoring (UNEP-WCMC 2010). An adaptive approach can help develop strategies that deliver ecological, economic and social benefits (PA 2009). Practitioners have found that, when its co-management dimensions are emphasized, this approach can be a pragmatic way to build consensus among multiple stakeholders in meeting forest management and biodiversity conservation goals (Innes et al. 2009, Maris and Béchet 2010). However, the pilot activities supporting most adaptive management initiatives for biodiversity conservation have often lacked the financial and human resources to replicate or scale up practices developed at the project level (Bille 2010). For adaptive management to be effective in forest biodiversity conservation on a larger scale, greater and more sustained investment in social and institutional capacity will be necessary.

To support and improve forest management practices, new tools, methods and practices are being developed to monitor biodiversity and increase stakeholder participation. For example, new technology and mapping systems have been used to guide forest conservation practices and inform policy (**Box 4**). More generally, it is now recognized that effective forest conservation and management require institutions and processes that incorporate multiple levels and forms of information and knowledge, and that build learning partnerships (Berkes 2007, Andersson and Ostrom 2008). In addition, implementing market-based mechanisms for climate change mitigation through forest conservation, such as reducing emissions from deforestation and forest degradation in developing countries (REDD+), require much better monitoring, reporting and verification systems than currently exist (Angelsen 2009). In response to these needs, new ways to generate, manage and share information and knowledge that can be used in forest conservation and management are emerging.

Box 4: Managing information for change

Forest management is being revolutionized by technologies that increase the speed at which vast amounts of spatial and temporal data can be analyzed and synthesized. Tools to enable near real-time monitoring of forests and carbon stocks are under development. An example is the Earth Engine platform launched by Google in 2010. This new technology platform is designed to improve access to satellite imagery, ground-sampling and other Earth observation data, and to provide computational resources for processing high-resolution data on a global scale that can help monitor deforestation and forest degradation. It also provides an open application framework that allows scientists to develop and run computer programs such as forest area change detection and biomass and carbon estimation (Google 2010). Although forest extent and carbon stocks can be monitored using these new tools, they will need to be complemented by on-the-ground monitoring to assess biodiversity.

In addition, a wide range of new techniques can support community-based participatory data collection using Geographic Information Systems (GIS). These techniques appear to offer a new and powerful way to include local groups in planning and decision-making. They are already being used throughout Africa, Asia and Latin America to engage local communities and assist with forest monitoring and management.

A recent Amazon Conservation Team project in the states of Pará and Amazonas in northern Brazil trained five indigenous groups to create cultural and land use maps of their territories. These maps include over 5 000 indigenous place names and other traditional designations and over 10 million hectares of land of cultural, natural and historical significance (Amazon Conservation Team 2010). The maps have been used in decision-making and the development of forest conservation strategies. This process has facilitated co-operation among stakeholders.

Members of the Tiriyó indigenous group and researchers in the Republic of Suriname. Participatory mapping can help indigenous groups make informed decisions about land use and forest conservation. *Credit: Amazon Conservation Team*

Giving full value to living forests

One of the greatest constraints on forest biodiversity conservation has been market failures, such as a lack of price signals and undervaluation of the multiple services provided by forests, meaning that forests may be considered to be 'worth more dead than alive' (Mooney 2000). Better recognition of the value of living forests' biodiversity and ecosystem services is one of the keys to better conservation outcomes. Not only is slowing the rate of deforestation central to biodiversity conservation and the protection of ecosystem services, but it is one of the quickest and most economical carbon abatement options (Prince's Rainforest Project 2009, Corbera et al. 2010). Stern (2007) estimated that it would cost only US$10-15 billion a year to halve the rate of deforestation by 2030. By comparison, the total value of forest product removals in 2005 was US$122 billion, not accounting for other values such as employment and services (FAO 2010). The extent of forest within protected areas has doubled during the past 20 years, but that level of progress has not been matched by financial investments (FAO 2010). This is particularly true in tropical developing countries that are rich in biodiversity, where funding for protected areas is 70 per cent below what is required for more effective conservation (TEEB 2010). Historically, official development assistance (ODA) has been the largest source of such funding. However, an important new source is market-based mechanisms, including eco-tourism, the sale of certified forest products, payments for ecosystem services, and biodiversity offsets (Crowe and ten Kate 2010). Payments for ecosystem services have gained importance as an approach that could potentially promote economic growth as well as financing biodiversity conservation (TEEB 2009) (**Figure 4**).

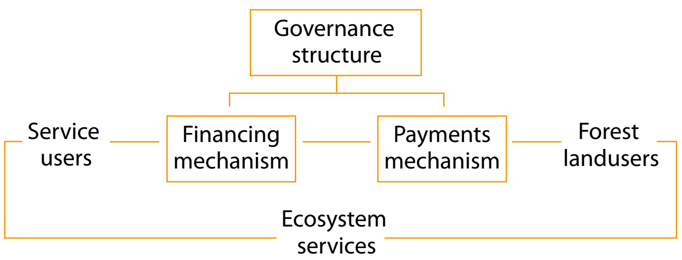


Figure 4: Most payments for ecosystem services schemes are characterized by voluntary transactions involving well-defined environmental services or forms of land use that are likely to secure those services (for example, food, fibre, water purification or recreational services). Through financing and payment mechanisms, service users pay forest land users for providing those services. *Source: Pagiola and Platais (2005)*

REDD+ is a new policy mechanism that adopts the payments for ecosystem services approach on a global scale. Its purpose is to reduce emissions from deforestation and forest degradation, while also generating financial flows from North to South. REDD+ has been facilitated by initiatives such as the Interim REDD+ Partnership (REDD+ Partnership 2010) and was endorsed at the UN Climate Change Conference in Cancún (UNFCCC 2010). Many scientists and practitioners believe REDD+ can deliver co-benefits additional to climate change mitigation, including forest biodiversity conservation (Angelsen 2009, Dickson and Osti 2010, Strassburg et al. 2010). Other stakeholders are concerned about the political and economic implications of market-based mechanisms and the possibility that REDD+ implementation arrangements could ignore the rights of indigenous and forest-dependent people to their territories and resources (GFC 2008, IIPFCC 2009, Phelps et al. 2010). Such concerns have been acknowledged in UNFCCC negotiations through recognition that environmental and social safeguards are needed with regard to REDD+ (UNFCCC 2009, Sikor et al. 2010). If successful, REDD+ could generate substantial revenues for conservation and sustainable forest management, as well as benefiting rural poverty reduction and improvement of rural livelihoods.

Maps from a study by Strassburg et al. (2010) illustrate the strong congruence between carbon stocks and biodiversity, especially in the case of forest ecosystems (**Figure 5**). This study and a review by Miles et al. (2010) suggest that synergies for co-benefits are considerable in many cases, but not in all. REDD+ with appropriate safeguards offers prospects for achieving biodiversity conservation goals in developing countries that have proved elusive since the 1992 Earth Summit. Experience with payments for ecosystem services provides guidance with regard to the development of REDD+ regimes that will deliver biodiversity co-benefits to a wide range of stakeholders (Wunder and Wertz-Kanounnikoff 2009). For example, the World Bank has announced a Wildlife Premium Market Initiative that will provide payments to the rural poor for protecting high biodiversity-value wildlife in forests within the context of a REDD+ mechanism (World Bank 2010).

Achieving the potential co-benefits of REDD+ at local level will depend on many elements: REDD+ design and financing arrangements; good governance structures and regulatory systems; an adaptive approach to the design and implementation of national and sub-national policies and strategies; agreement on and implementation of safeguards; clear guidance principles; effective capacity building; and adequate technology transfer (Angelsen 2009, Karousakis 2009, AWGLCA 2010, Busch et al. 2010, Dickson and Osti 2010).

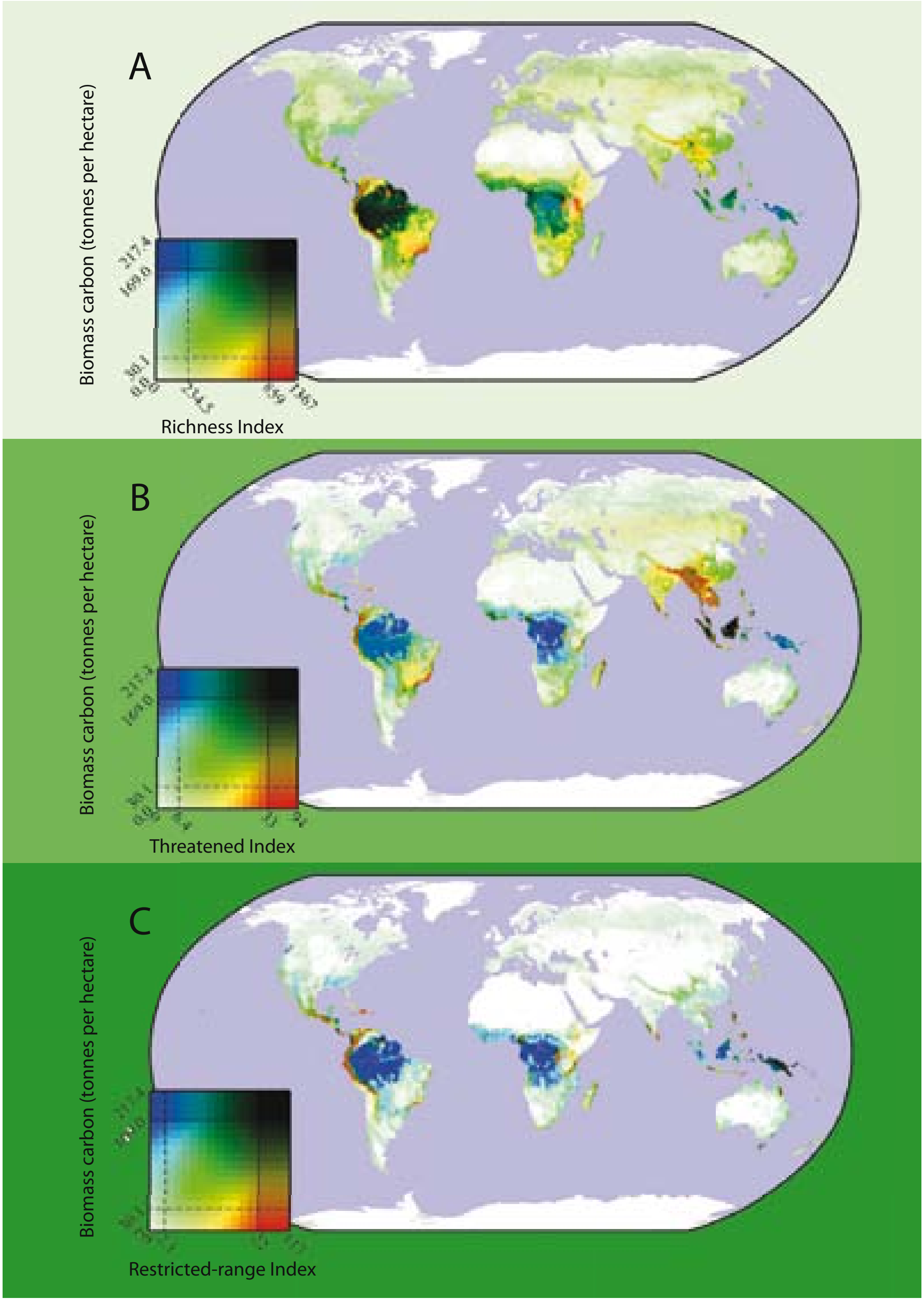


Figure 5: Global congruence between biomass carbon and biodiversity richness. Two-dimensional colour scales are used to display both the concentration of biomass carbon and biodiversity and the congruence between them. The intensity on the vertical blue axis represents above- and below-ground biomass carbon density (tonnes of carbon per hectare) and the intensity on the horizontal red axis the richness of the respective biodiversity index (number of species per cell). The maps show the global congruence between biomass carbon and (A) overall species richness, (B) threatened species richness, and (C) restricted-range species richness. Darker shading corresponds to higher concentrations of carbon and biodiversity. *Source: Strassburg et al. (2010)*

Trends in forest governance

Good forest governance is fundamental to achieving better biodiversity conservation outcomes (Agrawal et al. 2008, Sasaki and Putz 2009). Forest governance includes formal and informal institutions, as well as structures of authority and processes that determine to whom and how forests are allocated and how they are used and managed (Burris et al. 2005, Cashore 2009). Historically, forest governance has been characterized by state-centred, top-down approaches relying on command and control mechanisms that provide little recognition of the rights or interests of traditional owners (Agrawal et al. 2008). However, there have been strong trends away from this form of governance, driven by a realization of its limitations and the success of alternative models (Berkes 2007, Andersson and Ostrom 2008). Three critical trends in forest governance are described below. They are relevant to biodiversity conservation in a number of ways.

The first trend recognizes the persistence of the concession model of forest management. Under this model, governments allow private companies exclusive long-term resource rights to public forests in exchange for revenues. Concessions remain the dominant form of management of commercially valuable tropical forests (Agrawal et al. 2008). While well-designed and well-regulated concession agreements can promote sustainable forest management and reduce illegal logging, the converse is also true (Christy et al. 2007). Improving the governance of forest concessions therefore remains central to forest biodiversity conservation.

The second trend relates to greater decentralization in the management of the broader landscape. Governance at this level should take into account the socio-political context beyond local-level and forest-focused decision making (Lele et al. 2010). Decades of experience show that conserving biodiversity in protected areas depends crucially upon the inclusion of local people, particularly in countries with weak institutions where there are strong pressures on land (Sunderland et al. 2008, Sayer 2009). Local participation, empowerment and leadership are now widely acknowledged by practitioners as central to successful forest conservation initiatives (CBD 2009, Pfund 2010). Where local people are involved in this way, innovative governance can capitalize on opportunities provided by the participation of multiple actors in both policy design and implementation (Seppala et al. 2009).

The third trend relates to creating governance conditions for effectively implementing and benefiting from market-based mechanisms as a complement to—but not a substitute for—the role of the state (Gunningham 2009, Bille 2010, TEEB 2010). This is reflected in the 4th principle of the Ecosystem Approach framework of the Convention on Biological Diversity, which calls for aligning economic signals, sanctions and rewards with good ecosystem management (CBD 2009). A review by Bond et al. (2009) of lessons learned from payments for ecosystem services and REDD reported that the success of market-based instruments is strongly contingent on enabling economic, institutional, informational and cultural preconditions, such as clarity of land rights, functional systems to monitor compliance and apportion payments, and sufficient levels of trust and co-operation among stakeholders.

Each of these trends has the potential to work for or against forest biodiversity conservation. Evidence from a series of research studies indicates that the success of decentralized forest management regimes based on collective action is variable (Shackleton et al. 2010). Similarly, the increasing role of private sector forest ownership and management can have mixed results for conservation, ranging from highly enabling to greatly constraining (Lele et al. 2010, McDermott et al. 2010). There have also been challenges with regard to achieving the objectives of market-based instruments. An example is forest certification, which has had some success in supporting biodiversity conservation (Zagt et al. 2010) but mainly outside tropical forests (**Figure 6**). According to Cashore et al. (2006), the low uptake of tropical forest certification reflects poor forest governance and limited market demand for certified products. The importance of new forms of forest governance for forest biodiversity conservation is increasing, as experience with their implementation grows and as markets and society respond to public concern about deforestation, forest degradation and biodiversity loss.

Looking ahead

Loss of forest biodiversity can reduce the resilience of forests and leave them more vulnerable to mounting pressures, including climate change. Growing evidence suggests that biodiversity loss makes forest ecosystems more susceptible to existing pressures such as pests and allows outbreaks that cause substantial

Primary and secondary forests

Primary forests are natural forests that are undisturbed (directly) by humans (FAO 2005).

Secondary forests are forests that are regenerated largely through natural processes, following significant human or natural disturbance of the original forest vegetation (FAO 2005).

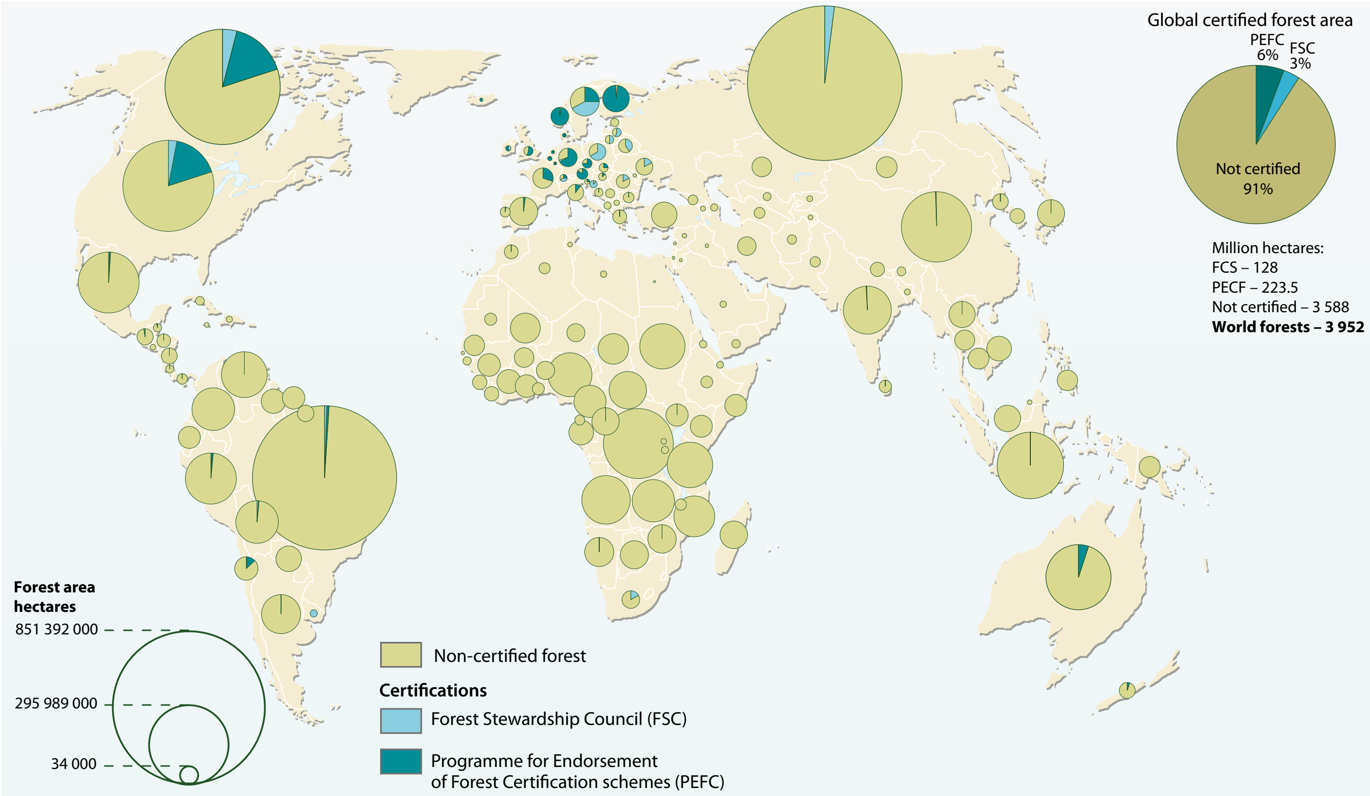


Figure 6: Global distribution of forest certification in 2009. Most certified forest areas are found in North America and Europe. Certification of biodiversity-rich tropical forests has so far been limited. *Source: Adapted from FAO (2009), FSC (2009), PEFC (2009), and UNEP/GRID-Arendal (2009)*

degradation or even ecosystem collapse. Degraded forests are less able to sustain and deliver the goods and services that society values and needs.

Primary forests, which have the highest biodiversity value, are the focus of the greatest biodiversity conservation efforts (FAO 2010). However, other forests—including managed and secondary forests and forests in remnant patches and corridors, on sites being restored and rehabilitated, and in agro-ecosystems or peri-urban landscapes—are also critical for biodiversity conservation. The value of these forests and their interdependencies are increasingly recognized in landscape approaches to biodiversity conservation.

Innovative and effective responses are necessary to meet the challenges of forest biodiversity conservation. The foundations for such responses have been established. Ecosystem-based approaches to forest management are fundamental to forest biodiversity conservation. They recognize the diversity of values and interests in forests, the need for people to participate in decisions about forests in order to enable more effective conservation outcomes, and the need to sustain these outcomes in a landscape context. Similarly, adaptive management strategies focus on learning from the experience of all stakeholders to improve forest management and biodiversity conservation. Improved forest governance is also crucial. It can draw on a range of innovative market-based instruments and more community-based mechanisms. The emergence of REDD+ exemplifies the opportunities, but also the challenges, of using market-based instruments that can potentially deliver major biodiversity conservation benefits. New information technologies that improve monitoring and enhance science-based policy development are beginning to play a key role in conservation efforts.

Like the International Year of Biodiversity in 2010, the International Year of Forests in 2011 emphasizes the importance of forest biodiversity. Each illustrates a paradox. Whereas knowledge and understanding of biodiversity, and of its value, have never been greater, neither have the pressures on biodiversity been greater in human history than they are today. Conservation of forest biodiversity is fundamental to sustaining forests and people in a world adapting to climate change.

References

Agrawal, A., Chhatre, A. and Hardin, R. (2008). Changing Governance of the World's Forests. *Science*, 320, 1460-1462

Alfaro, R.I., Hantula, J., Carroll, A., Battisti, A., Fleming, R., Woods, A., Hennon, P.E., Lanfranco, D., Ramos, M., Müller, M., Lilja, A. and Francis, D. (2010). Forest Health in a Changing Environment. Chapter 7 in: Mery, G., Katila, P., Galloway, G., Alfaro, R., Kanninen, M., Lobovikov, M. and Varjo, J. (eds.), *Forests and Society – Responding to Global Drivers of Change*. International Union of Forest Research Organizations (IUFRO) World Series. METLA, Helsinki

Alkemade, R., van Oorschot, M., Miles, L., Nellemann, C., Bakkenes, M. and ten Brink, B. (2009). GLOBIO3: A Framework to Investigate Options for Reducing Global Terrestrial Biodiversity Loss. *Ecosystems*, 12, 374-390

Amazon Conservation Team (2010). Participatory Ethnographic Mapping: Mapping Indigenous Lands. Amazon Conservation Team, Arlington, Virginia. http://www.amazonteam.org/index.php/193/Participatory_Ethnographic_Mapping_Mapping_Indigenous_Lands

Anand, M.O., Krishnaswamy, J., Kumar, A. and Bali, A. (2010). Biodiversity conservation in human-dominated landscapes in the Western Ghats: Remnant forests matter. *Biological Conservation*, 143, 2363-2374

Andersson, K.P. and Ostrom, E. (2008). Analyzing decentralized resource regimes from a polycentric perspective. *Policy Sciences*, 41, 71-93

Angelsen, A. (ed.) (2009). *Realising REDD+*. Centre for International Forestry Research, Bogor

Asner, G.P., Knapp, D.E., Broadbent, E.N., Oliveira, P.J.C., Keller, M. and Silva, J.N. (2005). Selective Logging in the Brazilian Amazon. *Science*, 310, 480-482

AWGLCA (2010). *Report of the Ad Hoc Working Group on Long-term Cooperative Action under the Convention on its eighth session from 7 to 15 December 2009*. FCCC/AWGLCA/2009/17. Copenhagen

Bauhus, J., Puettmann, K. and Messier, C. (2009). Silviculture for old-growth attributes. *Forest Ecology and Management*, 258, 525-537

Benayas, J.M.R., Newton, A.C., Diaz, A. and Bullock, J.M. (2009). Enhancement of biodiversity and ecosystem services by ecological restoration: A meta-analysis. *Science*, 325, 1121-1124

Berkes, F. (2007). Community-based conservation in a globalized world. Proceedings of the National Academy of Sciences, 104, 15188-15193

Biggs, R., Carpenter, S.R.R. and Brock, W.A. (2009). Turning back from the brink: Detecting an impending regime shift in time to avert it. *Proceedings of the National Academy of Sciences*, 106, 826-831

Bille, R. (2010). Action without change? On the use and usefulness of pilot experiments in environmental management. *Veolia Environment*, 3, 1-6

Bond, I., Grieg-Gran, M., Wertz-Kanounnikoff, S., Hazlewood, P., Wunder, S. and Angelsen, A. (2009). *Incentives to sustain forest ecosystem services: A review and lessons for REDD*. International Institute for Environment and Development (IIED), London

Bond, W.J. and Parr, C.L. (2010). Beyond the forest edge: Ecology, diversity and conservation of the grassy biome. *Biological Conservation*, 143, 2395-2404

Brockerhoff, E., Jactel, H., Parrotta, J.A., Quine, C. and Sayer, J. (2008). Biodiversity and Planted Forests – Oxymoron or Opportunity? *Biodiversity and Conservation*, 17, 925-951

Burris, S., Drahos, P. and Shearing, C. (2005). Nodal governance. A*ustralian Journal of Legal Philosophy*, 30, 30-58

Busch, J., Godoy, F., Turner, W.R. and Harvey, C.A. (2010). Biodiversity co-benefits of reducing emissions from deforestation under alternative reference levels and levels of finance. *Conservation Letters*, No. doi: 10.1111/j.1755-263X.2010.00150.x

Carroll, A.L., Taylor, S.W., Régnière, J. and Safranyik, L. (2004). Effects of climate and climate change on the mountain pine beetle. In: Shore, T.L., Brooks, J.E. and Stone, J.E. (eds.), *Challenges and Solutions: Proceedings of the Mountain Pine Beetle Symposium*. Canadian Forest Service, Pacific Forestry Centre, Kelowna, British Columbia

Cashore, B. (2009). *Key Components of Good Forest Governance*. ASEAN Forests Clearing House Mechanism, ASEAN Secretariat, Jakarta

Cashore, B., Gale, F., Meidinger, E. and Newsom, D. (2006). Conclusion. In: Cashore, B., Gale, F., Meidinger, E. and Newsom, D. (eds.), *Confronting Sustainability: Forest Certification in Developing and Transitioning Countries*. Yale School of Forestry and Environmental Studies, New Haven

CBD (1992). Convention on Biological Diversity, Text and Annexes. The Interim Secretariat for the CBD, Geneva Executive Centre, Geneva

CBD (2009). Connecting Biodiversity and Climate Change Mitigation and Adaptation. Report of the Second Ad Hoc Technical Expert Group on Biodiversity and Climate Change. Secretariat of the Convention on Biological Diversity, Montreal

CBD (2010). *Global Biodiversity Outlook 3*. Secretariat of the Convention on Biological Diversity, Montreal

Christy, L., Di Leva, C., Lindsay, J. and Talla Takoukam P. (2007). *Forest Law and Sustainable Development: Addressing Contemporary Challenges Through Legal Reform*. World Bank Law, Justice, and Development Series. World Bank, Washington, D.C.

Corbera, E., Estrada, M. and Brown, K. (2010). Reducing greenhouse gas emissions from deforestation and forest degradation in developing countries: Revisiting the assumptions. *Climatic Change*, 100, 355-388

Crooks, K.R. and Sanjayan, M. (eds.) (2006). *Connectivity Conservation*. *Conservation Biology* 14. Cambridge

Crowe, M. and ten Kate, K. (2010). *Biodiversity offsets: Policy options for government*. Forest Trends, Washington, D.C.

DeFries, R.S., Rudel, T., Uriarte, M. and Hansen, M. (2010). Deforestation driven by urban population growth and agricultural trade in the twenty-first century. *Nature Geoscience*, 3, 178-181

Dickson, B. and Osti, M. (2010). *What are the ecosystem-derived benefits of REDD+ and why do they matter?* Multiple Benefits Series 1. UN-REDD Programme, Nairobi

FAO (2000). *Global Forest Resources Assessment 2000*. Food and Agriculture Organization of the United Nations, Rome

FAO (2005). *Global Forest Resources Assessment Update. 2005 Terms and Definitions*. Forest Resources Assessment Working Paper 83. Food and Agriculture Organization of the United Nations, Rome

FAO (2007). *The State of the World's Forests 2007*. Food and Agriculture Organization of the United Nations, Rome

FAO (2009a). *The State of the World's Forests 2009*. Food and Agriculture Organization of the United Nations, Rome

FAO (2009b). Forests and the global economy: 10 million new jobs. Press release. Food and Agriculture Organization of the United Nations, Rome

FAO (2010). *Global Forest Resources Assessment 2010*. Food and Agriculture Organization of the United Nations, Rome

Franklin, J. and Lindenmayer, D. (2009). Importance of matrix habitats in maintaining biological diversity. *Proceedings of the National Academy of Sciences*, 106(2), 349-350

FSC (2009). *Annual Report 2009*. Forest Stewardship Council, Bonn

Gardner, T.A., Barlow, J., Chazdon, R.L., Ewers, R., Harvey, C.A., Peres, C.A. and Sodhi, N.S. (2009). Prospects for tropical forest biodiversity in a human-modified world. *Ecology Letters*, 12, 561-582

Gardner, T.A., Barlow, J., Sodhi, N.S. and Peres, C.A. (2010). A multi-region assessment of tropical forest biodiversity in a human-modified world. *Biological Conservation*, 143(10), 2293-2300

GFC (2008). *Life as commerce: The impact of market-based conservation on Indigenous Peoples, local communities and women*. Global Forest Coalition, Asunción, Paraguay. http://www.globalforestcoalition.org/img/userpics/File/publications/LIFE-AS-COMMERCE2008.pdf

Gilbert-Norton, L., Wilson, R., Stevens, J.R. and Beard, K.H. (2010). A meta-analytic review of corridor effectiveness. *Conservation Biology*, 24, 660-668

Google (2010). The Earth Engine. Google.org. http://googleblog.blogspot.com/2009/12/seeing-forest-through-cloud.html

Grantham, H.S., Bode, M., McDonald-Madden, E., Game, E.T., Knight, A.T. and Possingham, H.P. (2009). Effective conservation planning requires learning and adaptation. *Frontiers in Ecology and the Environment*, 8, 431-437

Groffman, P.M., Baron, J.S., Blett, T., Gold, A.J., Goodman, I., Gunderson, L.H., Levinson, B.M., Palmer, M.A., Paerl, H.W., Peterson, G.D., LeRoy Poff, N., Rejeski, D.W., Reynolds, J.F., Turner, M.G., Weathers, K.C. and Wiens, J. (2006). Ecological Thresholds: The Key to Successful Environmental Management or an Important Concept with No Practical Application? *Ecosystems*, 9, 1-13

Gunningham, N. (2009). Environment law, regulation and governance: Shifting architectures. *Journal of Environmental Law*, 21, 179-212

Haines-Young, R. and Potschin, M. (2009). The links between biodiversity, ecosystem services and human well-being. In: Raffaelli, D. and Frid, C. (eds.), *Ecosystem ecology: A new synthesis. BES Ecological Reviews Series*. Cambridge University Press, Cambridge

IIPFCC (2009). Statement on Shared Vision under AWG LCA, Copenhagen, 7 December 2009. International Indigenous Peoples' Forum on Climate Change. http://indigenouspeoplesissues.com

Innes, J., Joyce, L., Kellomaki, M., Louman, B., Ogden, A., Parrotta, J. and Thompson, I. (2009). Management for adaptation. Chapter 6 in: Seppala, R., Buck, A. and Katila, P. (eds.), *Adaptation of forests and people to climate change*. IUFRO World Series 22. International Union of Forest Research Organizations, Vienna

IUCN (2010). *Plants under pressure – a global assessment. The first report of the IUCN Sampled Red List Index for Plants*. Royal Botanic Gardens, Kew, UK, Natural History Museum, London, and International Union for Conservation of Nature

Kanowski, P. and Murray. H. (2008). *Intensively Managed Planted Forests. Toward best practice*. The Forests Dialogue, TFD Secretariat, New Haven

Karousakis, K. (2009). *Promoting Biodiversity Co-Benefits in REDD*. Organisation for Economic Co-operation and Development, Environment Working Papers. OECD, Paris

Klenner, W., Arsenault, A., Brockerhoff, E.G. and Vyse, A. (2009). Biodiversity in forest ecosystems and landscapes: A conference to discuss future directions in biodiversity management for sustainable forestry. *Forest Ecology and Management*, 258, S1-S4

Kurz, W.A., Dymond, C.C., Stinson, G., Rampley, G.J., Neilson, E.T., Carroll, A.L., Ebata, T. and Safranyik, L. (2008). Mountain pine beetle and forest carbon: Feedback to climate change. *Nature*, 452, 987-990

Lamb, D., Erskine, P. and Parrotta, J.A. (2005). Restoration of degraded tropical forest landscapes. *Science*, 310, 1628-1632

Leadley, P., Pereira, H.M., Alkemade, R., Fernandez-Manjarrés, J.F., Proença, V., Scharlemann, J.P.W. and Walpole, M.J. (2010). *Biodiversity Scenarios: Projections of 21st century change in biodiversity and associated ecosystem services*. Secretariat of the Convention on Biological Diversity, Montreal

Lele, S., Wilshusen, P., Brockington, D., Seidler, R. and Bawa, K. (2010). Beyond exclusion: Alternative approaches to biodiversity conservation in the developing tropics. *Current Opinion in Environmental Sustainability*, 2, 94-100

Lindenmayer, D., Fischer, J., Felton, A., Crane, M., Michael, D., Macgregor, C., Montague-Drake, R., Manning, A. and Hobbs, R. (2008). Novel ecosystems resulting from landscape transformation create dilemmas for modern conservation practice. *Conservation Letters*, 1(3), 129-135

Lindenmayer, D. and Hunter, M. (2010). Some Guiding Concepts for Conservation Biology. *Conservation Biology*, 24, 1459-1468

MA (2005a). *Ecosystems and Human Well-being: Biodiversity Synthesis*. Millennium Ecosystem Assessment. Island Press, Washington, D.C.

MA (2005b). *Ecosystems and Human Well-being: Synthesis*. Millennium Ecosystem Assessment. Island Press, Washington, D.C.

Malhi, Y., Aragao, L.E.O.C., Galbraith, D., Huntingford, C., Fisher, R., Zelazowski, P., Sitch, S., McSweeney, C. and Meir, P. (2009). Exploring the likelihood and mechanism of a climate-change induced dieback of the Amazon rainforest. *Proceedings of the National Academy of Sciences*, 106, 20610-20615

Maris, V., and Béchet, A. (2010). From adaptive management to adjustive management: A pragmatic account of biodiversity values. *Conservation Biology*, 24, 966-973

Menéndez, R., González, A., Hill, J.K., Braschler, B., Willis, S.G., Collingham, Y., Fox, R., Roy, D.B. and Thomas, C.D. (2006). Species richness changes lag behind climate change. *Proceedings of the Royal Society B*, 273(1593), 1465-1470

Midgley, G.F., Bond, J., Kapos, V., Ravilious, C., Scharlemann, J.P.W. and Woodward, F.I. (2010) Terrestrial carbon stocks and biodiversity: Key knowledge gaps and some policy implications. *Current Opinion in Environmental Sustainability*, 2, 264-270

Miles, L., Dunning, E., Doswald, N. and Osti, M. (2010). *A safer bet for REDD+: Review of the evidence on the relationship between biodiversity and the resilience of forest carbon stocks*. Working Paper v.2. Multiple Benefits Series 10. Prepared on behalf of the UN-REDD Programme. UNEP World Conservation Monitoring Centre, Cambridge

Mooney, H. (2000). Worth more dead than alive. *Nature*, 403, 593-594

Nellemann, C. and Corcoran, E. (eds). (2010). *Dead Planet, Living Planet – Biodiversity and Ecosystem Restoration for Sustainable Development*. A Rapid Response Assessment. United Nations Environment Programme, UNEP/GRID-Arendal, Arendal

Nellemann, C., MacDevette, M., Eickhout, B., Svihus, B., Prins, A.G. and Kaltenborn, B.P. (eds). (2009). *The Environmental Food Crisis*. A UNEP Rapid Response Assessment. United Nations Environment Programme, UNEP/GRID-Arendal, Arendal

Neves Silva, L. (2009). *Ecosystem integrity and forest plantations*. NGPP Ecosystem Integrity Technical Paper, WWF International

NGPP (2010). Case study 8/ Conserving the Atlantic Rainforest in Brazil. New Generation Plantations Project. http://newgenerationplantations.com/showcase.html

Nitschke, C.R. and Innes, J.L. (2008). Integrating climate change into forest management in South-Central British Columbia: An assessment of landscape vulnerability and development of a climate-smart framework. *Forest Ecology and Management*, 256, 313-327

PA (2009). *The Economic Cost of Climate Change in Africa*. Practical Action Consulting, Pan-African Climate Justice Alliance, Nairobi

Pagiola, S., Platais, G. (2005). Introduction to Payments for Environmental Services. Presentation. World Bank, Washington. D.C.

Paquette, A. and Messier, C. (2010) The role of plantations in managing the world's forests in the Anthropocene. *Frontiers in Ecology and the Environment*, 8, 27-34

PEFC (2009). PEFC Annual Review 2009. Programme for the Endorsement of Forest Certification, Geneva

Pfund, J.L. (2010). Landscape-scale research for conservation and development in the tropics: Fighting persisting challenges. *Current Opinion in Environmental Sustainability*, 2 (1-2), 117-126

Phelps, J., Webb, E.L. and Agrawal, A. (2010). Does REDD+ Threaten to Recentralize Forest Governance? *Science*, 328, 312-313

Prince's Rainforest Project (2009). An emergency package for tropical forests. Prince's Rainforest Project, London. http://www.rainforestsos.org/

Raffa, K.F., Aukema, B.H., Bentz, B.J., Carroll, A.L., Hicke, J.A., Turner, M.G. and Romme, W.H. (2008). Cross-scale drivers of natural disturbances prone to anthropogenic amplification: The dynamics of bark beetle eruptions. *Bioscience*, 58(6), 501-517

Rayner, J., Buck, A. and Katila, P. (eds.) (2010). *Embracing complexity: Meeting the challenges of international forest governance.* IUFRO World Series, 28. International Union of Forest Research Organizations, Vienna

REDD+ Partnership (2010). About the REDD+ Partnership. http://reddpluspartnership.org

Ribeiro, M.C., Metzger, J.P., Martensen, A.C., Ponzoni, F.J. and Hirota, M.M. (2009). The Brazilian Atlantic forest: How much is left, and how is the remaining forest distributed? Implications for conservation. *Biological Conservation*, 142, 1141-1153

Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, F.S., Lambin, E., Lenton, T.M., Scheffer, M., Folke, C., Schellnhuber, H., Nykvist, B., De Wit, C.A., Hughes, T., van der Leeuw, S., Rodhe, H., Sörlin, S., Snyder, P.K., Costanza, R., Svedin, U., Falkenmark, M., Karlberg, L., Corell, R.W., Fabry, V.J., Hansen, J., Walker, B., Liverman, D., Richardson, K., Crutzen, P. and Foley, J. (2009). Planetary boundaries: Exploring the safe operating space for humanity. *Ecology and Society*, 14(2), 32

Safranyik, L. and Carroll, A.L. (2006). The biology and epidemiology of the mountain pine beetle in lodgepole pine forests. In: Safranyik, L. and Wilson, B. (eds.), *The Mountain Pine Beetle: A Synthesis of its Biology, Management and Impacts on Lodgepole Pine*. Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, Victoria

Sasaki, N. and Putz, F.E. (2009). Critical need for new definitions of "forest" and "forest degradation" in global climate change agreements. *Conservation Letters*, 2, 226-232

Sayer, J. (2009). Reconciling Conservation and Development: Are Landscapes the Answer? *Biotropica*, 41(6), 649-652

Schmitt, C.B., Burgess, N.D., Coad, L., Belokurov, A., Besançon, C., Boisrobert, L., Campbell, A., Fish, L., Gliddon, D., Humphries, K., Kapos, V., Loucks, C., Lysenko, I., Miles, L., Mills, C., Minnemeyer, S., Pistorius, T., Ravilious, C., Steininger, M. and Winkel, G. (2009). Global analysis of the protection status of the world's forests. *Biological Conservation*, 142(10), 2122-2130

Schulze, C.H., Waltert, M., Kessler, P.J.A., Pitopang, R., Veddeler, D., Mühlenberg, M., Gradstein, S.R., Leuschner, C., Steffan-Dewenter, I. and Tscharntke. T. (2004). Biodiversity indicator groups of tropical land-use systems: Comparing plants, birds, and insects. *Ecological Applications*, 14,1321-1333

Seppala, R., Buck, A. and Katila, P. (2009). Executive summary and key message: *Adaptation of forests and people to climate change: A global assessment report*. IUFRO World Series 22. International Union of Forest Research Organizations, Vienna

Shackleton, C.M., Willis, T.J., Brown, K. and Polunin, N.V.C. (2010). Reflecting on the next generation of models for community-based natural resources management. *Environmental Conservation*, 37, 1-4

Sikor, T., Stahl, J., Enters, T., Ribot, J.C., Singh, N., Sunderlin, W.D. and Wollenberg, L. (2010). REDD-plus, forest people's rights and nested climate governance. *Global Environmental Change*, 20, 423-425

Slingenberg, A., Braat, L., van der Windt, H., Rademaekers, K., Eichler, L. and Turner, K. (2009). *Study on understanding the causes of biodiversity loss and the policy assessment framework*. European Commission Directorate-General for Environment. ECORYS Nederland BV, Rotterdam

Stern, N. (2007). *The Economics of Climate Change*. Cambridge University Press, Cambridge

Strassburg, B.B.N., Kelly, A., Balmford, A., Davies, R.G., Gibbs, H.K, Lovett, A., Miles, L., Orme, C.D.L., Price, J., Turner, R.K. and Rodrigues, A.S.L. (2010). Global congruence of carbon storage and biodiversity in terrestrial ecosystems. *Conservation Letters*, 3(2), 98-105

Sunderland, T., Ehringhaus, C. and Campbell, B. (2008). Conservation and development in tropical forest landscapes: A time to face the trade-offs? *Environmental Conservation*, 34(4), 276-279

Tabarelli, M., Aguiar, A.V., Ribeiro, M.C., Metzger, J.P. and Peres, C.A. (2010). Prospects for biodiversity conservation in the Atlantic Forest: Lessons from ageing human-modified landscapes. *Biological Conservation*, 143, 2328-2340

Taylor, S.W. and Carroll, A.L. (2004). Disturbance, forest age dynamics and mountain pine beetle outbreaks in BC: A historical perspective. In: Shore, T.L., Brooks, J.E. and Stone, J.E. (eds.), *Challenges and Solutions: Proceedings of the Mountain Pine Beetle Symposium*. Canadian Forest Service, Pacific Forestry Centre, Kelowna

Taylor, S.W., Carroll, A.L., Alfaro, R.I. and Safranyik, L. (2006). Forest, climate and mountain pine beetle dynamics. In: Safranyik, L. and Wilson, B. (eds.), *The Mountain Pine Beetle: A Synthesis of its Biology, Management and Impacts on Lodgepole Pine*. Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, Victoria

TEEB (2009). Report for National and International Policy Makers. The Economics of Ecosystems and Biodiversity. http://www.teebweb.org/ForPolicymakers/tabid/1019/Default.aspx

TEEB (2010). TEEB for Local and Regional Policy Makers. The Economics of Eco-systems and Biodiversity. http://www.teebweb.org/ForLocalandRegionalPolicy/tabid/1020/Default.aspx

Thompson, I., Mackey, B., McNulty, S. and Mosseler, A. (2009). *Forest Resilience, Biodiversity, and Climate Change. A synthesis of the biodiversity/resilience/stability relationship in forest ecosystems*. Secretariat of the Convention on Biological Diversity, Montreal

UNEP (2007). *Global Environment Outlook 4*. United Nations Environment Programme, Nairobi

UNEP/GRID-Arendal (2009). Vital Forest Graphics. http://maps.grida.no/go/collection/vital-forest-graphics

UNEP-WCMC (2010). Framing the flow: Innovative approaches to understand, protect and value ecosystem services across linked habitats. Silvestri, S. and Kershaw, F. (eds.). United Nations Environment Programme and World Conservation Monitoring Centre, Cambridge

UNFCCC (2009). Report of the Conference of the Parties on its fifteenth session, held in Copenhagen from 7 to 19 December 2009. Addendum. Part Two: Action taken by the Conference of the Parties at its fifteenth session. Decision 4/CP.15 Methodological guidance for activities relating to reducing emissions from deforestation and forest degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries. United Nations Framework Convention on Climate Change, Bonn. http://unfccc.int/resource/docs/2009/cop15/eng/11a01.pdf

UNFCCC (2010). Outcome of the Ad Hoc Working Group on long-term Cooperative Action under the Convention. United Nations Framework Convention on Climate Change. http://unfccc.int/meetings/cop_16/items/5571.php

Vergara, W. and Scholz, S.M. (2010). *Assessment of the risk of Amazon dieback*. World Bank Studies. World Bank, Washington, D.C.

Vos, C., Berry, P., Opdam, P., Baveco, H., Nijhor, B., O'Hanley, J., Bell, C. and Kuipers, H. (2008). Adapting landscapes to climate change: Examples of climate-proof ecosystem networks and priority adaptation zones. *Journal of Applied Ecology*, 45, 1722-1731

Walker, B. and Salt, D. (2006). Resilience thinking: Sustaining ecosystems and people in a changing world. Island Press, Washington, D.C.

World Bank (2010). Remarks for Opening Plenary of the High Level Segment – COP10, Nagoya, Japan. http://web.worldbank.org/WBSITE/EXTERNAL/NEWS/0,,contentMDK:22745069~pagePK:34370~piPK:34424~theSitePK:4607,00.html

World Bank (2004). Sustaining Forests: A Development Strategy. World Bank, Washington, D.C.

Wunder, S. and Wertz-Kanounnikoff, S. (2009). Payments for ecosystem services: A new way of conserving biodiversity in forests. *Journal of Sustainable Forestry*, 28, 576-596

Zagt, R.J., Sheil, D. and Putz, F.E. (2010). Biodiversity conservation in certified forests: An overview. In: Sheil, D., Putz, F.E. and Zagt, R.J. (eds)., *Biodiversity conservation in certified forests*. ETFRN News No. 51. Tropenbos, Wageningen