# focus B Biodiversity and ecosystem services in a changing climate

*Earth supports a complex web of 3 million to 10 million species of plants and animals[1] and an even greater number of microorganisms. For the first time a single species, humankind, is in a position to preserve or destroy the very functioning of that web.[2] In people's daily lives only a few species appear to matter. A few dozen species provide most basic nutrition—20 percent of human calorie intake comes from rice,[3] 20 percent comes from wheat;[4] a few species of cattle, poultry, and pigs supply 70 percent of animal protein. Only among the 20 percent of animal protein from fish and shell fish is a diversity of dietary species found.[5] Humans are estimated to appropriate a third of the Sun's energy that is converted to plant material.[6]*

But human well-being depends on a multitude of species whose complex interactions within well-functioning ecosystems purify water, pollinate flowers, decompose wastes, maintain soil fertility, buffer water flows and weather extremes, and fulfill social and cultural needs, among many others (box FB.1). The Millennium Ecosystem Assessment concluded that of 24 ecosystem services examined, 15 are being degraded or used unsustainably (table FB.1). The main drivers of degradation are land-use conversion, most often to agriculture or aquaculture; excess nutrients; and climate change. Many consequences of degradation are focused in particular regions, with the poor disproportionately affected because they depend most directly on ecosystem services.[7]

## Threats to biodiversity and ecosystem services

In the past two centuries or so, humankind has become the driver of one of the major extinction events on Earth. Appropriating major parts of the energy flow through the food web and altering the fabric of the land cover to favor the species of greatest value have increased the rate of species extinction 100 to 1,000 times the rate before human dominance of Earth.[8] In the past few decades people have become aware of their impacts on biodiversity and the threats of those impacts. Most countries have biodiversity protection programs of varying degrees of effectiveness, and several international treaties and agreements coordinate measures to slow or halt the loss of biodiversity.

Climate change imposes an additional threat. Earth's biodiversity has adjusted to past changes in climate—even to rapid changes—through a mix of species migration, extinctions, and opportunities for new species. But the rate of change that will continue over the next century or so, whatever the mitigation efforts, far exceeds past rates, other than catastrophic extinctions such as after major meteorite events. For example, the rates of tree species migration during the waxing and waning of the most recent ice age about 10,000 years ago were estimated to be about 0.3–0.5 kilometers a year. This is only a tenth the rate of change in climate zones that will occur over the coming century.[9] Some species will migrate fast enough to thrive in a new location, but many will not keep up, especially in the fragmented landscapes of today, and many more will not survive the dramatic reshuffling of ecosystem composition that will accompany climate change (map FB.1). Best estimates of species losses suggest that about 10 percent of species will be condemned to extinction for each 1°C temperature rise,[10] with even greater numbers at risk of significant decline.[11]

Efforts to mitigate climate change through land-based activities may support the maintenance of biodiversity and ecosystem services or threaten them further. Carbon stocks in and on the land can be increased through reforesta-

### BOX FB.1 *What is biodiversity? What are ecosystem services?*

Biodiversity is the variety of all forms of life, including genes, populations, species, and ecosystems. Biodiversity underpins the services that ecosystems provide and has value for current uses, possible future uses (option values), and intrinsic worth.

The number of species is often used as an indicator of the diversity of an area, though it only crudely captures the genetic diversity and the complexity of ecosystem interactions. There are 5 million to 30 million distinct species on Earth; most are microorganisms and only about 1.75 million have been formally described. Two-thirds of the diversity is in the tropics; a 25 hectare plot in Ecuador was found to have more tree species than exist in all of the United States and Canada, along with more than half the number of mammal and bird species in those two countries.

Ecosystem services are the ecosystem processes or functions that have value to individuals or society. The Millennium Ecosystem Assessment described five major categories of ecosystem services: *provisioning,* such as the production of food and water; *regulating,* such as the control of climate and disease; *supporting,* such as nutrient cycles and crop pollination; *cultural,* such as spiritual and recreational benefits; and *preserving,* such as the maintenance of diversity.

*Sources:* Millennium Ecosystem Assessment 2005; Kraft, Valencia, and Ackerly 2008; Gitay and others 2002.

**Table FB.1 Assessment of the current trend in the global state of major services provided by ecosystems**

| Service | Subcategory | Status | Notes |
|---|---|---|---|
| **Provisioning services** | | | |
| Food | Crops | ↑ | Substantial production increase |
| | Livestock | ↑ | Substantial production increase |
| | Capture fisheries | ↓ | Declining production due to overharvest |
| | Aquaculture | ↑ | Substantial production increase |
| | Wild foods | ↓ | Declining production |
| Fiber | Timber | +/– | Forest loss in some regions, growth in others |
| | Cotton, hemp, silk | +/– | Declining production of some fibers, growth in others |
| | Wood fuel | ↓ | Declining production |
| Genetic resources | | ↓ | Lost through extinction and crop genetic resource loss |
| Biochemicals, natural medicines, pharmaceuticals | | ↓ | Lost through extinction, overharvest |
| Fresh water | | ↓ | Unsustainable use for drinking, industry, and irrigation; amount of hydro energy unchanged, but dams increase ability to use that energy |
| **Regulating services** | | | |
| Air quality regulation | | ↓ | Decline in ability of atmosphere to cleanse itself |
| Climate regulation | Global | ↑ | Globally, ecosystems have been a net sink for carbon since mid-century |
| | Regional and local | ↓ | Preponderance of negative impacts (for example, changes in land cover can affect local temperature and precipitation) |
| Water regulation | | +/– | Varies depending on ecosystem change and location |
| Erosion regulation | | ↓ | Increased soil degradation |
| Water purification and waste treatment | | ↓ | Declining water quality |
| Disease regulation | | +/– | Varies depending on ecosystem change |
| Pest regulation | | ↓ | Natural control degraded through pesticide use |
| Pollination | | ↓ | Apparent global decline in abundance of pollinators |
| Natural hazard regulation | | ↓ | Loss of natural buffers (wetlands, mangroves) |
| **Cultural services** | | | |
| Spiritual and religious values | | ↓ | Rapid decline in sacred groves and species |
| Aesthetic values | | ↓ | Decline in quantity and quality of natural lands |
| Recreation and ecotourism | | +/– | More areas accessible but many degraded |

*Source*: Millennium Ecosystem Assessment 2005.

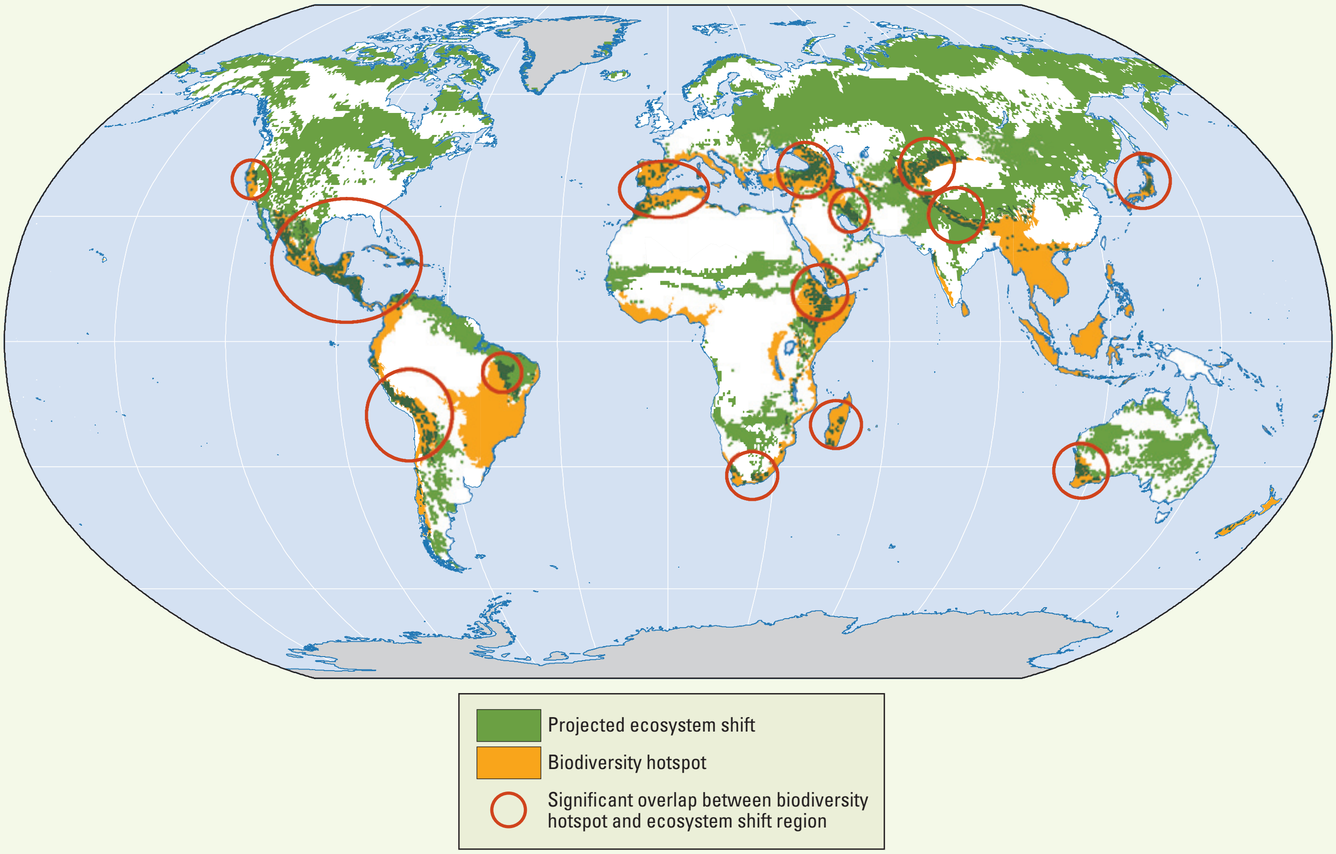
tion and revegetation and through such agricultural practices as reduced soil tillage. These activities can create complex and diverse landscapes supportive of biodiversity. But poorly planned mitigation actions, such as clearing forest or woodland to produce biofuels, can be counterproductive to both goals. Large dams can provide multiple benefits through irrigation and energy production but also can threaten biodiversity through direct inundation and dramatic changes in downstream river flows and the dependent ecosystems.

## What can be done?

Changes in priorities and active and adaptive management will be needed to maintain biodiversity under a changing climate. In some places, active management will take the form of further improving protection from human interference, while in others conservation may need to include interventions in species and ecosystem processes that are stronger and more hands-on than today's. In all cases biodiversity values must be actively considered—in the face of climate change and in the context of competing uses for land or sea.

This requires an ongoing process to anticipate how ecosystems will respond to a changing climate while interacting with other environmental modifiers. Some species will die out, others will persist, and some will migrate, forming new combinations of species. The ability to anticipate such change will always be incomplete and far from perfect, so any management actions must be within a framework that is flexible and adaptive.

**Map FB.1 While many of the projected ecosystem changes are in boreal or desert areas that are not biodiversity hotspots, there are still substantial areas of overlap and concern**




*Source*: WDR team based on Myers and others (2000) and Fischlin and others (2007).

*Note*: The map shows the overlap between biodiversity hotspots—regions with exceptional concentrations of endemic species undergoing exceptional loss of habitat (Conservation International and Myers and others 2000)—and the projected changes in terrestrial ecosystems by 2100 relative to the year 2000, as presented by the Intergovernmental Panel on Climate Change in Fischlin and others (2007), figure 4.3 (a), p. 238. The changes should be taken as only indicative of the range of possible ecosystem changes and include gains or losses of forest cover, grassland, shrub- and woodland, herbaceous cover, and desert amelioration.

Some species loss is inevitable, and some species may need to be protected in botanical and zoological gardens or in seed banks. It is essential that key species in the delivery of ecosystem services are identified and, if necessary, actively managed. Proactive management of land and the seas under a changing climate is a fairly new and ill-defined process. Relatively little knowledge has been developed on identifying realistic management responses, so significant sharing of learning, best practices, and capacity building will be necessary.

### *Conservation reserves*

Any extensions or modifications to the conservation priority areas (conservation reserves) need to capture altitudinal, latitudinal, moisture, and soil gradients. Proposals to expand or modify conservation reserves could lead to clashes over priorities for land allocation and for resources within biodiversity management (such as money for land acquisition versus that for active habitat manipulation). Powerful tools exist for selecting the optimal allocation of lands to achieve particular conservation goals that could balance competing demands.[12]

But protected areas alone are not the solution to climate change. The current reserve network has increased rapidly over the past decade to cover about 12 percent of Earth's land area,[13] but it is still inadequate to conserve biodiversity. Given demographic pressures and competing land uses, protected areas are not likely to grow significantly. This means that the lands that surround and connect areas with high conservation values and priorities (the environmental matrix), and the people who manage or depend on these lands will be of increasing importance for the fate of species in a changing climate.

There will be a greater need for more flexible biodiversity conservation strategies that take the interests of different social groups into account in biodiversity management strategies. So far the principal actors in creating protected areas have been nongovernmental organizations and central governments. To ensure the flexibility needed to maintain biodiversity, a wide range of managers, owners, and stakeholders of these matrix lands and waters will need to be engaged in management partnerships. Incentives and compensation for these actors may be required to maintain a matrix that provides refugia and corridors for species. Some of the options include extending payments for environmental services, "habitat banking,"[14] and further exploration of "rights-based approaches to resources access," as used in some fisheries.

***Biodiversity planning and management***

A plan for actively managing the viability of ecosystems as the climate changes should be developed for all conservation lands and waters and significant areas of habitat. Elements include:

- Climate-smart management plans for coping with major stressors, such as fire, pests, and nutrient loads.
- Decision procedures and triggers for changing management priorities in the face of climate change. For example, if a conservation area is affected by two fires within a short period, making the reestablishment of the previous habitat and values unlikely, then a program to actively manage the transition to an alternative ecosystem structure should be implemented.
- Integration into the plans of the rights, interests, and contributions of indigenous peoples and others directly dependent on these lands or waters.

Such proactive planning is rare even in the developed world.[15] Canada has a proactive management approach to climate change in the face of rapid warming in its northern regions.[16] Other countries are outlining some of the core principles of proactive management: forecasting changes; managing regional biodiversity, including conservation areas and their surrounding landscape; and setting priorities to support decision making in the face of inevitable change.[17] But in many parts of the world, basic biodiversity management is still inadequate. In 1999 the International Union for Conservation of Nature determined that less than a quarter of protected areas in 10 developing countries were adequately managed and that more than 10 percent of protected areas were already thoroughly degraded.[18]

***Community-based conservation***

Community-based conservation programs could be adopted on a much larger scale. These programs attempt to enhance local user rights and stewardship over natural resources, allowing those nearest to natural resources, who already share in the costs of conservation (such as wildlife depredation of crops) to share in its benefits as well. But such programs are not panaceas, and more effort needs to go into designing effective programs.

Community participation is the sine qua non of successful biodiversity conservation in the developing world, but long-term success stories (such as harvesting sea turtle eggs in Costa Rica and Brazil) are rare.[19] Certain elements clearly contribute to the success that some programs have had regionally, such as the wildlife-focused programs in southern Africa. These elements include stable governments, high resource value (iconic wildlife), strong economies that support export-oriented resource use (including tourism and safari hunting), low human population densities, good local governance, and government policies that offer a social safety net to buffer against lean years. Even when these conditions are met, the benefits in some countries typically do not accrue to the poor.[20]

***Managing marine ecosystems***

Effective land management also has benefits for marine ecosystems. Sedimentation and eutrophication caused by land-based runoff reduce the resilience of marine ecosystems such as coral reefs.[21] The economic value of coral reefs is often greater than the value of the agriculture on the land that affects them.[22]

For fisheries the main tools for managing biodiversity are ecosystem-based fisheries management,[23] integrated coastal zone management including protected marine areas,[24] and binding international cooperation within the framework of the Law of the Sea.[25] Fisheries are seen as being in crisis, and fisheries mismanagement is blamed. But the fundamental requirements for fisheries management are known.[26] Climate change may provide an additional impetus to implement reforms, primarily by reducing fishing fleet overcapacity and fishing effort to sustainable levels.[27] A sustainable, long-term harvesting strategy must be implemented—one that assesses stock exploitation in relation to reference points that take uncertainty and climate change into account.[28] The key challenge is to translate high-level policy goals into operational actions for sustainable fisheries.[29]

## Payment for ecosystem services

Payment for ecosystem services has for some time been considered an efficient and equitable way to achieve many outcomes related to conservation and the provision of ecosystem services. Examples include paying upstream land managers to manage the watershed in ways that protect ecosystem services such as flows of clean water, sharing profits from game reserves with surrounding landholders whose property is damaged by the game, and most recently paying landholders to increase or maintain the carbon stocks on their land. Box FB.2 provides examples of the provision of multiple services of conservation and carbon sequestration.

Experience suggests that, because payments are provided only if a service is rendered, user-financed schemes tend to be better tailored to local needs, better monitored, and better enforced than similar government-financed programs.[30]

A significant opportunity for additional payments for conservation and improved land management may flow from the scheme for Reduced Emissions from Deforestation and forest Degradation (REDD) under consideration by the United Nations Framework Convention on Climate Change. REDD seeks to lower emissions by paying countries for reducing deforestation and degrada-

**BOX FB.2** *Payment for ecosystem and mitigation services*

Two successful payment programs are the Moldova Soil Conservation project and the bird conservation and watershed protection program in Bolivia's Los Negros Valley, both funded through the World Bank BioCarbon Fund. In Moldova, 20,000 hectares of degraded and eroded state-owned and communal agricultural lands are being reforested, reducing erosion and providing forest products to local communities.

The project is expected to sequester about 2.5 million tons of carbon dioxide equivalent by 2017. In Bolivia, farmers bordering Amboró National Park are paid to protect a watershed containing the threatened cloud forest habitat of 11 species of migratory birds, with benefits both for local biodiversity and for dry-season water supplies.

*Source:* World Bank Carbon Finance Unit.

tion. These payments could be part of a market-based mechanism within an enhanced Clean Development Mechanism process, or they could be nonmarket payments from a new financial mechanism that does not impinge on the emissions compliance mechanisms. The challenge of REDD is in its implementation, which is discussed in more detail in chapter 6.

REDD could make a significant contribution to both the conservation of biodiversity and mitigation of climate change if it protects biologically diverse areas that have high carbon stocks and are at high risk of deforestation. Techniques for identifying such areas are available and could be used to guide the allocation of financial resources (map FB.2).[31]

To deal effectively with the changing impacts and competing uses of ecosystems under a changing climate, governments will need to introduce strong, locally appropriate policies, measures, and incentives to change long-established behaviors, some of which are already illegal. These actions will run counter to some community preferences, so the balance between appropriate regulation and incentives is critical. REDD holds potential benefits for forest-dwelling indigenous and local communities, but a number of conditions will need to be met for these benefits to be achieved. Indigenous peoples, for example, are unlikely to benefit from REDD if their identities and rights are not recognized and if they do not have secure rights to their lands, territories, and resources (box FB.3). Experience from community-based natural resource management initiatives has shown that the involvement of local people, including indigenous peoples, in participatory monitoring of natural resources can provide accurate, cost-effective, and locally anchored information on forest biomass and natural resource trends.

## Ecosystem-based adaptation

"Hard" adaptation measures such as coastal defense walls, river embankments, and dams to control river flows all present threats to biodiversity.[32] Adaptation goals can often be achieved through better management of ecosystems rather than through physical and engineering interventions; for example, coastal ecosystems can be more effective as buffer zones against storm surges than sea walls. Other options include catchment and flood plain management to adjust downstream water flows and the introduction of climate-resilient agroecosystems and dry-land pastoralism to support robust livelihoods.

Ecosystem-based adaptation aims to increase the resilience and reduce the vulnerability of people to climate change through the conservation, restoration, and management of ecosystems. When integrated into an overall adaptation strategy, it can deliver a cost-effective contribution to adaptation and generate societal benefits.

In addition to the direct benefits for adaptation, ecosystem-based adaptation activities can also have indirect benefits for people, biodiversity, and mitigation. For example, the restoration of mangrove systems to provide shoreline protection from storm surges

**BOX FB.3** *Excerpts from the Declaration of Indigenous Peoples on Climate Change*

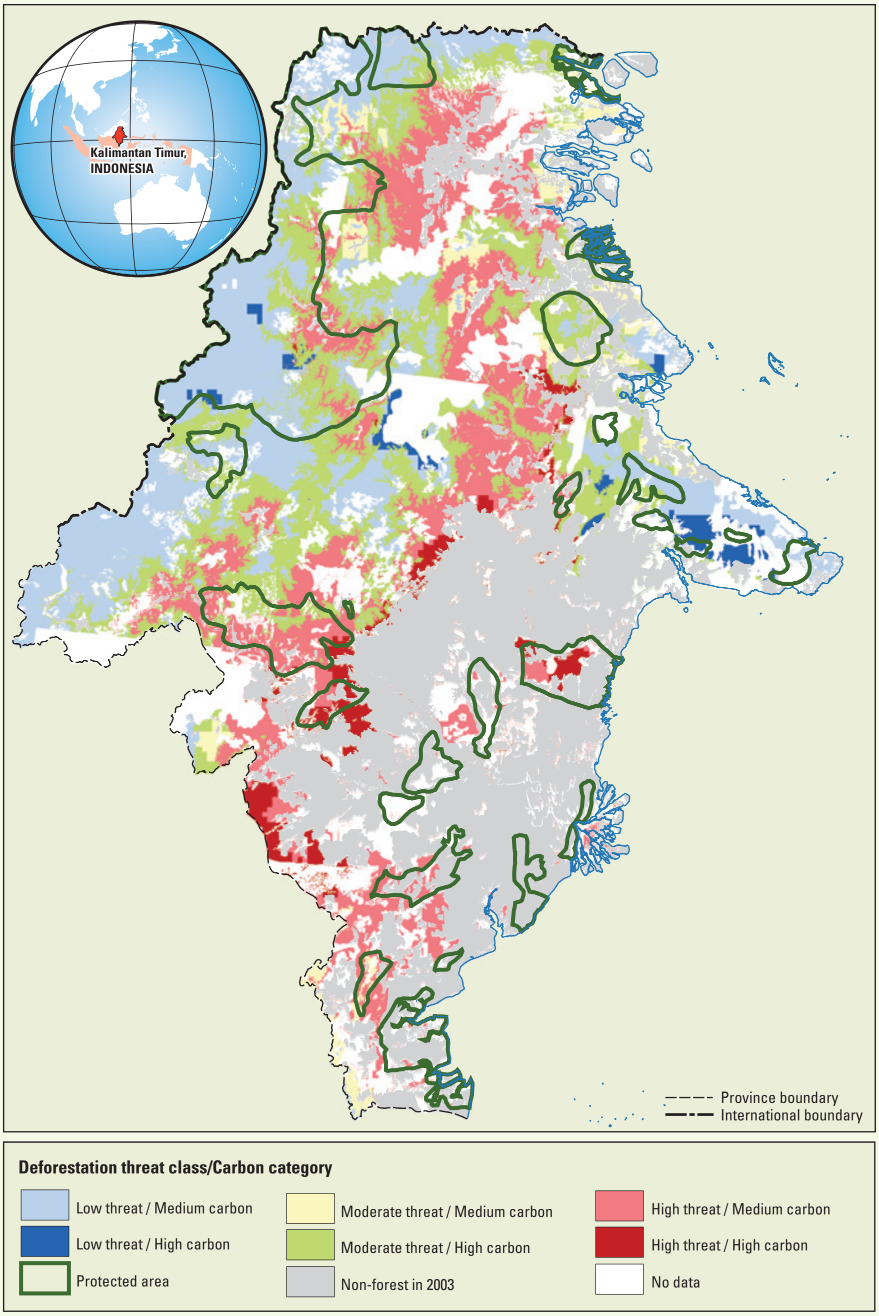
"All initiatives under Reducing Emissions from Deforestation and Degradation (REDD) must secure the recognition and implementation of the rights of Indigenous Peoples, including security of land tenure, recognition of land title according to traditional ways, uses and customary laws and the multiple benefits of forests for climate, ecosystems, and peoples before taking any action." (Article 5)

"We call for adequate and direct funding in developed and developing States and for a fund to be created to enable Indigenous Peoples' full and effective participation in all climate processes, including adaptation, mitigation, monitoring, and transfer of appropriate technologies, in order to foster our empowerment, capacity building, and education. We strongly urge relevant United Nations bodies to facilitate and fund the participation, education, and capacity building of Indigenous youth and women to ensure engagement in all international and national processes related to climate change." (Article 7)

"We offer to share with humanity our Traditional Knowledge, innovations, and practices relevant to climate change, provided our fundamental rights as intergenerational guardians of this knowledge are fully recognized and respected. We reiterate the urgent need for collective action." (Concluding Para).

The declaration was issued during the Indigenous Peoples Global Summit on Climate Change held in Anchorage on April 24, 2009.

**Map FB.2 Unprotected areas at high risk of deforestation and with high carbon stocks should be priority areas to benefit from a REDD mechanism.**




*Sources:* Brown and others 1993; Harris and others 2009.

*Note:* A recent study for the East Kalimantan region of Indonesia used GEOMOD and a database of carbon stocks in Indonesia's tropical forests to identify the best areas for REDD activities. The resulting map identifies areas with high deforestation threat that also have high carbon stocks. The overlay of the existing or proposed protected areas allows decision makers to see where to direct financial resources and focus the protection efforts to get the most benefits under a REDD mechanism (namely, the dark red areas—high threat/high carbon—not included within the boundaries of already existing protected areas).

can also increase fishery opportunities and sequester carbon. Ecosystem-based adaptation options are often more accessible to the rural poor, women, and other vulnerable groups than options based on infrastructure and engineering. Consistent with community-based approaches to adaptation, ecosystem-based adaptation builds effectively on local knowledge and needs.

Ecosystem-based adaptation may require giving priority to some ecosystem services at the expense of others. Using wetlands for coastal protection may require emphasis on silt accumulation and stabilization, for example, possibly at some expense to wildlife and recreation. Slope stabilization with dense shrubbery is an effective ecosystem-based adaptation to increasing rainfall intensity under climate change. However, in the dry periods often associated with the increasingly variable rainfall patterns under climate change the slopes may be exposed to wildfires that destroy the shrubs and lead to disastrous reversals of the adaptation goals. So, ecosystem-based adaptation must be assessed for risk and cost-effectiveness.

## Notes

1. McGinley 2007.
2. Vitousek and others 1999.
3. Fitzgerald, McCouch, and Hall 2009.
4. Brown 2002.
5. WHO and FAO 2009.
6. Haberl 1997.
7. Millennium Ecosystem Assessment 2005.
8. Lawton and May 1995.
9. England and others (2004) estimated the average rate of glacial retreat to be 0.1 kilometer a year about 8,000 years ago during the last ice age, which ultimately placed a constraint on how fast species could migrate poleward.
10. Convention on Biological Diversity 2009; Fischlin and others 2007.
11. Foden and others 2008.
12. Bode and others 2008; Joseph, Maloney, and Possingham 2008; McCarthy and Possingham 2007.
13. UNEP-WCMC 2008.
14. This is a form of trading high-conservation-value lands. Some holders of such lands will choose to place them in a habitat bank. If a need arises to damage similar land elsewhere, such as for highway easements, the project proponents must buy the rights to land of equivalent conservation value from the bank.
15. Heller and Zavaleta 2009.
16. Welch 2005.

17. Hannah and others 2002; Hannah, Midgley, and Miller 2002.

18. Dudley and Stolton 1999.

19. Campbell, Haalboom, and Trow 2007.

20. Bandyopadhyay and Tembo 2009.

21. Smith, Gilmour, and Heyward 2008.

22. Gordon 2007.

23. FAO 2003; FAO 2005; Stiansen and others 2005.

24. Halpern 2003; Harmelin-Vivien and others 2008.

25. Lodge and others 2007.

26. Cunningham and Bostock 2005.

27. OECD 2008; World Bank 2008.

28. Beddington, Agnew, and Clark 2007.

29. FAO 2003; FAO 2005; ICES 2008a; ICES 2008b.

30. Wunder, Engel, and Pagiola 2008.

31. Brown and others 1993; Harris and others 2009.

32. This section draws upon material being prepared by the Ad Hoc Technical Expert Group on Biodiversity and Climate Change 2009 for the Convention on Biological Diversity and the UN Framework Convention on Climate Change.

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