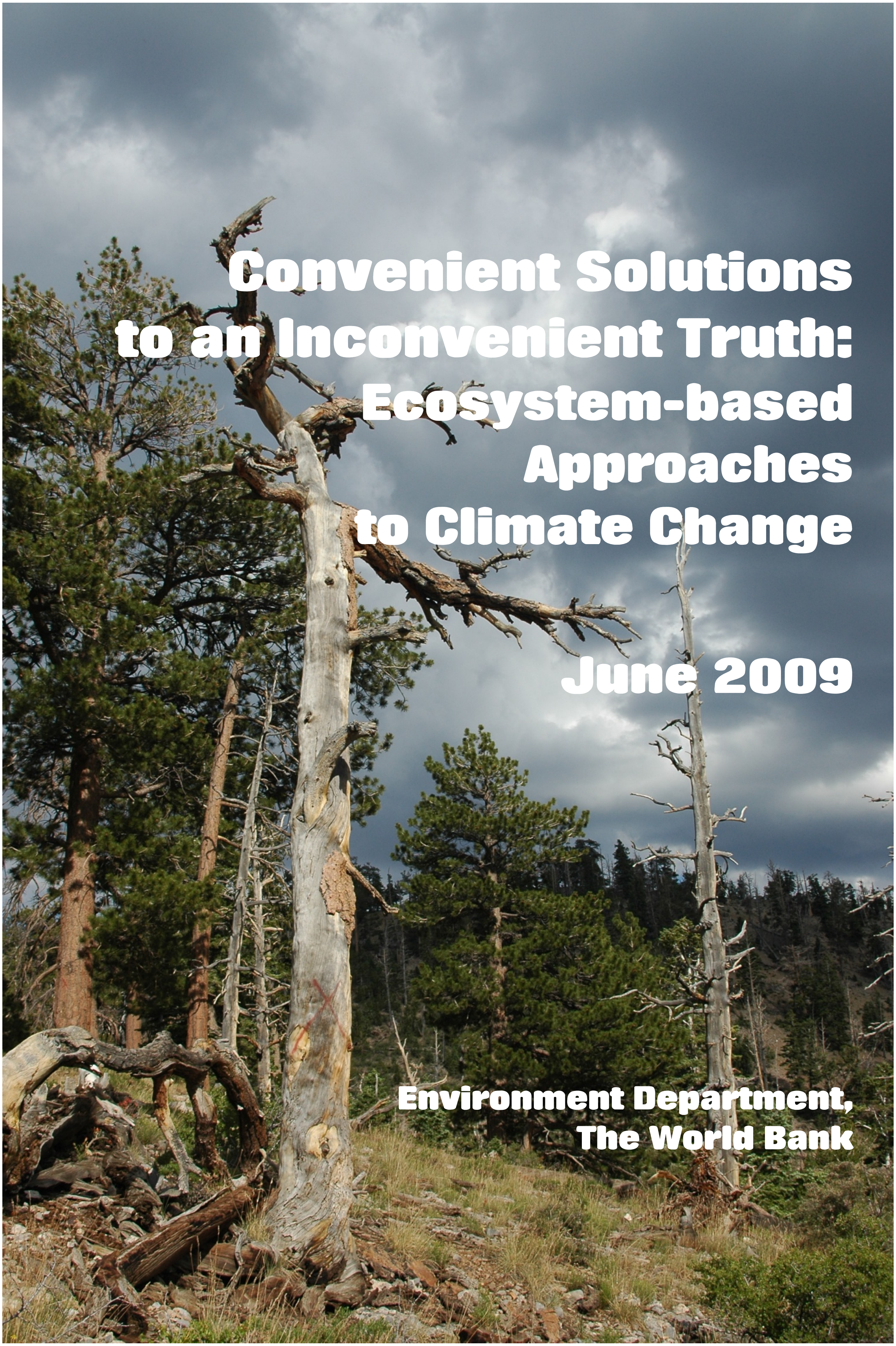

Convenient Solutions to an Inconvenient Truth: Ecosystem-based Approaches to Climate Change

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Glossary and Acronyms

AHTEG: Ad Hoc Technical Group for Biodiversity and Climate Change

CARICOM: Caribbean Community

CBD: Convention on Biological Diversity

CDM: Clean Development Mechanism under the Kyoto Protocol

CERs: Credit Emission Reduction, issued in return for a reduction of atmospheric carbon emissions through projects under the Kyoto Protocol's CDM. One CER equals an emission reduction of one tonne of CO_2. Storage of 12gms of carbon would be equivalent to reducing CO_2 emissions by 44gms.

CIFs: Climate Investment Funds

CFR: Cape Floristic Region, the smallest floral kingdom located in South Africa

CO_2: Carbon dioxide, a greenhouse gas

CO_2 e: Equivalent to the concentration of CO_2 that would cause the same level of warming as a given type and concentration of another GHG.

CPACC: Caribbean Planning for Adaptation to Climate Change

CTI: Coral Triangle Initiative

DPL: World Bank Development Policy Lending

EU: European Union

ESW: Economic and Sector Work

FAO: Food and Agriculture Organization

FCPF: Forest Carbon Partnership Facility

FIP: Forest Investment Program

GEF: The Global Environment Facility

GFP: Growing Forest Partnerships

GHG: Green house gases, including carbon dioxide, methane, nitrous oxide etc.

GISP: Global Invasive Species Programme

GtC: Gigatons of carbon or 10^9 tons of carbon

IAS: Invasive alien species

IFRC: International Federation of Red Cross and Red Crescent Societies

IIED: International Institute for Environment and Development

IPCC: Intergovernmental Panel on Climate Change

IUCN: International Union for Conservation of Nature

LULUCF: Land Use, Land Use Change and Forestry

MABC: The MesoAmerican Biological Corridor

MDG: Millennium Development Goal

MEA: Millennium Ecosystem Assessment

Mm^3: Million cubic meters

MtC: Megatons of carbon, or 10^6 carbon

Mt CO_2e: Megatons of carbon dioxide equivalent or 10^6 tons of carbon dioxide equivalent

ODA: Overseas Development Assistance

PES: Payments for Ecosystem Services

PPCR: Pilot Program for Climate resilience

REDD: Reduced Emissions from Deforestation and Degradation

EA: Strategic Environmental Assessment

SIDs: Small Island Developing States

SCF: The Strategic Climate Fund

SLM: Sustainable land management

SFCCD: Strategic Framework for Climate Change and Development

SPS: Silvopastoral system

UNFCC: United Nations Framework Convention on Climate Change

UN-REDD: The United Nations Collaborative Program on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries

WWF: World Wide Fund for Nature

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Executive Summary

The World Bank's mission is to alleviate poverty and support sustainable development. Climate change is a serious environmental challenge that could undermine these goals. Since the Industrial Revolution, the mean surface temperature of Earth has increased an average 2° Celsius due to the accumulation of greenhouse gases in the atmosphere. Most of this change has occurred in the past 30 to 40 years, and the rate of increase is accelerating. These rising temperatures will have significant impacts at a global scale and at local and regional levels. While it remains important to reduce greenhouse gas emissions and reverse climate change in the long run, many of the impacts of climate change are already in evidence. As a result, governments, communities, and civil society are increasingly concerned with anticipating the future effects of climate change while searching for strategies to mitigate, and adapt to, its current and future effects.

Global warming and changes in climate have already had observed impacts on natural ecosystems and species. Natural systems such as wetlands, mangroves, coral reefs, cloud forests, Arctic and high latitude ecosystems are especially vulnerable to climate-induced disturbances. Enhanced protection and management of biological resources and habitats can mitigate impacts and contribute to solutions as nations and communities strive to adapt to climate change. Biodiversity is the foundation and mainstay of agriculture, forests, and fisheries. Biological resources provide the raw materials for livelihoods, agriculture, medicines, trade, tourism, and industry. Forests, grasslands, freshwater, and marine and other natural ecosystems provide a range of services, often not recognized in national economic accounts but vital to human welfare: regulating water flows and water quality, flood control, pollination, decontamination, carbon sequestration, soil conservation, and nutrient and hydrological cycling.

Current efforts to address climate change focus mainly on reducing emissions of greenhouse gases, mainly through cleaner energy strategies, and on attempting to reduce vulnerability of communities at risk by improving infrastructure to meet new energy and water needs. This report attempts to set out a compelling argument for including ecosystem-based approaches to mitigation and adaptation as a third and essential pillar in national strategies to address climate change. The report is targeted at both Bank task teams and country clients. Such ecosystem-based strategies can offer cost-effective, proven and sustainable solutions contributing to, and complementing, other national and regional adaptation strategies.

Ecosystem-based Mitigation

Terrestrial and oceanic ecosystems play a significant role in the global carbon cycle. Natural habitats are a net store of carbon with terrestrial ecosystems removing 3 GtC and oceans another 1.7 GtC from the atmosphere every year. Worldwide soils alone are estimated to store 1553 Gt. Natural ecosystems serve as major carbon stores and sinks, mitigating and reducing greenhouse gas emissions from energy- related or land use changes. Biological mitigation of greenhouse gases can occur through (a) sequestration by increasing the size of carbon pools (e.g. through afforestation, reforestation and restoration of natural habitats) b) maintaining existing carbon stores (for example, avoided deforestation or protecting wetlands); (c) maintenance of the ocean carbon sink; and, (d) substitution of fossil fuel energy by cleaner technologies based on biomass. The estimated upper limit of the global potential of biological mitigation options through afforestation, reforestation, avoided deforestation, and improved

agriculture, grazing, and forest management is 100GtC by the year 2050, which is equivalent to about 10–20 percent of projected fossil-fuel emissions during that period.

Forests cover about 30 percent of total land area, but they store about 50 percent of the Earth's terrestrial carbon (1,150 GtC) in plant biomass, litter and debris, or in the soil. About 20 percent of total GHG emissions are caused by deforestation and land use changes but in tropical regions emissions attributable to land clearance are much higher, up to 40 percent of national totals. Reducing deforestation and degradation (REDD) is the forest mitigation option with the largest potential for maintaining carbon stocks in standing forests over the short term.

Various types of wetlands – including swamp forests, mangroves, peatlands, mires and marshes – are also important carbon sinks and stores. Anaerobic conditions in inundated wetland soils and slow decomposition rates contribute to long term soil carbon storage and formation of carbon rich peats. Peatlands can extend up to 20 m in depth and represent some 25 percent of the world soil carbon pool, an estimated 550 GtC; they are estimated to sequester another 0.3 tC/ha/yr. Maintaining and restoring wetland habitats protects these carbon sinks; clearance and drainage can lead to peat collapse and further carbon emissions.

Grasslands occur on every continent except Antarctica, and constitute about 34 percent of the global terrestrial carbon stock. Changes in grassland vegetation due to overgrazing, conversion to crop land, desertification, fire, fragmentation, and introduction of non-native species affect their carbon storage capacity, and may in some cases even lead to grasslands becoming a net source of CO_2. For example, they may lose 20 to 50 percent of their soil organic carbon content through cultivation, soil erosion, and land degradation. Burning of biomass, especially in tropical savannas, contributes over 40 percent of gross global carbon dioxide emissions.

Oceans, too, are substantial reservoirs of carbon, holding approximately 50 times more carbon than presently in the atmosphere. They are efficient in taking up atmospheric carbon through plankton photosynthesis, mixing of atmospheric CO_2 with sea water, formation of carbonates and bicarbonates, conversion of inorganic carbon to particulate organic matter and by burial of carbon rich particles in the deep sea.

Clearly enhanced protection and improved management of natural ecosystems can contribute to both reductions in GHG emissions and carbon sequestration. Many protected areas, for instance, overlie areas of high carbon stocks. It has been estimated that globally, ecosystems represented within terrestrial protected areas store over 312 GtC or 15 percent of the terrestrial carbon stock, although the extent to which these stocks are protected varies with management effectiveness.

Ecosystem-based Adaptation

Adaptation is becoming an increasingly important part of the development agenda. Protecting forests, wetlands, coastal habitats and other natural ecosystem can provide social, economic, and environmental benefits, both directly through more sustainable management of biological resources and, indirectly, through protection of ecosystem services. Natural ecosystems maintain the full range of goods and ecosystem services, including natural resources such as water, timber and fisheries on which human livelihoods depend; these services are especially important to the most vulnerable sectors of society. Protected areas, and the natural habitats within them, can protect watersheds and regulate water flow and water quality; prevent soil erosion; influence rainfall regimes and local climate; conserve renewable harvestable resources and genetic reservoirs; and protect breeding stocks, natural pollinators, and seed dispersers, which maintain ecosystem health. Over the last decade, an increasing number of Bank projects have been making explicit linkages between conservation and sustainable use of natural ecosystems, carbon sequestration and watershed values associated with erosion control, clean water supplies, and flood control. Better protection and management of key habitats and natural resources can benefit poor, marginalized and indigenous communities by protecting ecosystem services and maintaining access to resources during difficult times, including drought and disaster.

In response to climate change, many countries are likely to invest in even more infrastructure for coastal defenses and flood control to reduce the vulnerability of human settlements to climate change. Increased water shortages will increase demand for new irrigation facilities and new reservoirs. Similarly, natural ecosystems can reduce vulnerability to natural hazards and extreme climatic events and complement, or substitute for, more expensive infrastructure investments to protect coastal and riverine settlements. Floodplain forests and coastal mangroves provide storm protection, coastal defenses, and water recharge, and act as safety barriers against natural hazards such as floods, hurricanes, and tsunamis, while wetlands filter pollutants and serve as water recharge areas and nurseries for local fisheries. Traditional engineered solutions often work against nature, particularly when they aim to constrain regular ecological cycles, such as annual river flooding and coastal erosion, and could further threaten ecosystem services if creation of dams, sea walls, and flood canals leads to habitat loss. Instead, in Ecuador and Argentina, flood control projects utilize the natural storage and recharge properties of critical forests and wetlands by integrating them into “living with floods” strategies that incorporate forest protected areas and riparian corridors – simple and effective solutions that protect both communities and natural capital.

Three of the world’s greatest challenges over the coming decades will be biodiversity loss, climate change, and water shortages. Biodiversity loss will lead to the erosion of ecosystem services and will increase vulnerability to the impacts of climate change. Climate change will lead to water scarcity, increased risk of crop failure, pest infestation, overstocking and permanent degradation of grazing lands and livestock deaths. Water shortages affect agricultural productivity, food security and human health. Impacts from these challenges are already imposing severe economic and social costs, and they are likely to get more severe as climate change continues, particularly affecting already vulnerable communities.

Changing climate and rainfall patterns are expected to have significant impacts on agricultural productivity, especially in arid and semi-arid regions that are already marginal for agriculture. Most climate modeling scenarios indicate that the dry lands of West and Central Asia and North Africa, for instance, will be severely affected by droughts and high temperatures in the years to come. This could lead to land degradation and agricultural expansion. By 2050, almost 40 percent of the land currently under low impact agriculture could be converted to more intensive agricultural use with poor farmers being forced to open up ever more marginal lands. One study estimates that climate change could lead to a 50 percent reduction in crop yields for rain-fed agricultural crops by 2020. According to crop-climate models, in tropical countries even moderate warming can reduce yields significantly (1°C for wheat and maize and 2°C for rice) because many crops are already at the limit of their heat tolerance. The areas most vulnerable to climate change—centered in South Asia and Sub-Saharan Africa—also have the largest number of rural poor and rural populations dependent on agriculture. Recent studies show that farming, animal husbandry, informal forestry and fisheries make up only 7.3 percent of India's GDP, but these activities constitute 57 percent of GDP of the poor who are most reliant on natural resources and ecosystem services.

Climate change is likely to aid the spread of invasive alien species, further threatening agricultural productivity and food security through spread of weeds, pests, and diseases of crops and livestock. The introduction of new and adaptable exotic species for agriculture and to meet increasing demands for biofuels, mariculture, aquaculture, and reforestation presents a particular challenge. Ironically, in some cases, the very characteristics that make a species attractive for introduction under development assistance programs (fast-growing, adaptable, high reproductive output, tolerant of disturbance and a range of environmental conditions,) are the same properties that increase the likelihood of the species becoming invasive. Such events are costly; invasives accidentally introduced through development assistance programs include itch grass, a major weed in cereals in South and Central America, and a range of nematode pests. The economic impacts of IAS can be expensive, costing an estimated $140 billion annually in the United States alone.

Climate change can also be expected to have serious consequences on water resources. Melting glaciers, higher intensity and more variable rainfall events, and increasing temperatures will contribute to increased inland flooding, water scarcity and decreasing water quality. Overall, the greatest human requirement for freshwater resources is for crop irrigation, particularly for farming in arid regions and in the great paddy fields of Asia. In South Asia, hundreds of millions of people depend on perennial rivers such as the Indus, Ganges, and Brahmaputra –all fed by the unique water reservoir formed by the 16,000 Himalayan glaciers. Current trends in glacial melt suggest that the low flows will be substantially reduced as a consequence of climate change even as the demand for agricultural water is projected to rise by 6 to 10 percent for every 1 ˚C rise in temperature. As a result, even under the most conservative climate projections, the net cereal production in South Asian countries is likely to decline by 4 to 10 percent by the end of this century.

Municipal water accounts for less than a tenth of human water use, but clean drinking water is a critical need. Today, half of the world's population live in towns and cities and one-third of this urban population live without clean drinking water. These billion have-nots are unevenly distributed across the globe: 700 million city dwellers in Asia, 150 million in Africa, and 120 million in Latin America and the Caribbean. In recent years, governments and city councils have begun to take an increasing interest in the opportunities for offsetting or reducing some of the costs of maintaining urban water supplies—and, perhaps even more importantly, water quality—through management of natural resources, particularly forests and wetlands. Most protected areas are established to protect their biodiversity values but many could be justified on the basis of the other ecosystem services that they provide. From China to Ecuador and Mexico to Kenya, protected areas in forest watersheds safeguard the drinking supplies for some of the world's major cities In Indonesia the Gunung Gede-Pangrango National Park in Indonesia, for instance, safeguards the drinking water supplies of Jakarta, Bogor, and Sukabumi and generates water with an estimated value of $1.5 billion annually for agriculture and domestic use, while Kerinci National Park safeguards water supplies for more than 3.5 million people and 7 million hectares of agricultural land.

Bank projects and programs are already supporting biodiversity conservation and protecting natural habitats and ecosystem services, thereby contributing to effective mitigation and adaptation strategies. Pilot projects which integrate protection of natural habitats and "green" infrastructure into watershed management, flood control and coastal defense, already demonstrate the cost effectiveness of such ecosystem-based approaches.
Climate change highlights the need to replicate and scale up such interventions including:

- Protecting terrestrial, freshwater, and marine ecosystems and ecological corridors to conserve terrestrial and aquatic biodiversity and ecosystem services.
- Integrating protection of natural habitats into strategies to reduce vulnerability and disaster risks (including protection from natural hazards such as floods, cyclones and other natural disasters).
- Scaling up country dialogue and sector work on valuation of ecosystem services and the role of natural ecosystems, biodiversity and ecosystem services in underpinning economic development.
- Emphasizing the linkages between protection of natural habitats and regulation of water flows and quality of water, essential for agriculture, food security, and domestic and industrial supplies.
- Scaling up investments for protected areas and ecosystem services linked to sector lending, such as infrastructure, agriculture, tourism, water supply, fisheries, forestry.
- Promoting greater action on management of invasive alien species, which are linked to land degradation, and impact negatively on food security, and water supplies.
- Emphasizing the multiple benefits of forest conservation and sustainable forest management (carbon sequestration, water quality, reducing risks from natural hazards, poverty alleviation, biodiversity conservation).
- Promoting investments in natural ecosystems as a response to mitigation (avoided deforestation) and adaptation (wetland services).
- Integrating indigenous crops and traditional knowledge on agrobiodiversity and water management into agricultural projects as part of adaptation strategies.
- Promoting more sustainable natural resource management strategies linked to agriculture, land use, habitat restoration, forest management and fisheries.
- Developing new financing mechanisms and integrating ecosystem benefits into new adaptation and transformation funds.
- Using strategic environment assessments as tools to promote protection of biodiversity and ecosystem services.
- Monitoring investments in ecosystem protection within mainstream lending projects and documenting good practices for dissemination and replication.
- Developing new tools to measure the benefits of integrated approaches to climate change (ecosystem services, biodiversity conservation, carbon sequestration, livelihood co-benefits and resilience).

Promoting further integration of ecosystem-based approaches into climate change responses and national adaptation strategies will require access to much greater sources of funding, including capitalizing on opportunities to protect natural ecosystems as part of major energy and infrastructure projects. The Bank is also facilitating the development of market-based financing mechanisms and piloting new avenues to deepen the reach of the carbon market. New initiatives and investment funds such as the Forest Carbon Partnership Facility, Forest Investment program and the Pilot Program for Climate Resilience provide exciting additional opportunities to better protect natural capital, benefit communities and utilize cost-effective green technology to address the challenges of climate change.

Chapter 1. The World Bank and Biodiversity Conservation: A Contribution to Action for Climate Change

Introduction

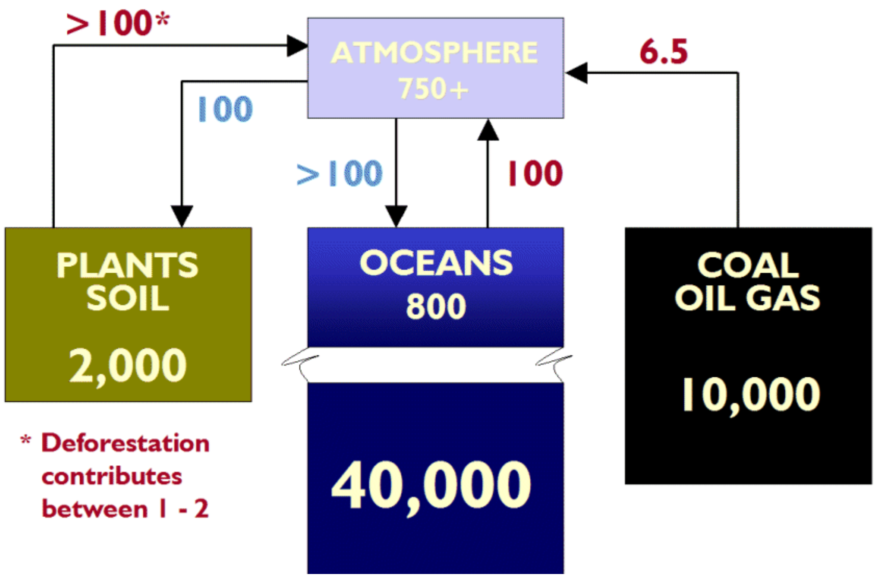
Climate change is a serious environmental challenge that could undermine the drive for sustainable development. The global mean surface temperature has increased by an average of 0.6° Celsius (°C) over the last 100 years, largely due to the accumulation of greenhouse gases in the atmosphere (IPCC, 2002). Most of this change has occurred in the past 30 to 40 years, and the rate of increase is accelerating. These rising temperatures will have significant impacts at a global scale and at local and regional levels. While it remains important to reduce greenhouse gas emissions and reverse climate change in the long run, many of the impacts of climate change are already in evidence. As a result, governments, communities, and other sectors of civil society are increasingly concerned with anticipating the future effects of climate change while searching for strategies to mitigate and adapt to its current and future effects.

The World Bank's mission is to alleviate poverty and support sustainable development. The conservation and sustainable use of natural habitats and biodiversity will contribute to these goals by protecting ecosystem services that are critical to fulfilling these objectives. Biodiversity is the foundation and mainstay of agriculture, forests, and fisheries. Biological resources provide the raw materials for livelihoods, sustenance, medicines, trade, tourism, and industry. Genetic diversity provides the basis for new breeding programs, improved crops, enhanced agricultural production, and food security. Forests, grasslands, freshwater, and marine and other natural ecosystems provide a range of services, often not recognized in national economic accounts but vital to human welfare: regulating water flows and water quality, flood control, pollination, decontamination, carbon sequestration, soil conservation, and nutrient and hydrological cycling. Sound ecosystem management provides countless streams of benefits to, and opportunities for, human societies, while also supporting the web of life. Ecosystem services and biodiversity conservation contribute to environmental sustainability, a critical Millennium Development Goal (MDG) and a central pillar of World Bank assistance.

The *Millennium Ecosystem Assessment* showed that over the past 50 years human activities have changed ecosystems more rapidly and extensively than at any comparable period in our history. These changes have contributed to many net development gains but at growing environmental and social costs: habitat loss, land degradation, and reduced access to adequate water and natural resources for many of the world's poorest people. Climate change is likely to compound this environmental degradation.

Terrestrial and oceanic ecosystems play a significant role in the global carbon cycle. About 60 gigatons of carbon (GtC) annually are taken up and released by terrestrial ecosystems, and another 90 GtC are taken up and released by marine systems (Matthews et al., 2000). These natural fluxes are large compared to the approximately 6.3 GtC currently emitted annually from fossil fuels and industrial processes and another 1.6 GtC per year from deforestation, predominantly in the tropics (IPCC, 2002). Natural habitats are a net sink of carbon. Worldwide soils alone are estimated to store 1555 GtC (Matthews et al., 2000). Furthermore, terrestrial ecosystems are removing an estimated 3 GtC and oceans another 1.7 GtC from the atmosphere every year. Appropriate management of terrestrial and aquatic habitats can, therefore, make a significant contribution to reducing greenhouse gases.

Figure 1.1. Approximate stores (gigatons) and fluxes of carbon (gigatons of carbon per year (GtC/yr))



Source: Woods Hole Institute (http://www.whrc.org/carbon/index.htm).

Impacts of Climate Change on Ecosystems and Biodiversity

Habitat loss and fragmentation, overexploitation, pollution, the impact of invasive alien species and, increasingly, climate change all threaten the very biological resources and ecosystem services on which humankind depends. Increased atmospheric CO2 concentrations, increased land and ocean temperatures, and changes in precipitation and sea level rise will affect both natural systems and human welfare. Global warming and climate changes have already had observed impacts on natural ecosystems and species (Moritz et al., 2008; Zonneveld et al. 2009). Wetlands, mangroves, coral reefs, cloud forests and Arctic ecosystems are particularly vulnerable. Climate change is also expected to increase the likelihood of species extinctions and may affect species distribution and behaviour, reproduction and migration patterns and frequency, as well as intensity of pest and disease outbreaks, all of which are likely to impact on crop production, food security and human health.

Some of the most threatened ecosystems globally are Mediterranean-type habitats such as those found in the Cape Floral Kingdom, Mediterranean basin, and southern Chile. The Cape Floristic Region (CFR) is the smallest of the world's six floral kingdoms, protecting unique Mediterranean-type vegetation known as fynbos. The CFR covers an area of 90,000 square kilometers and is the only floral kingdom to be located entirely within the geographical confines of a single country, South Africa. The CFR contains 9,600 species of vascular plants, many of them endemic; it has been identified as one of the world's "hottest" biodiversity hotspots. The rich biodiversity of the CFR is under serious threat as a result of the conversion of natural habitat to permanent agriculture and to rangelands for cattle, sheep, and ostriches; inappropriate fire management; rapid and insensitive infrastructure development; over-exploitation of marine resources and wild flowers; and infestation by alien species. Some important habitats have already been reduced by over 90 percent, while less than 5 percent of land in the lowlands enjoys any conservation status. Climate change will increase the threats to these threatened ecosystems and put increasing pressure on water resources, while increasing vulnerability to fire and the spread of invasive alien species. Maintaining ecological connectivity and reducing further habitat degradation will be critical strategies for protecting biodiversity and ecosystem services.

Box 1.1. Monitoring the Impact of Climate Change in a Biodiversity Hotspot

The Succulent Karoo Biome covers 116,000 square kilometers of desert along the Atlantic coast of South Africa and southern Namibia and supports the world's richest succulent flora. It is one of the world's biodiversity hotspots, one of the 34 most endemic species-rich and threatened regions on Earth. Together these hotspots harbor more than 75 percent of the most threatened mammals, birds and amphibians, yet they have already lost more than 85 percent of their original habitat cover. These critical areas for biodiversity are also home to millions of people who are highly dependent on healthy ecosystems for their livelihoods and well-being.

This transboundary area—comprising the Richtersveld, Gariep River, Ais-Ais, and the Fish River canyon—has a staggering 2,700 plant species, of which 560 are endemic. Compared to other hotspots, the vegetation in the Richtersveld remains relatively intact in spite of pressures from overgrazing and diamond mining. In recognition of these values, the Richtersveld Cultural and Botanical Landscape has recently been included in UNESCO's World Heritage List

The area is now globally recognized as an example of a biodiversity hotspot under apparent and imminent threat from climate change. Projected time frames for onset of significant impacts vary from 30 to 50 years, although some botanists believe that early signs of global warming may be already evident in the higher mortalities of *Aloe* species in the Richtersveld. The implications of climate change on ecosystems and livelihoods are highly significant. Given expected climate change scenarios and the fact that 75 percent of the land is under communal management, a GEF-funded project in the Richtersveld has opted for a three-tiered strategy for conservation action: (1) forward planning by integrating biodiversity into land use management planning; (2) improved reactive management and implementation of environmental management plans for livestock and mining; and (3) monitoring the effectiveness of land use planning and management in achieving conservation objectives (for example, monitoring the distribution of *Aloe pillansii* as an indicator species for climate change).

More specifically, the unique attributes of the Richtersveld make the region highly suitable as an international ecological research location for the study of global climate change. The South African research community is currently engaged in the development of a network of long-term ecological research sites that act as ecological observatories for change in ecosystems. In this context, the people of the Richtersveld are in the process of forming research partnerships to study global climate change. Specific attention will be given to designing a protected area network resilient to species loss. Maintaining ecological connectivity and the prevention of habitat degradation are essential "lines of defense" against the impacts of climate change.

Climate change is likely to accelerate the ongoing impoverishment of global biodiversity and degradation of ecosystems caused by unsustainable use of natural capital, and other environmental stresses. Permafrost melt in Mongolia, for instance, is exacerbating the effects of habitat degradation caused by overgrazing, affecting water resources and other ecosystem services – see Box 1.2. Similarly, the warming of coastal waters, coral die-off, and impacts on coastal fisheries caused by climate change are increasing the impacts on marine systems of overexploitation by industrial and artisanal fisheries, as well as pollution from ships' waste and land sources. Such degradation and disturbance in terrestrial and aquatic ecosystems generate niches that can be exploited by invasive alien species, leading to further ecosystem change and degradation.

Box 1.2. Climate Change and Biodiversity Loss in Hövsgöl National Park, Mongolia

Hövsgöl National Park is centered on Lake Hövsgöl, lying at 1,700m above sea level in the mountains of northern Mongolia. Here the winters are long and vicious, with temperatures dropping to below -40° C. The Lake Hövsgöl area lies at the southern edge of the taiga forest, and is underlain by permafrost (layers of frozen soil). The region is used by traditional graziers and their livestock. Uncontrolled grazing by sheep, goats, and cattle on the mountain slopes around the lake and the gathering of fuel wood have caused the forest edge to retreat. This loss of forest exposes the ground to sunlight. As a result, the permafrost melts at a faster rate than normal, and aerobic decomposition occurs, producing GHG. The region has already had an average temperature increase of about 1.4 C° over the last 35 years.

In 2001, the Mongolian Academy of Sciences received a five-year GEF grant to study the dynamics of biodiversity loss and permafrost melt in Hövsgöl National Park. The research determined that the active-layer thickness of the permafrost in the Hövsgöl region varied in association with livestock grazing pressure. Removal of vegetation cover increases mean summer surface and ground temperatures, accelerating the rate of permafrost melt. The researchers concluded that climate change impacts on the steppe and forests are very similar to, and magnify, those caused by nomadic pastoralism and forest cutting. To mitigate these strategies, herders need to change grazing strategies to adapt to changing conditions in this harsh and fragile environment. The conclusions regarding land use practices have been summarized in a Herders' Handbook which includes recommendations for more rotational grazing to reduce pressure and improve range management. While little can be done to alter the immediate course of climate change, protecting vegetation cover through appropriate land-use practices can slow the rate of permafrost melt and help to protect Mongolia's water resources, biodiversity and natural ecosystems. These lessons are also relevant to other areas within the temperate mountain forest-grassland mosaics that stretch from Eastern Europe to eastern Russia and northern China.

Impacts on Human Communities and Livelihoods

Habitat loss and degradation will also increase human vulnerability to climate change. Climate change will affect the physical and biological characteristics of coastal areas, modifying their ecosystem structure and functioning. As a result, coastal nations face losses of marine resources and fisheries, and shoreline habitats such as wetlands and mangroves. Increases in ocean temperatures cause corals to bleach and, under sustained warm conditions, to die. Research in the Caribbean shows that nearly 30 percent of warm-water corals have disappeared since the beginning of the 1980s, a change largely due to increasingly frequent and intense periods of warm sea temperatures. The increase of CO_2 in the atmosphere is also resulting in an acidification of the oceans, affecting the calcification of reef plants and animals, especially corals, and thus reducing the ability of reefs to grow vertically and keep pace with rising sea levels. The drowning of atolls and destruction of corals have long-term implications for coastal zone protection, ecosystem integrity, ecosystem services, and productivity of the tropical seas and fisheries.

Climate change, sea level rise and more frequent extreme weather events such as hurricanes, will have repercussions on coastal development, water supply, energy, agriculture, and health, among other sectors. The Intergovernmental Panel on Climate Change (IPCC) has assessed the likely regional impacts of climate change – see Box 1.3. Table 1.1 shows potential climate-related threats in different Bank client countries, many of them among the world's poorest nations. Many countries will suffer even if sea-level rises only one meter, a conservative estimate. A more dramatic rise of up to five meters would have even greater impacts, flooding large areas in the Philippines, Brazil, Venezuela, Senegal, and Fiji as well as the lower-lying islands and coastal states.

Box 1.3. Likely Regional Impacts on Human Communities and Livelihoods

The regional likelihood of impacts have been studied and reported on in the Fourth Assessment of the IPCC. The magnitude and timing of impacts will vary with the amount and rate of climate change.

Africa

- By 2020, between 75 and 250 million of people are projected to be exposed to increased water stress due to climate change.
- By 2020, in some countries, yields from rain-fed agriculture could be reduced by up to 50 per cent.
- Towards the end of the century, projected sea level rise will affect low-lying coastal areas with large populations. The cost of adaptation could amount to at least 5 to 10 per cent of GDP.
- By 2080, arid and semi-arid land is projected to increase by 5 to 8 per cent.

Asia

- By the 2050s, freshwater availability in Central, South, East and South-East Asia, particularly in large river basins, is projected to decrease.
- Coastal areas, especially heavily populated delta regions in South, East and South-East Asia, will be at greatest risk due to increased flooding from the sea and, in some megadeltas, flooding from the rivers.
- Climate change is projected to compound the pressures on natural resources and the environment associated with rapid urbanization, industrialization and economic development.
- Endemic morbidity and mortality due to diarrheal disease, primarily associated with floods and droughts, are expected to rise in East, South and South-East Asia.

Latin America

- By mid-century, increases in temperature and associated decreases in soil water are projected to lead to gradual replacement of tropical forest by savannah in eastern Amazonia.

- Similarly, areas of semi-arid vegetation will tend to be replaced by arid-land vegetation.
- Risk of significant biodiversity loss through species extinction in many areas of tropical Latin America.
- Changes in precipitation patterns and the disappearance of glaciers are projected to significantly affect water availability for human consumption, agriculture and energy generation.

Small Islands

- Sea level rise is expected to exacerbate inundation, storm surge, erosion and other coastal hazards.
- By 2050, climate change is expected to reduce water resources in many small islands, e.g. in the Caribbean and Pacific, to the point where they become insufficient to meet demand during low-rainfall periods.
- With higher temperatures, increased invasion by non-native species is expected to occur, particularly on mid- and high-latitude islands.

Table 1.1. Six Climate Threats, and the 12 Countries Most at Risk

Low Income | Middle Income | High Income

Drought	*Flood*	*Storm*	*Coastal 1m*	*Agriculture*
Malawi	Bangladesh	Philippines	All low-lying Island States	Sudan
Ethiopia	China	Bangladesh	Vietnam	Senegal
Zimbabwe	India	Madagascar	Egypt	Zimbabwe
India	Cambodia	Vietnam	Tunisia	Mali
Mozambique	Mozambique	Moldova	Indonesia	Zambia
Niger	Laos	Mongolia	Mauritania	Morocco
Mauritania	Pakistan	Haiti	China	Niger
Eritrea	Sri Lanka	Samoa	Mexico	India
Sudan	Thailand	Tonga	Myanmar	Malawi
Chad	Vietnam	China	Bangladesh	Algeria
Kenya	Benin	Honduras	Senegal	Ethiopia
Iran	Rwanda	Fiji	Libya	Pakistan

The impacts of climate change in Latin America and the Caribbean have been studied in some detail (Vergara, 2005). They include potential sea-level rise that threatens coastal habitats and human settlements; increased sea surface temperatures; melting of tropical glaciers and snow caps; warming, and drying out of moorlands and other high altitude ecosystems in the Andes; higher frequency and distribution of forest fires; the spread of tropical disease vectors into the Andes piedmont; changes in agricultural productivity; and impacts on coastal and watershed ecosystems. These changes will have major impacts on the region's rich biodiversity and ecosystem services as well as on human health and livelihoods.

The biophysical implications of sea-level rise will vary greatly in different coastal zones depending on the nature of coastal landforms and ecosystems. For example, flooding conditions in the Pampas in the province of Buenos Aires would be exacerbated by any degree of sea-level rise because of the reduced effectiveness of the natural drainage system. Some coastal areas in Central America and on the Atlantic coast of South America, such as the river deltas of the Magdalena in Colombia, would be subject to inundation risk, as would the large, flat deltas of the Amazon, Orinoco, and Paraná rivers. Estuaries such as the Río de la Plata would also suffer increasingly from saltwater intrusion, creating problems in freshwater supply. Potential sea-level rise changes already reported for the Caribbean Basin range from 3 to 8 mm in three years and will impact both human populations and natural ecosystems. Anticipated increases will threaten aquifer-based freshwater supplies through saline intrusion in many of the smaller islands as well as leading to flooding of coastal zones. This is a major concern, given that over 50 percent of the people in most Caribbean states reside within 2 km of the coast. Resources critical to island and coastal populations—including beaches, wetlands, fresh water, fisheries, coral reefs and atolls, and wildlife habitat—are all at risk.

At the other end of the altitudinal spectrum, climate change is affecting mountain ecosystems. Glacial retreat in the Andes is occurring at an alarming rate. Recent measurements show catastrophic declines in glacier volumes, which are likely to result in substantial impacts on water flows to Andean valleys. At lower mountain altitudes, changes observed include loss of water regulation, increased likelihood of flash fires, and changes in ecosystem composition and resilience. Moreover, as temperatures increase, there is a substantive risk of recurring glacial overflows caused by ice melting, placing large downstream populations and infrastructure at imminent risk. Warming is also affecting the moorlands, high-altitude ecosystems with unique and abundantly diverse flora and fauna that are also a storage area for water and soil carbon. Recent research shows that climate change will be even more pronounced in high-elevation mountain ranges, which are warming faster than adjacent lowlands. Hydrological and ecological changes of this magnitude would result in a loss of unique biodiversity, as well as a loss of many of the ecosystem goods and services provided by these mountains, especially water supply, basin regulation, and associated hydropower potential.

Climate change is expected to affect the supply and demand for water resources, and in turn will have an impact on environmental flows. All freshwater ecosystems will face ecologically-significant impacts by the middle of this century. There will be no “untouched” ecosystems, and many water bodies are likely to be profoundly transformed in key ecological characteristics such as flow regime, thermal stratification patterns, and the propensity to cycle between oligotrophic (nutrient poor) and eutrophic (nutrient rich) states. While aquatic life depends on both the quantity and quality of water, changes in flows are of particular concern because they govern so many ecosystem processes. Many tropical regions, for instance, have flooding in the wet season and low flows or no flow during the dry season. In temperate latitudes, spring sees high water following snowpack melt. However, these “normal” patterns can mask the amount of “normal variability” in environmental flows from one year to the next. Eastern Africa, for instance, typically shows inter-annual variability of 30 percent, so a very wet year can be followed by a very dry one. The Amazon sees little variability between years, but the Pantanal to the south shows relatively large swings. In most regions, climate change is increasing the amount of inter-annual variability — more droughts and/or more floods, more very hot days, more intense precipitation — which has a big impact on environmental flows, local agriculture and human livelihoods (Matthews et al., 2009).

Why Protecting Ecosystems and Biodiversity Matters in a Changing World

Current efforts to address climate change focus mainly on reducing emissions of greenhouse gases, mainly through cleaner energy strategies, and improved infrastructure to meet new energy and water needs and reduce the vulnerability of communities at risk. Both of these approaches are necessary. Nevertheless, in many countries, including the poorest nations, these responses could, and should be complemented by greater emphasis on natural capital and ecosystem-based approaches to mitigation and adaptation, through improved conservation and more sustainable management of natural habitats and resources.

Improved ecosystem management can enhance resilience to climate change, protect carbon stores and contribute to adaptation strategies. Climate change is already impacting on ecosystems and livelihoods, but enhanced protection and management of biological resources can mitigate these impacts and contribute to solutions as nations and communities strive to adapt to climate change. Such ecosystem-based strategies can offer cost-effective, proven and sustainable solutions to climate change, contributing to, and complementing, other national and regional adaptation strategies

Protecting forests, wetlands, coastal habitats and other natural ecosystem can provide social, economic, and environmental benefits, both directly through more sustainable management of biological resources and indirectly through protection of ecosystem services. Protected areas, and the natural habitats within them, can protect watersheds and regulate water flow and water quality; prevent soil erosion; influence rainfall regimes and local climate; conserve renewable harvestable resources and genetic reservoirs; and protect breeding stocks, natural pollinators, and seed dispersers, which maintain ecosystem health. Floodplain forests and coastal mangroves provide storm protection and act as safety barriers against natural hazards such as floods, hurricanes, and tsunamis, while natural wetlands filter pollutants and serve as nurseries for local fisheries. Better protection and management of key habitats and natural resources can benefit poor, marginalized and indigenous communities by maintaining ecosystem services and maintaining access to resources during difficult times, including in times of drought and disaster.

The World Bank Group is already a major global funder of biodiversity initiatives, including support to 598 projects in over 120 countries during the last 20 years. This biodiversity portfolio represents over $6 billion in biodiversity investments, including Bank contributions and leveraged co-financing – see Table 1.2. Many of those projects are already promoting sound natural resource management that could contribute to mitigation and adaptation through maintaining and restoring natural ecosystems, improving land and water management, and protecting large blocks of natural habitats across altitudinal gradients. Improved protection of high biodiversity forests, grasslands, wetlands, and other natural habitats provides benefits for livelihoods as well as carbon storage.

Bank projects directly support biodiversity conservation and sustainable use in a range of natural habitats, from coral reefs to some of the world's highest mountains and from tropical evergreen and monsoon forests to savannas grasslands and unique dry lands, limestone, marine and freshwater ecosystems. Many are in centers of recognized global importance for biodiversity: mega-diversity hotspots, remaining wilderness areas, the Global 200 Ecoregions described by Worldwide Fund for Nature (WWF), and Endemic and Important Bird Areas. Many projects are in countries and regions where communities are most vulnerable to the impacts of climate change. By promoting investments in these locations, the Bank is helping client countries to meet the 2010 targets of the Convention on Biological Diversity (CBD) and to prepare for the impacts of climate change.

Table 1.2. Total Biodiversity Investments by Year and Funding Source (million USD)

FY	GEF	IBRD	IDA	Trust Funds	Carbon Finance	Total WBG Investments	Co-Financing	Total Biodiversity Funding
1988	0.00	3.79	2.86	0.00	0.00	6.65	8.95	15.60
1989	0.00	3.16	3.93	0.00	0.00	7.09	5.21	12.30
1990	0.00	129.26	14.22	0.00	0.00	143.48	91.00	234.48
1991	0.00	97.17	35.48	0.00	0.00	132.65	129.94	262.59
1992	23.20	91.21	125.97	0.00	0.00	240.37	130.17	370.55
1993	29.79	17.13	28.37	0.00	0.00	75.29	43.68	118.97
1994	51.27	27.94	54.01	0.00	0.00	133.21	63.95	197.17
1995	44.06	55.81	34.80	36.66	0.00	171.33	176.06	347.40
1996	74.23	40.89	5.07	0.30	0.00	120.48	70.48	190.96
1997	95.90	39.29	103.78	2.00	0.00	240.97	158.46	399.43
1998	78.27	59.64	122.86	0.20	0.00	260.96	252.68	513.64
1999	45.12	15.87	40.15	3.23	0.00	104.36	101.97	206.34
2000	52.07	49.59	14.05	7.35	0.00	123.05	60.74	183.80
2001	166.75	49.54	29.41	27.90	0.00	273.59	268.68	542.27
2002	164.92	15.10	55.49	5.67	0.00	241.18	205.21	446.39
2003	81.31	33.33	62.29	0.00	0.00	176.92	110.68	287.60
2004	103.46	38.95	66.60	4.42	0.44	213.87	274.97	488.84
2005	118.63	88.64	73.20	14.46	0.00	294.93	154.38	449.31
2006	156.02	78.65	25.39	17.70	19.20	296.96	172.33	469.29
2007	70.61	35.54	27.52	3.02	1.04	137.73	55.78	193.51
2008	48.36	33.38	0.80	1.10	0.00	83.64	178.11	261.75
Totals	*$1,403.95*	*$1,003.86*	*$926.23*	*$124.00*	*$20.68*	***$3,478.72***	*$2,713.45*	***$6,192.18***

Source: World Bank, 2008a.

A substantial amount of Bank biodiversity funding has been dedicated to protected areas, but there is an increasing focus on improving natural resource management and on mainstreaming biodiversity conservation into forestry, coastal zone management, and agriculture. Beyond these "traditional" natural resource sectors, the Bank has successfully tested modalities for supporting protection and improved management of natural habitats through Bank-funded energy and infrastructure projects and development policy lending (DPL). The Bank is also currently developing innovative new climate investment funds, including funds that will target natural ecosystems, and especially forests, as carbon stores.

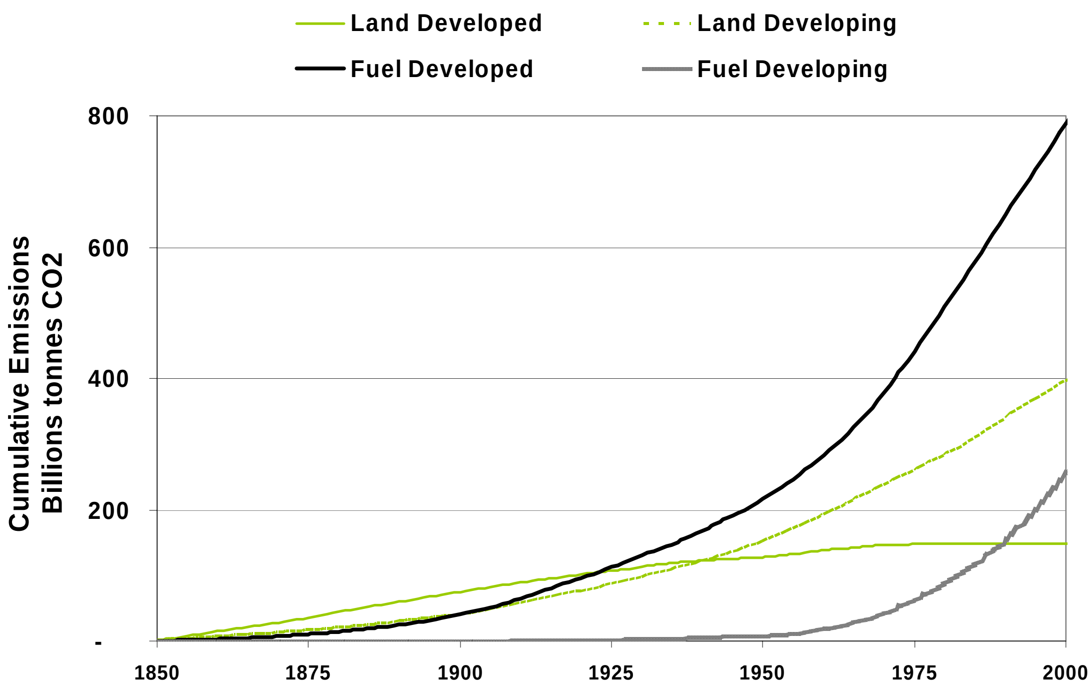
The global focus on climate change, and national needs to address likely impacts, provide a new imperative to protect the natural capital and ecosystem services upon which many communities depend. The Bank's access to lending resources and multiple financing instruments provides opportunities to promote ecosystem-based approaches to climate change within national agendas as a critical part of sustainable development. Such efforts would complement assistance to clients in developing adaptation strategies as well as ongoing dialogues on governance and improved natural resource management. The new multi-donor climate investment funds described in Chapter 5 provide exciting new opportunities to protect habitats and ecosystem services while addressing the climate change agenda.

This report attempts to set out a compelling argument for including ecosystem-based approaches as a third and essential pillar in national strategies to address climate change. Many of the case studies presented in boxes derive from lessons learned and best practice in Bank projects. Natural ecosystems can contribute to strategies to reduce greenhouse gas emissions and can complement infrastructure investments to reduce vulnerability to climate change. Chapter 2 examines the role of natural ecosystems as carbon stores and sinks. It also provides information and examples of how effective conservation action can contribute to low-technology, low-cost mitigation actions. Chapter 3 demonstrates how integrating protection of natural habitats and management of natural resources into adaptation plans can contribute to cost-effective strategies for reducing vulnerability to climate change. Chapter 4 emphasizes the links between ecosystem services and human livelihoods, agriculture and water. The final chapter provides an overview of available financing instruments to support ecosystem-based approaches to climate change, including climate investment funds and the larger carbon market.

Chapter 2. Natural Ecosystems and Mitigation

Climate change is already impacting natural systems, weather events, and life and livelihoods. The current level of greenhouse gases (GHG) in the atmosphere is equivalent to approximately 430 parts per million (ppm) CO_2 (CO_2 equivalent or CO_2e) which is almost double the amount before the Industrial Revolution (Stern, 2006). If emissions remain at current rates, by 2050 the GHG concentrations in the atmosphere will reach 550ppm and continue to increase thereafter – Figure 2.1. While emissions from fuel are the main culprits, land use change also contributes significantly to overall GHG levels.

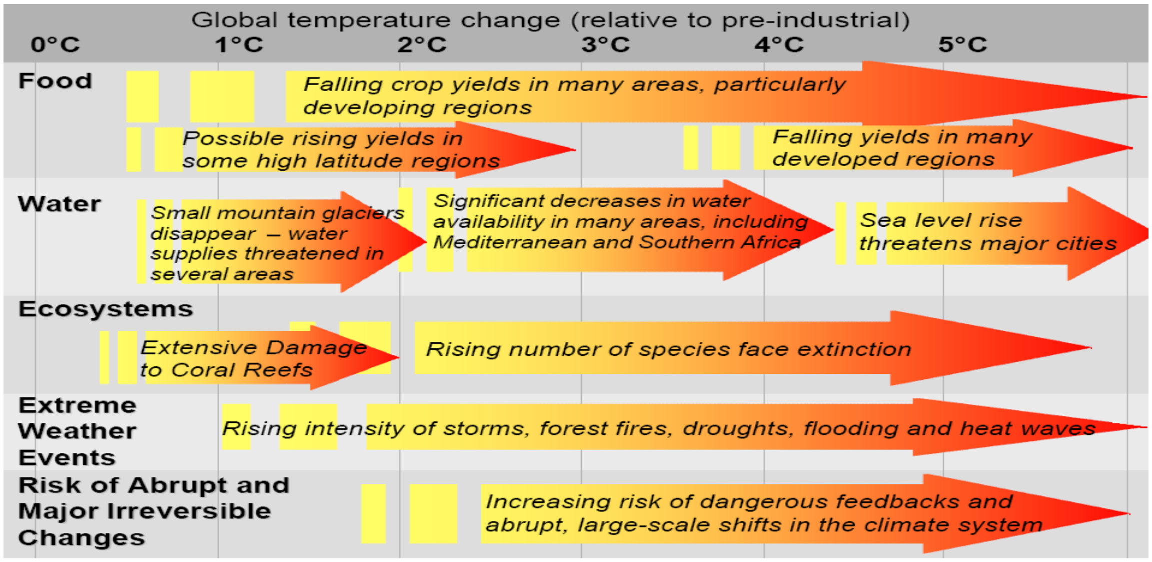
Figure 2.1. Historic GHG emissions.



Source: Carbon Dioxide Information Analysis Center (www.cdiac.ornl.gov).

It is highly likely that associated global average temperature rise with this GHG concentration would be above 2^0C. As shown in Figure 2.2, such changes in temperature would have adverse effects on food security, water availability, weather conditions, species diversity and would severely affect ecosystems like coral reefs. Therefore it is extremely important for countries to mitigate climate change and reduce GHG emissions to a level that the Earth's natural sinks can balance. According to the IPCC Fourth Assessment Report (2007) low to medium stabilization levels (450-550 ppm CO_2e) would prevent drastic harm to ecosystems and human livelihoods, but would only be achievable through concerted global efforts. Immediate implementation of mitigation measures is, therefore, essential to meet these emission goals. Biodiversity and natural ecosystems with their vast capacity to store carbon and regulate the carbon cycle can play a key role in such mitigation efforts.

Figure 2.2. Likely changes to Earth systems depending on mitigation activities undertaken.



Source: Stern, 2006.

Mitigation involves reducing greenhouse gas emissions from energy-related or land use changes, and enhancing natural GHG sinks. Biological mitigation of greenhouse gases can occur through (a) sequestration by increasing the size of carbon pools (e.g. through afforestation, reforestation and restoration of other natural habitats) b) maintaining existing carbon stores (for example, avoiding deforestation or protecting wetlands); (c) maintenance of healthy coral reefs and the ocean carbon sink; and, (d) substitution of fossil fuel energy by cleaner technologies which rely on biomass. The global potential of biological mitigation options through afforestation, reforestation, avoided deforestation, and agriculture, grazing land, and forest management is estimated at 100 GtC by the year 2050, which is equivalent to about 10–20 percent of projected fossil-fuel emissions during that period.

Afforestation and Reforestation

Under current guidance from the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol's Clean Development Mechanism (CDM), protection of standing forests and other natural habitats is not eligible for carbon credits. Instead most habitat-related mitigation activities focus on increased sequestration of carbon through afforestation and reforestation projects. The Bank is involved in a number of afforestation and reforestation efforts throughout the world – Box 2.1.

Box 2.1. Reforestation under the BioCarbon Fund

Brazil: Reforestation around Hydro Reservoirs
Natural will be restored on approximately 5,576 ha of land around four reservoirs created by hydroelectric plants in the state of Sao Paulo. Planting a mix of at least 80 native species will regenerate forested areas, protect the recreational use of the area, and improve the value of the lands for tourism. Many of the targeted sites are connected to existing forested areas, and link to riverine habitats. Restoration of forest is expected to sequester 0.67 Mt CO_2e by 2012

and 1.66 Mt CO_2e by 2017 along with increasing critical habitats and creating vital wildlife corridors, connecting the newly forested lands with existing conservation areas.

China: Pearl River Watershed Management
This project is reforesting 4,000 ha in the Guangxi Zhuang Autonomous Region, which includes half of the Pearl River basin and is an area of high biodiversity value. The sites selected for planting are shrub land, grassland, and areas with less than 30 percent tree cover. Seventy-five percent of the species planted will be native. Eucalyptus, grown in China for a century, will make up most of the exotics. The restoration of the forests along the middle and upper reaches of the Pearl River will serve as a demonstration model for watershed management. The use of the carbon sequestered by a plantation as a cash crop will generate income for local communities. As the first life-size land use, land use change and forestry (LULUCF) project in China, it will also test how afforestation activities can generate high-quality emission reductions in greenhouse gases that can be measured, monitored, and certified. The reforested land is expected to sequester around 0.34 Mt CO_2e by 2012 and around 0.46 Mt CO_2e by 2017, along with restoring forest connectivity between two nature reserves (Mulun and Jiuwandashan reserves in Huanjiang County) to provide a wildlife corridor for animal movements.

Kenya: Green Belt Movement
This project is reforesting 4,000 ha of degraded public and private lands with high community access in the Aberdare Range and Mount Kenya watersheds. These forests host a high number of threatened fauna species and are internationally recognized as an Important Bird Area (IBA). Although many of these forests are officially protected as a reserve, they are threatened by illegal logging and cultivation. The project will pay local communities and provide them with the technology and knowledge to reforest and manage these lands. Replanting on denuded steep slopes will reduce the erosion process, protect water sources, and regulate water flows. Communities will be organized into Community Forest Associations (CFAs) who will develop management plans. The long term goal is to use the re-grown forest in a sustainable manner for a variety of products, including fuel wood, charcoal, timber, medicinal, among other uses. Planting of trees on lands around the reserve forests is expected to reduce pressure on remaining natural forests, while the planting of native species will enrich local biodiversity and protect ecosystem services. The project is expected to sequester around 0.1 Mt CO_2e by 2012 and 0.38 Mt CO_2e by 2017.

These projects promote carbon sequestration but are often linked to maintenance of other ecosystem services and local benefits, such as watershed protection or provision of fuel wood and fodder. Similarly, the World Bank, through the BioCarbon fund, is financing reforestation of over 23,000 ha of *Acacia senegalensis*, a species native to the whole African Sahel, on communal degraded land throughout Mali and Niger. Plantation of this robust native species will restore habitat for native insects, animals and birds and is projected to sequester approximately 0.3 Mt CO_2e by 2017 and 0.8 Mt CO_2e by 2035 in Mali, and 0.24 Mt CO_2e by 2012 and around 0.82 Mt CO_2e by 2017 in Niger. The project will greatly aid the local communities by creating jobs and increasing their incomes through sales of high quality Arabic gum – Box 2.2.

Box 2.2. Building Resilience by promoting Native Vegetation in Mali

For the past 30 years the Nara area of Northern Mali has suffered decreases in rainfall and water levels, land degradation, loss of forest canopy and change in plant species composition. Tree cutting for firewood, charcoal and shifting agriculture has been a leading cause of deforestation in the area. The loss of natural vegetation reduced resilience of the arid zone ecosystems to recurrent droughts. As a consequence of land degradation, the Nara people are facing famine, poverty, and migration. In an already drought-afflicted region, additional climatic stresses are going to be detrimental to food security and development.

Improved management of natural resources and indigenous vegetation can help to build resilience against climate change and contribute to more sustainable livestock husbandry and farming. The BioCarbon Fund is providing funding for reforesting around 6,000 ha of *Acacia senegalensis*, a species endemic to the whole African Sahel. It is superbly adapted to harsh ecological conditions and produces several environmental benefits. Besides producing gum, it enables the rehabilitation of degraded areas that have become unfit for agriculture. *Acacia's* powerful root system makes it efficient for dune-fixing as well as wind and water erosion control. Its nitrogen-fixing ability improves soil fertility. Local organizations and farmers in the Nara region will develop and manage cost-effective modern nurseries, plant trees, maintain plantations, and harvest Arabic gum. The project will also diversify agricultural activities through intercropping with groundnuts and cowpeas. By restoring healthy populations of *Acacia senegalensis* the project will also benefit local biodiversity and provide more fodder for local cattle.

The project is expected to sequester around 0.3 Mt CO_2e by 2017 and 0.8 Mt CO_2e by 2035. Overall the project is expected to create about 1,700 jobs for plantation management and the production, transport, and selling of Arabic gum. In addition, the management of the nurseries will create another 200 jobs. Some 10,000 farming families are expected to benefit from the project with their own *Acacia* plantations (approximately one hectare per participant). Hundreds of farming families are expected to receive social benefits through additional revenues generated by Arabic gum, grains and forage, combined with payments from Credit Emission Reductions (CERs).

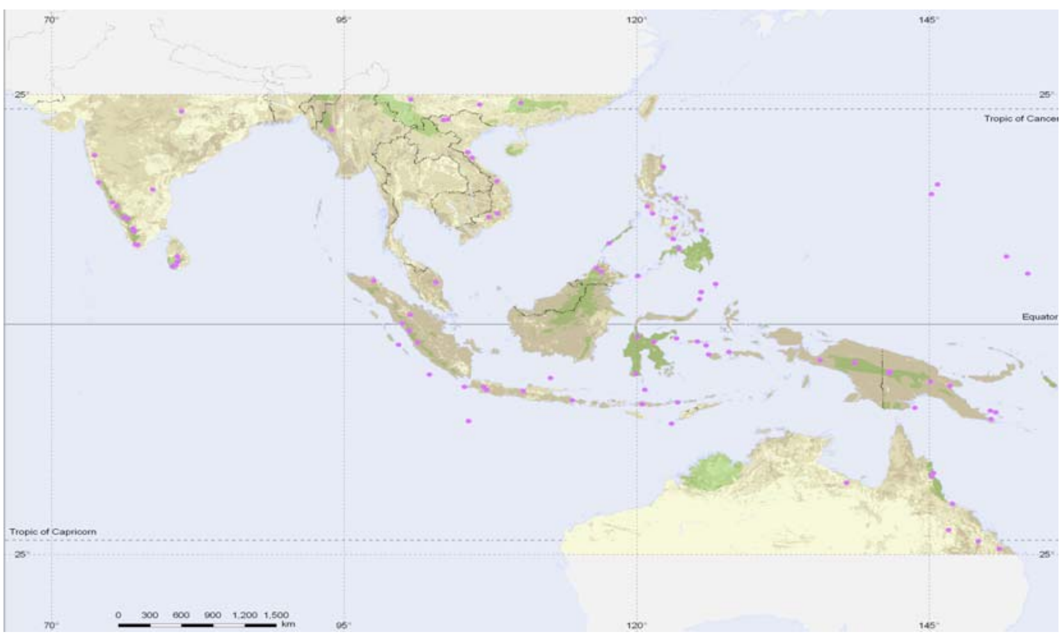
Afforestation and reforestation projects will impact biodiversity and ecosystem services depending on the land use and ecosystem being replaced and management applied. The reforestation of degraded lands has the potential to produce the greatest benefits for biodiversity, especially with careful species and site selection, planting of native species and efforts to accommodate the range of needs of native wildlife. Plantations or natural reforestation may contribute to the dispersal capabilities of wildlife by extending areas of forest habitat or providing connectivity between habitat patches in a formerly fragmented landscape. Even single-species plantations may provide some biodiversity benefits if they incorporate features such as retaining borders of native forest along river banks or protecting natural wetlands. In contrast, planting with fast-growing exotic species, or species with known potential to become invasive, is likely to provide few biodiversity gains, but may provide other short-term benefits by reducing soil erosion or providing a ready source of fuel wood and timber.

Plantations of native tree species will support more biodiversity than exotic species. Plantations of mixed tree species will usually support more biodiversity than monocultures, especially if designed to allow for the colonization and establishment of diverse understory plant communities. Since loss of soil carbon occurs for several years following harvesting and replanting—due to the exposure of soil, increased leaching and runoff, and reduced inputs from litter—long-rotation plantations in which vegetation and soil carbon is allowed to accumulate are more beneficial than short-rotation plantations. Short-rotation forests, with their simpler structure, foster lower species richness than longer-lived forests, but products from short-rotation plantations may alleviate harvesting pressure on primary forests.

Securing Carbon Stores through Protection and Restoration of Natural Ecosystems

A comparison of the world's biologically important areas with the map of global carbon distribution shows that many areas of remaining terrestrial habitats and high biodiversity value overlap areas with large carbon reservoirs. Figure 2.3 illustrates this overlap of biologically-rich areas with carbon stores for Southeast Asia. In such areas, establishment of protected areas or strengthened management can be expected to simultaneously contribute to the protection of existing carbon reservoirs.

Figure 2.3. Areas of high biodiversity (in green) correlate with high carbon sinks (in purple) in Southeast Asia



Source: UNEP/WCMC, 2008.

Forests

Forests cover about 30 percent of the world's land area, but they store about 50 percent of the Earth's terrestrial carbon (1,150 GtC) in plant biomass, litter and debris, or in the soil (IPCC, 2000). The relative sizes of these carbon pools depend on the forest types and the ecoregions in which they occur (Table 2.1). Land use changes including expansion of human settlements, conversion to agricultural land, and unsustainable logging practices are major threats to these forests, resulting both in habitat loss and fragmentation. At the current rate of deforestation, about 13 million ha/yr (FAO, 2005), the world's forests are severely threatened. As these forests are lost so too are the ecosystem services that they provide, including their role as carbon stores and sinks.

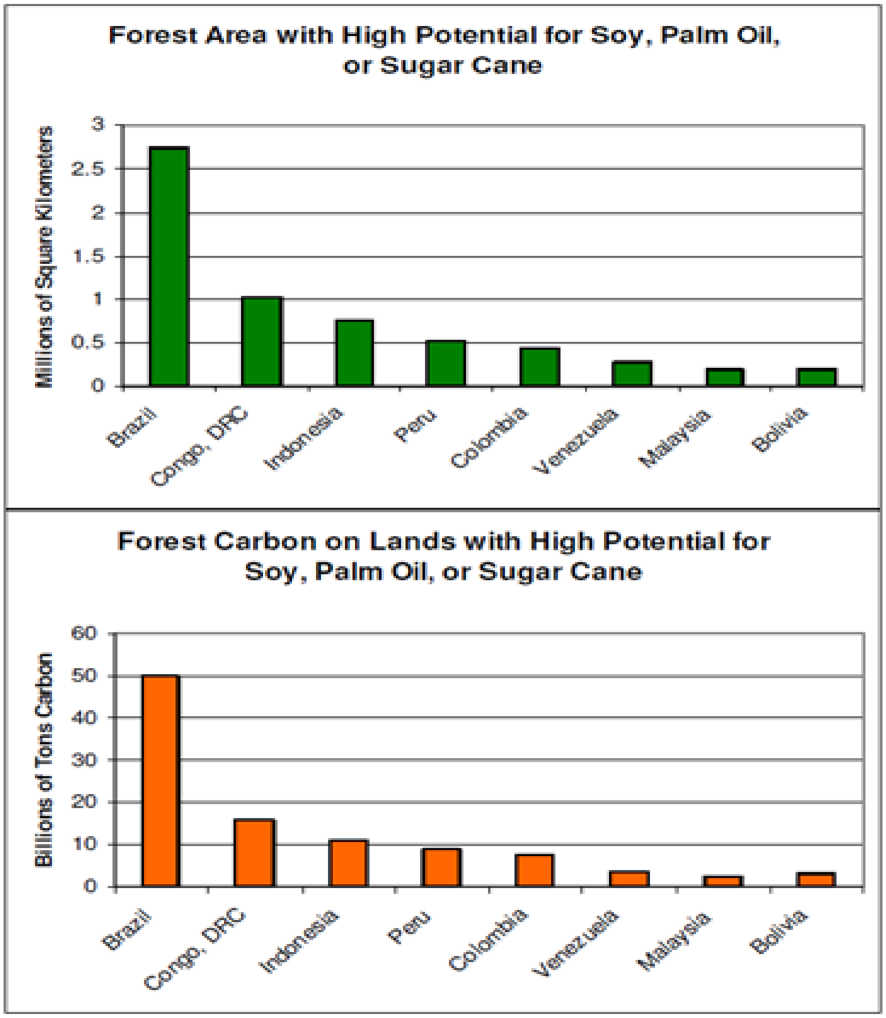
Table 2.1. Carbon Stocks in Forest Ecosystems

Biome		Carbon Stocks (GtC)			
	Area (10^6 km^2)	*Vegetation*	*Soil*	*Total*	*Relative* ($GtC/10^6$ km^2)
Tropical Forests	17.6	212	216	428	24
Temperate Forests	10.4	59	100	159	15
Boreal Forests	13.7	88	471	559	41
Tropical Savannas	22.5	66	264	330	15
Temp. Grasslands	12.5	9	295	304	24
Deserts/Semi-deserts	45.5	8	191	199	4
Tundra	9.5	6	121	127	13
Wetlands	3.5	15	225	240	69
Croplands	16.0	3	128	131	8
TOTAL	**151.2**	**466**	**2011**	**2477**	**16**

Source: IPCC, 2000

About 20 percent of the world's GHG emissions are caused by deforestation and land use changes globally. The problem is especially acute in the tropics, which include some of the world's most biologically-rich countries. In tropical regions, emissions attributable to deforestation and other land clearance are much higher, up to 40 percent of national totals. Indonesia and Brazil together, for instance, currently account for approximately 54 percent of all emissions from forest loss (Baumert et al., 2006). As shown in Figure 2.4, some forests with high potential for cash crops also have significant carbon reserves, making these forests and carbon reserves highly vulnerable to deforestation activities. Thus most of Indonesia's GHG emissions come from deforestation and land clearance, including clearing and burning of peat swamp forests for agricultural production and oil palm production. If current rates of deforestation in Indonesia remain the same through 2012, it is estimated that emissions from this deforestation would equal almost 40 percent of the annual emission reduction targets set for Annex 1 countries under the Kyoto Protocol (Santili et al., 2005). Clearly reducing deforestation and forest degradation in key biodiversity countries affords exciting new opportunities to address climate change, conservation and development.

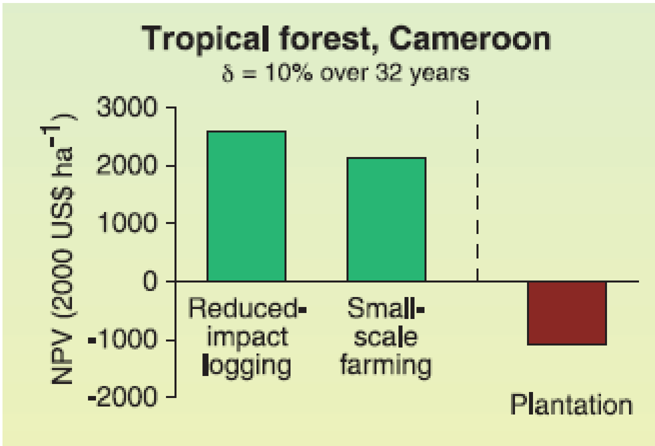
Figure 2.4. Forest area and forest carbon stocks on lands suitable for major drivers of tropical deforestation



Source: Page et al., 2002.

Key strategies for conserving forests include establishment and strengthened management of protected forests and more sustainable forest management (SFM). It has been estimated, for example, that improvements in SFM could store an extra 170 MtC/year by 2010, or about 3 percent of total global CO_2 emissions (IPCC, 2000). Many Bank projects with a focus on improved forest management and protected areas are already contributing to maintaining carbon stores in these forests. Russia, for example, contains about 22 percent of the world's forests, including 25 percent of all old-growth forests. These 770 million hectares of forests make up the largest share of temperate and boreal forests among Bank client countries and harbor important endangered and endemic biodiversity as well as protecting permafrost areas which are important carbon stores. Because of Russia's large size and forest cover, there is a compelling need to balance economic development in the forest sector with sustainable forest management. Improving forest and fire management in the Russian Far East is retaining important carbon stores in the boreal forests and underlying peatlands while also protecting the region's rich biodiversity, including tigers, in Khabarovsk Kray.

Box 2.3. Economic Argument for Sustainable Forest Management



A study from Mount Cameroon, Cameroon, comparing low-impact logging with more extreme land-use change found that private benefits favor forest conversion to small-scale agriculture. Conversion to oil palm and rubber plantations, however, yielded negative private benefits once the effect of market distortions was removed. Social benefits from non-timber forest products (NTFPs), sedimentation control, and flood prevention were highest under sustainable forestry, as were global benefits from carbon storage and a range of option, bequest, and existence values. Overall, the total economic value (TEV) of sustainable forestry was 18 percent greater than that of small-scale farming ($2570 compared with $2110 ha).

Source: Balmford et al., 2002.

Reducing deforestation and degradation (REDD) is the forest mitigation option with the largest potential for maintaining carbon stocks in standing forests over the short term. The 13th Conference of the parties to the UN Convention on Climate Change in Bali in December 2007 called for greater action on avoided deforestation to provide new opportunities for rewarding nations and communities for improved forest protection and management. The ongoing discussion regarding the inclusion of existing forests into international climate mitigation frameworks represents a significant opportunity for both climate and conservation efforts. Acceptance of REDD as a viable international emissions abatement mechanism could offer a new platform and financing mechanism for protecting biodiversity, ecosystem services and forest livelihoods.

The Bank is currently developing and testing new financing mechanisms to pilot modalities for REDD. The Ankeniheny-Mantadia-Zahamena Corridor Restoration and Conservation Carbon Project is an innovative initiative to conserve and restore the threatened humid forests of Madagascar. The project is promoting natural regeneration and ecological restoration of around 3,020 hectares on degraded land along the buffer zone of two national parks: the Analamazaotra Special Reserve and Mantadia National Park complex. Through the creation of a sustainable use protected area, the project aims to protect an area of 425,000 ha, reducing GHG emissions from deforestation and forest degradation. The reforestation component of the project is expected to sequester around 0.12 Mt CO_2e by 2012 and around 0.35 Mt CO_2e by

2017 (Kyoto compliant), while the avoided deforestation component could generate as much as 4 Mt CO_2e by 2017 (non-Kyoto compliant). Funds from the sale of carbon credits on the voluntary market are being used to finance sustainable livelihood activities in the region, including fruit tree orchards and fuel wood plantations that will increase farmers' income and reduce pressure on native forests.

Box 2.4. Carbon and Conservation in the Forests of Indonesia

In December 2004 a tsunami struck Aceh province, causing a large-scale humanitarian crisis, especially along the west coast. In this narrow coastal belt, communities and agricultural lands border directly on protected forests and the karst mountain ranges of the Gunung Leuser National Park and Ecosystem in the south and the Ulu Masen Forest Complex in the north. Over two-thirds of the province remains under forests. Even within Indonesia, a mega-diversity country, this area is unique, comprising the largest remaining contiguous forested area (3.3 million ha) with the richest assemblage of wildlife in Southeast Asia, including tigers, elephants, rhinos, and orangutans. These areas also provide valuable ecosystem services needed for Aceh's recovery, including water supply, flood prevention, erosion mitigation, and climate regulation.

The post-disaster reconstruction effort raised concerns about how the enormous amount of timber needed for rebuilding could be obtained without endangering these forests. In August 2005, a long-awaited peace accord between the Indonesian government and the Free Aceh Movement effectively removed the barrier to widespread logging activities. Two environmental NGOs, Leuser International Foundation and Flora and Fauna International (FFI), both with a long history of working in Aceh, prepared a proposal to the Multi Donor Fund (MDF) for the Aceh Forest and Environment Project (AFEP) to ensure the protection of Aceh's forests.

The main objectives of AFEP are to (a) protect the environmental services provided by Aceh's coastal and terrestrial forest ecosystems during, and beyond, the reconstruction, and (b) mainstream environmental concerns in the reconstruction process. AFEP produces accurate and timely information on the state of the province's forests, and is building the capacity of the provincial forest and conservation administration. It is helping to develop a model for community-based sustainable forest management, and fostering integration of forest and conservation issues into the overall land-use planning process through development of provincial, district, and sub-district-level spatial plans. Forest monitoring is carried out at three mutually supportive levels: through remote sensing, aerial surveys, and ground-level community monitoring teams. Aceh's Governor Irwandi declared a logging moratorium to provide a time-out, during which new policies and programs can be formulated and implemented. The project's flexible approach to post-disaster, post-conflict reconstruction has benefited from local participation, including collaboration with religious leaders to include environmental and conservation messages into mosque sermons.

The project is also assisting the government of Aceh in developing and promoting REDD assistance for Aceh. A REDD pilot project plan for Ulu Masen achieved the Climate, Community and Biodiversity (CCB) Standards certification in February 2008. The project is expected to prevent 100 million tonnes of GHG emissions over the next 30 years, by reducing deforestation in Ulu Masen forest by a staggering 85 percent. The expected 3.3 million carbon credits generated annually will help to finance forest conservation as well as development projects for local villagers, who are some of Indonesia's poorest communities.

Wetlands

Natural ecosystems are not all equal in their values for biodiversity conservation nor in their roles in carbon storage and providing other ecosystem services. Various types of wetlands – including swamp forests, mangroves, peat lands, mires and marshes – are important carbon sinks and stores. Depending on hydrology and vegetation type, both above and below ground carbon storage can be very significant in these ecosystems. Anaerobic conditions in inundated wetland soils that slow decomposition rates contribute to long term soil carbon storage and formation of carbon rich peats. Such slow decomposition processes over thousands of years form peat lands that can extend more up to 20 m in depth, and represents some 25 percent of the world soil carbon pool, an estimated 550Gt carbon (Parish et al., 2008). Peat lands act as carbon sinks sequestering an estimated 0.3 tC/ha/yr, even after accounting for methane emissions (Pena, 2009). Moreover, all peatlands, including those in the boreal zones and Arctic, are refugia for some of the world's rarest species of wetland-dependent flora and fauna.

In recent decades, drainage and conversion for agriculture has led to massive loss of wetland habitats and changed peat lands from a global carbon sink to an emerging source of carbon. Changes in hydrology and a reduction in soil saturation level exposes the peat soil to air causing the peat to collapse and the soil carbon to oxidize to carbon dioxide. It is estimated that 3 billion tons of CO_2 annually, about 10 percent of all reported emissions, is due to this degradation (Parish et. al, 2008). Two thirds of these emissions are concentrated in Southeast Asia where clearance of swamp forests to expand oil palm plantations and agriculture threaten these unique habitats. Ironically, these swamp forests are being cleared in Indonesia to expand oil palm production for biofuels.

Working against this trend, Wetlands International has been collaborating with the provincial government and the Indonesian Department of Conservation (PHKA) to establish a new national park in South Sumatra. The Sembilang Park and adjacent Berbak National Park, Indonesia's first Ramsar site, together protect some of Sumatra's most important remaining lowland forests, including large tracts of peat swamp forests and the most important mangroves in western Indonesia. These areas are important carbon sinks but also provide protection for large mammals (tiger, Sumatran rhino, and tapir), migratory birds, and breeding populations of rare storks. The extensive coastal mangrove swamps also provide critical spawning and nursery grounds for inshore fisheries, an important source of local livelihoods. Thus the conservation efforts, supported through a GEF project, are contributing to conservation and social benefits as well as protecting a major carbon store.

Coastal wetlands, including mangroves, serve as carbon stores and sinks. It has been estimated that mangroves store as much as 45 tC/ha (Bouillon et al., 2008) and sequester another 1.5 tC/ha/yr (Ong, 1993). These amounts are probably a gross underestimation due to the lack of information about fine root activities. This amount of carbon sequestration is comparable with other tropical forests. In addition to carbon sequestration, coastal wetlands also provide a wide range of other ecosystem services, including coastal defense, protection against extreme weather events, trapping sediment and providing nutrients and nurseries for coastal fisheries. A study on the Mesoamerican reef, for example, showed that there are as many as 25 times more fish on reefs close to mangrove areas than in areas where mangroves have been cut down. High population pressure in coastal areas has, however, led to the conversion of many mangrove areas to other uses, including infrastructure, aquaculture, rice and salt production. Almost

225,000 metric tons of carbon sequestration potential is lost each year because of the current rates of mangrove destruction. In addition to their lost value as a carbon sink, disturbed mangrove soils release more than 11 million metric tons of carbon annually.

Box 2.5. Trinidad and Tobago: Nariva Wetland Restoration and Carbon Offsets

The Nariva Protected Area (7,000 ha) is one of the most important protected areas in Trinidad and Tobago, and is also a Ramsar site. Its varied mosaic of vegetation communities includes tropical rain forest, palm forests, mangroves, and grass savannahs. However, these ecosystems have been threatened by hydrological changes arising from a newly constructed water reservoir upstream and more than 10 years (1985–96) of illegal forest clearing by rice farmers**.**

A Bank project to restore the Nariva wetlands provides a unique opportunity to combine the goals of greenhouse gas mitigation with adaptation needs. The project will support carbon sequestration through the reforestation and restoration of the natural drainage regime of the Nariva wetlands ecosystem. Restoration of the wetlands will strengthen their natural buffer service for inland areas, representing an adaptation measure to anticipated increases in weather variability.

Afforestation and reforestation activities over 1200 ha of the wetlands is expected to generate carbon credits for approximately 193,000 t CO_2e up to the year 2017, which will be purchased by the BioCarbon Fund. This investment will in turn fund the restoration work, including::

- Restoration of natural hydrology to accelerate the restoration of Nariva's ecological functions, including active management of the landscape to ensure the survival of the existing forest as well as reforested areas.
- Between 1,000 and 1,500 hectares are being reforested with native terrestrial and aquatic species. Mechanical and chemical treatment of invasive species may be required to open areas for more natural plant communities.
- A fire management program will protect the newly restored vegetation.
- A monitoring plan will record the response of reforestation activities and monitor biodiversity, including key species.

Grasslands

Grasslands, including savannahs, occur on every continent except Antarctica, and constitute about 34 percent of the global terrestrial carbon stock, most of which is stored in their soil systems. Changes in grassland vegetation due to overgrazing, conversion to crop land, desertification, fire, fragmentation, and introduction of non-native species affect their carbon storage capacity, and may in some cases, even lead to them becoming a net source of CO_2. For example, it has been found that grasslands may lose 20 to 50 percent of their soil organic carbon content through cultivation, soil erosion, and land degradation. Moreover, burning of biomass, especially in tropical savannas, contributes over 40 percent of gross global carbon dioxide emissions (Matthews et al., 2000).

This loss of carbon storing capacity in grasslands is accompanied by the loss of grassland dependent- birds and herbivore species, leading to biodiversity loss. Approximately 23 of 217 Endemic Bird Areas (EBAs) name grassland as the key habitat type. In the US, population trend data over a nearly 30-year period showed a constant decrease in the numbers of grassland dependent species. Similarly, within the protected Serengeti ecosystem, studies show that the population of African herbivores has stabilized but areas outside the protected area boundaries have experienced decreases in herbivore densities as increasing pressure and land conversion have led to loss and degradation of grassland habitats.

Improved management of production grasslands (for example, grazing management, protected grasslands and set-aside areas, grassland productivity improvements, and fire management) can enhance carbon storage in soils and vegetation while enhancing other ecosystem services – see Box 2.6. Silvopastoral projects in Central America have also demonstrated the economic and ecological benefits of increasing tree cover in cattle pastures. Such agroforestry systems have the potential to sequester carbon, improve livelihoods, and provide functional links between forest fragments and other critical habitat as part of a broad landscape management strategy for biodiversity conservation.

Box 2.6. Safeguarding Grasslands to Capture Carbon: Lessons from China

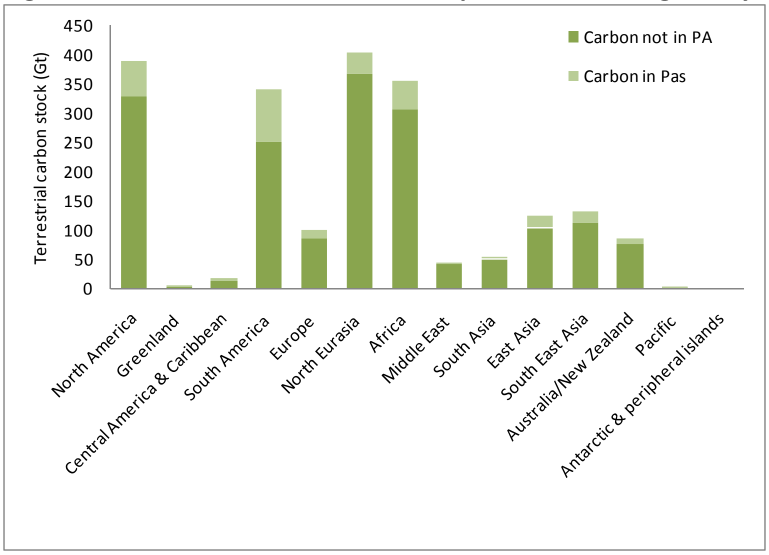
The vast area and wide distribution of China's grasslands suggests that they could have widespread effects on regional climate and global carbon cycles. The Gansu and Xinjiang Pastoral Development project focuses on producing global environmental benefits by restoring biodiversity and increasing the productivity of grassland resources in the globally significant ecoregions of Tien Shan, Altai Shan, and Qilian Shan. These benefits will result from implementation of participatory grassland management plans, especially changed grassland utilization through delaying and shortening the spring and summer grazing periods in the high mountain grasslands. Reduced grazing pressures will lead to increased species diversity, increased biomass productivity, and improved grazing conditions for wild ungulates, as well as herds of sheep and other livestock managed by local herders.

Reduced grazing pressure resulting from implementation of participatory grassland management plans provides significant carbon benefits. Improved pasture management practices increase the amount of carbon entering the soil as plant residues, suppress the rate of soil carbon decomposition, and reduce soil loss due to overgrazing. The project is also promoting more intensive management of lowland pastures, with inputs of inorganic and organic fertilizers, as well as production of livestock foodstuffs to reduce pressure on mountain pastures. Improved grazing management practices, such as rotational grazing, include community-based regulation of grazing intensity and frequency. The economic benefits of carbon sequestration were estimated using the shadow price of CO_2 damages at $20 per ton of CO_2 per year (discounted at a 12 percent interest rate over the 20-year period), which is equivalent to $5.50 per ton of carbon. It was estimated that adoption of better management practices on the pastures would elicit a carbon gain of about 3 to 15 tons of carbon per year, depending on the degree of pasture degradation. Over a 3-30 year period, carbon benefits from reduced grazing and improved management are expected to increase up to 50 tC/ha.

Protected Areas: A Convenient Solution to Protect Carbon Sinks and Ecosystem Services

Protected areas are the cornerstones of biodiversity conservation and a valuable buffer against the impacts of climate change. They are also a promising tool for reducing emissions from habitat degradation and deforestation as they generally have well-defined boundaries and incorporate legal restrictions on land use change. Many protected areas overlay areas of high carbon stocks. It has been estimated that globally ecosystems within protected areas store over 312 GtC or 15 percent of the terrestrial carbon stock (Campbell et al., 2008), but the degree to which carbon stocks are protected varies among regions, as shown in Figure 2.5.

Figure 2.5. Extent of carbon stored in protected areas globally.



Source: Campbell et al., 2008

Designation of protected areas alone does not guarantee protection of the natural ecosystems within their boundaries. Although many studies show that deforestation is often less within protected areas compared to unprotected areas outside, many protected areas have weak or no effective management and suffer from encroachment. Between 2000 and 2005, over 1.7 million ha were cleared within protected areas in the humid tropics alone, i.e. 0.81 percent of forest cover was lost (UNEP-WCMC, 2008). Globally, more strictly protected areas (IUCN management categories I and II) in humid tropical forests showed lower forest loss (0.53 percent) than the protected area network overall. Based on these deforestation estimates, UNEP-WCMC calculated that forest loss in protected areas contributed as much as 990 Mt CO_2e in carbon emissions between 2000 and 2005, or around 3 percent of total emissions from tropical deforestation. The real emissions levels depend on the use to which the deforested areas are put, for example arable crops, pasture, and oil palm. The estimated total carbon loss from deforestation within protected areas during 2000-2005 was especially high in the Neotropics because of the high carbon content and high rate of deforestation in the Brazilian Amazon's arc of deforestation.

Clearly protected areas can play an important role in maintaining carbon stores as well as biodiversity, especially if they are well protected and effectively managed, A major share of Bank and GEF biodiversity funding has gone to creation of sustainable protected area networks, including establishment of new parks and support to strengthen existing protected areas, including promotion of innovative models of management and new financing. Projects include conservation planning and establishment of new protected areas and biological corridors (for example, in Georgia, Ghana, Central America, and Brazil); improved management of "paper parks" and existing protected areas (India, Pakistan, Madagascar, Uganda, Bolivia, Ecuador, and Russia); control of invasive exotic plants (Mauritius, Seychelles, and South Africa); protection and restoration of wetlands and other native habitats (Bulgaria, Croatia, and Indonesia); promoting community management of terrestrial and marine protected areas, indigenous reserves, sacred groves, and clan conservation areas (Colombia, Ecuador, Ghana, Indonesia, Peru, Papua New Guinea, and Samoa); and, promoting mechanisms to ensure sustainable finance for protected areas and conservation (Bhutan, Madagascar, Tanzania, and Peru). Large areas of natural habitat are being conserved through transboundary projects in regions such as Central Asia and MesoAmerica, as well as by planning and establishing new protected areas within a mosaic of other improved management systems in the extensive forest wilderness areas of Brazil and Russia.

The Bank's role in supporting biodiversity conservation and protected areas in biologically-rich countries could be further optimized by targeting additional carbon funds to prioritized areas that have both high biodiversity and high carbon stocks – Box 2.7. In Vietnam, for instance 58 percent of the high biodiversity areas overlap with areas of high carbon stocks but protected areas cover only about 30 percent of these high biodiversity areas. Similarly in Papua New Guinea, only 17 percent of the areas that are high in biodiversity and carbon are within protected areas (UNEP-WCMC, 2008). New conservation strategies focusing on ecosystem services as well as biodiversity could focus additional attention and resources to areas where protection would lead to both biodiversity and carbon sequestration benefits.

Box 2.7. Amazon Region Protected Areas Program (ARPA): A Storehouse for Carbon and Biodiversity

The ARPA program is an initiative of the Brazilian government to support biodiversity conservation in the Brazilian Amazon, one of the world's largest remaining wilderness areas and an important carbon store. Under the ARPA program, Brazil has created 22.28 million ha of protected areas in the Amazon since 2000, surpassing its first phase target of 18 million ha. With government support and additional grant funding form GEF, KfW and WWF, ARPA has also strengthened the management of an additional 8.65 million hectares of existing protected areas. With these 30.93 million hectares of biodiversity -rich forests—a mosaic of state, provincial, private, and indigenous reserves—ARPA is the biggest protected area program globally. Plans for the future are even more ambitious—to create a system of well-managed parks and other protected areas, including extractive and indigenous reserves, that together encompass some 500,000 km^2, an area surpassing in size the entire U.S. National Park system.

ARPA was established to protect the rich biodiversity of the Amazonian Basin, but the mosaic of protected areas contributes to both Brazilian and global efforts to fight climate change through avoided deforestation. The carbon stock in ARPA reserves is estimated at 4.5 billion tons of carbon, with potential reductions in emissions estimated at 1.8 billion tons of carbon. This role is recognized in the 2006 Stern Review on the Economics of Climate Change.

The ARPA program has tested and demonstrated the value of public-private partnerships and different institutional models, both in implementation of the overall program and management arrangements at individual forest sites. The program funding is disbursed through an NGO (the Brazilian Biodiversity Fund, or FUNBIO), which allows greater flexibility and innovation to improve operational effectiveness and creation of accounts that are co-managed by protected area managers in the field for small-scale service payments and purchases. A new trust fund to finance the recurrent costs to manage these areas has been created and capitalized up to $20 million.

The innovative design of ARPA has mainstreamed biodiversity conservation into land use planning and management under the Amazon's state governments and is now being replicated elsewhere. Many states are leveraging additional funds to support newly-created federal and state areas. In addition, ARPA has been able to engage the private sector of Brazil and European donors to provide large funds to support protected areas. The project has worked with WWF and many other NGOs through a collaborative and global effort to protect Amazon biodiversity. Innovative institutional arrangements are now being scaled up and replicated in other large-scale projects and programs. In late 2007, FUNBIO agreed with the state of Rio de Janeiro to develop a state environmental compensation fund and set up a program to support the state's protected areas based on the ARPA experience.

Coastal and Marine Systems as Carbon Reservoirs

Oceans are substantial reservoirs of carbon, with approximately 50 times more carbon than presently in the atmosphere (Falkowski et al. 2000). They are efficient in taking up atmospheric carbon, through plankton photosynthesis, mixing of atmospheric CO_2 with sea water, formation of carbonates and bicarbonate$_s$, conversion of inorganic carbon to particulate organic matter and by burial of carbon rich particles in the deep sea. All these processes are extremely important for maintenance of marine life at all tropic levels.

The current trend of increasing global atmospheric temperatures and increasing sea water acidity reduces the overall capacity of oceans to absorb more CO_2. If allowed to continue unabated, this could potentially change pH in the deep sea region as well which would hinder the processes associated with carbon particulate burial, a critical process in maintenance of a healthy atmospheric carbon dioxide concentration. Similarly complex interrelationships between water temperatures and ocean acidity in marine systems erodes calcification rates in shell-bearing organisms and threaten the survival of coral reefs. Coral reefs cover less than 1 percent of the Earth's surface but are home to 25 percent of all marine biodiversity. By the end of the century, current levels of carbon dioxide emissions could result in the lowest levels of ocean pH in 20 million years which would have severe adverse effects on ocean water chemistry (both coastal and deep sea), the marine life and food webs, and the function of oceans as a carbon reservoir.

Box 2.8. Crucial Role of Oceans in Climate Change

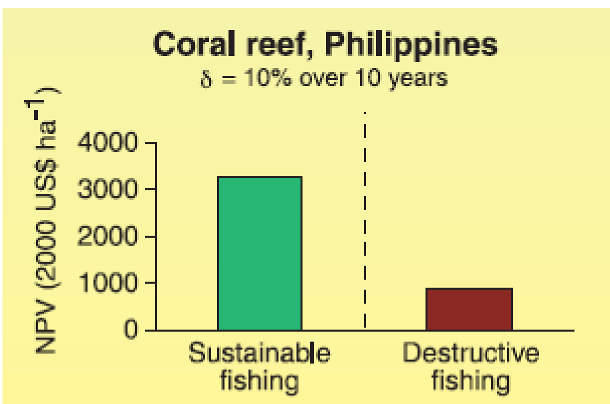
- Oceans are the earth's main buffer to climate change and will likely bear the greatest burden of impacts.
- Oceans removed about 25 percent of carbon dioxide emitted by human activities from 2000-2007.
- Oceans absorb more than 95 percent of the sun's radiation, making air temperatures tolerable for life on land.
- Oceans provide 85 percent of the water vapor in the atmosphere, these clouds are key to regulating climate on land and sea.

- Ocean health influences the capacity of oceans to absorb carbon.

Coral reefs may act as a net source of atmospheric CO_2, due to the production of CO_2 during calcification. However, the fate of the free CO_2 is dependent on the health of the ecosystem. In healthy reefs free CO_2 may be absorbed and recycled within the reef system. Terrestrial inputs of carbon, acidic seawater conditions, and nutrient enrichment, however, enhance the net release of CO_2 to the atmosphere. Efforts made to reduce nutrient enrichment in coastal areas regulate ocean acidity and water temperatures and improve ocean water quality secure healthy corals, native fish, planktons and seabird populations while maintaining the carbon reservoirs. Other coastal systems such as mangrove forests and sea-grass beds can also be important carbon stores and sinks.

Box 2.9. The Economics for Protecting Coral Reefs

A synthesis of economic studies examining exploitation of Philippine reefs demonstrated that, despite high initial benefits, destructive fishing techniques provided fewer benefits than did sustainable fishing. Unsustainable fishing reduced social benefits and had a total economic value of $870/ha. By comparison, a healthy reef which provides tourism, coastal protection and fisheries had a total economic value of $3300 ha.



Source: Balmford et al., 2002.

The signing of the Manado Declaration (Box 2.10) in May 2009 has made coastal and marine issues an important part of the climate change dialogue. Such issues are expected to become a central focus in future climate change negotiations.

Box 2.10. The Manado Declaration

On 14 May 2009, representatives from 76 participating countries officially adopted the Manado Ocean Declaration at the World Ocean Conference in Indonesia. Participants recommended that oceans and coastal area issues be included in future climate change negotiations including the UNFCCC Conference of Parties (COP) in December 2009 in Copenhagen. The declaration highlighted the need for financial resources and incentives to help developing countries protect oceans and seas, for renewable ocean technologies, and for funding for more research into the impact of climate change on oceans and the role of large bodies of water in fighting the harmful effects of climate change.

The Manado Ocean Declaration emphasized the following needs:

- Development of national strategies for sustainable management of coastal and marine ecosystems, in particular mangrove, wetlands, sea-grass, estuary and coral reefs, as protective and productive buffer zones that deliver valuable ecosystem goods and services and that have significant potential for addressing the adverse effects of climate change.
- Cooperation in furthering marine scientific research and integrated ocean observation systems.
- Education and public awareness to improve understanding on the role of oceans on climate change and vice-versa, and the roles of coastal and marine ecosystems in reducing the effects of climate change.
- Adequate measures to reduce sources of marine pollution, and assure integrated management and rehabilitation of coastal ecosystems.

Investing in Alternative Energy

Hydropower and other renewable energy sources such as wind and wave energy solutions have significant potential to mitigate climate change by reducing the greenhouse gas intensity of energy production. However, large-scale hydropower development can also have high environmental and social costs such as changes in land use, disruption of migratory pathways, and displacement of local communities. They can also disrupt environmental flows, reducing a freshwater ecosystem's potential to adapt to climate change. The ecosystem impacts of specific hydropower projects may be minimized depending on factors such as the type and condition of pre-dam ecosystems, type and operation of the dam (for example, water-flow management), and the depth, area, and length of the reservoir. Run-of-the-river hydropower and small dams have generally less impact on biodiversity than large dams, but the cumulative effects of many small units should be taken into account. Careful design and planning to protect natural ecosystems in and around the new facility can benefit both biodiversity and enhance the efficiency and effectiveness of the infrastructure investment. Protection of the native forests in the watershed of the Nam Theun 2 Dam in Lao PDR is a critical factor in reducing soil run-off and sedimentation in the reservoir, thereby extending the lifespan of the hydropower generation facility (see Box 2.11).

Box 2.11. Nakai Nam Theun: Forest Conservation to Protect a Hydropower Investment in Lao PDR

The Nam Theun 2 hydropower project in central Lao PDR will inundate 450 square kilometers of the Nakai Plateau, including substantial areas of semi-natural forest habitat. To offset this impact, a Bank loan for the environment will provide an unprecedented level of support for conservation in the adjacent Nakai Nam Theun National Protected Area. At around 4,000 square kilometers (including corridors), Nakai Nam Theun NPA is the largest single protected area in Laos, with 403 species of birds and a large number of mammals, including elephants and the rare saola (*Pseudoryx nghetinhensis*) and large mammals discovered as recently as the 1990s. The PA sits upon the spine of Indochina, the Annamite Mountains, a center of high biodiversity and species endemism. The borders of Nakai Nam Theun stretch from wet evergreen forests along the Vietnamese border to the limestone karst formations of central Lao, which harbor a new family of rodents that were first described in 2005. Married to this biodiversity is an astonishing ethno-linguistic diversity. The people living in, and immediately around, the protected area include 28 linguistically distinct groups and can name a greater number of forest products than have been recorded from any other area in Laos.

Under a new conservation authority established during the preparation of the project, the PA will be managed according to an integrated conservation and development model. Village agreements will be developed to detail resource use rules and regulations consistent with PA zones, including controlled use and totally protected zones. Village conservation teams provide a platform for management of natural resources and for biodiversity monitoring and enforcement. Sustainable alternative livelihood options will mitigate negative impacts resulting from restrictions on resource use in key core conservation areas. Communities will be empowered through provision of secure land rights, capacity building, recognition of indigenous knowledge, and equitable distribution of benefits to ensure that the most vulnerable and most forest-dependent groups are included in the process.

Previous conservation efforts in Laos have been undermined by lack of staff and long-term funding. Perhaps the most promising innovation in Nakai-Nam Theun is a new financial and administrative model. Since the protected area covers around 95 percent of the catchment for the Nam Theun 2 hydropower project, the developer will pay $1 million annually for PA protection over the 30-year concession period. The government of Laos is keen to apply similar financial models elsewhere, as it exploits its abundant water resources to mobilize resources for poverty reduction while maintaining the biodiversity base critical for many rural households. The funding for Nakai Nam Theun will be some two orders of magnitude greater than the total presently allocated from the central budget to the rest of the Lao protected areas system. The Bank is therefore establishing another fund for other local conservation areas to provide modest, demand-driven funding at a level appropriate to existing local capacity. Sustained support for the fund would also come from the revenues generated by natural resource industries. Through direct financing, and promotion of integrated development models, the Bank is providing biodiversity funding over a sufficient time-frame for conservation success to become its own champion in Lao PDR.

Construction of more dams and other irrigation infrastructure will increase due to the increasing need for alternative energy and irrigation in a warmer world. In order to maintain the mitigation and adaptation potential of freshwater ecosystems, infrastructure planning needs to take account of environmental flows. A thorough environmental flow assessment during project preparation can prevent high financial, social, reputational, and political cost. For example, in the Senegal basin, the water charter signed by the governments of Mali, Mauritania, Senegal, and Guinea recognized the provision of water flows to the mid-river floodplain and ensured the maintenance of agricultural and fishing activities. Similarly the Lesotho Highlands Water Project (LHWP) linked resource losses associated with reduced river flows to community livelihoods and downstream social impacts of the dams. The LHWP environmental flow experience offers important lessons in the following areas:

- Understanding the difference between downstream social impacts and upstream social impacts.

- Recognizing the difference in magnitude in the number of people who can be affected downstream of the dam (about 39,000 in Lesotho) compared to upstream of the dam (around 4,000).

- Developing an approach for systematically defining the affected communities (or "the population at risk") downstream of dams.

- Delineating the downstream socioeconomic impacts associated with changes in river flows.

- Defining approaches for addressing and mitigating the social impacts associated with significant changes in river flows and their limitations

Biofuels for Renewable Energy

New initiatives under the climate change agenda provide both opportunities and challenges for biodiversity conservation. Biofuels and bio-energy plantations, for example, can substitute for fossil fuels and may also provide benefits to small farmers engaged in their production. Policies in the United States and the European Union (EU) that mandate specific targets for biofuels in meeting national fuel needs are fuelling rapidly growing biofuel industries. However, without careful planning, biofuel production could lead to further clearance of natural habitats, either for biofuels themselves or for new agricultural land to replace converted crop lands. Moreover, many species being promoted for biofuel production are known to become invasive in some countries where they have been introduced (see Table 2.2). Few current biofuel programs are economically viable without subsidies and many have potential social and environmental costs, including intensified competition for land and water and possibly deforestation. While biofuel plantations on degraded and/or abandoned agricultural lands may prove beneficial, the expansion of biofuels in the tropics is also leading to clearance and loss of natural ecosystems, with consequent loss of biodiversity. The clearance of peat swamp forests for oil palm production in Indonesia, for instance, is estimated to have been a major contributor to Indonesia's GHG emissions, making Indonesia the third largest emitter of GHGs in 2006.

Table 2.2. Known Invasive Species Listed in Different Countries as Suitable for Biofuel Production

SPECIES NAME	COMMON NAME	NATIVE RANGE	INVASIVE STATUS
Artocarpus communis, A. altilis	Breadfruit	Pacific Islands, Southeast Asia	Fiji, Kiribati, Line Islands
Arundo donax	Giant reed	Eurasia	United States, Mexico, the Caribbean, Southern Europe, South Africa, Thailand, Australia, New Zealand, Hawaii
Azadirachta indica	Neem	India, Burma, Sri Lanka, Myanmar, Bangladesh	West Africa, Australia, Fiji, Mauritius
Brassica napus	Rapeseed/ canola	Eurasia	Australia, Ecuador, Fiji, Hawaii, New Caledonia
Camelina sativa	False flax	Eastern Europe and Southwest Asia	North America, Western Europe, Australia, Central America, South America, Japan

Elaeis guineensis	African oil palm	West Africa, Madagascar	Brazil, Micronesia, Florida USA
Gleditsia triacanthos	Honey locust	Eastern North America	Central Argentina, South Africa, Australia, USA, New Zealand
Jatropha curcas	Jatropha/ physic nut	Tropical America	Australia, South Africa, USA, Pacific Islands, Puerto Rico
Maclura pomifera	Osage orange	Central United States	Europe, USA, Australia, South Africa
Morus alba	Mulberry	Asia	Brazil, Ecuador, United States
Olea europaea	Olive tree	Mediterranean Europe	Australia, Hawaii, New Zealand
Phalaris arundinacea	Reed canary grass	Europe, Asia, North America	United States, South Africa, Australia, New Zealand, Chile, most temperate countries
Prosopis spp.	Mesquite	America	Eastern Africa (Sudan, Eritrea, Ethiopia, Djibouti), Southern Africa, India, Australia
Ricinus communis	Castor bean	East Africa	Brazil, Australia, Pacific islands, New Zealand, South Africa, Mexico, USA, Western Europe
Sorghum halepense	Johnson grass	Mediterranean to India	United States, Australia, Pacific Islands, Central and South America, Indonesia, Thailand
Ziziphus mauritiana	Chinese apple/ jujube	India, China	Australia, Africa, Afghanistan, China, Malaysia, northern Australia, Pacific and Caribbean region

Source: Global Invasive Species Programme, 2008

Pilot biofuel projects of various scales are already under way or in the planning stages, particularly in Asia, Africa, and South America to establish smallholder plantations of biofuel species such as *Jatropha curcas* for job creation, poverty alleviation, and restoration of degraded land. *Jatropha curcas* is a fast-growing, drought-resistant shrub or small tree that is native to southern Mexico and Central America but introduced to many tropical and sub-tropical countries. A member of the *Euphorbia* family, it can tolerate marginal, nutrient-poor soils and arid conditions, although it is relatively sensitive to frost. Because it is unpalatable to livestock, it has been widely used in rural communities in Africa as a hedge or 'living fence' around crops. Once mature, the trees annually produce about 4kg of seed, which have an oil content of 30-40 percent. The Bank is assessing the social and economic benefits of promoting *Jatropha* for biofuel production in Kenya. Biofuels may be a useful crop on degraded lands, including lands previously deforested for agricultural production, as in Brazil.

There is increasing evidence that biofuels are not a silver bullet. Economists, environmentalists, and social scientists, among others, have presented compelling evidence that (a) some biofuels are not economically attractive alternatives to fossil fuels in the absence of subsidies; (b) they may not provide significant savings in greenhouse gas production; (c) the cultivation of plant-based biofuels has serious environmental costs in terms of its impact on biodiversity; and that (d) the social impacts of the expansion of plant-based biofuels can have detrimental impacts on food availability and affordability, as well as other negative impacts on the poorest populations in the developing world (see Box 2.12). Accordingly, the Bank has worked with WWF to produce a prototype score card to assess when, where, and what biofuel production is environmentally and socially sustainable. This Biofuels Sustainability Scorecard will allow the user to rate a potential biofuel on a series of criteria that are key to the expected environmental sustainability of the biofuel and its production system.

Box 2.12. Biofuels—Too Much of a Good Thing?

With oil prices at record highs and with few alternative fuels for transport, several countries are actively supporting the production of liquid biofuels from agriculture—usually maize or sugarcane for ethanol, and various oil crops for biodiesel. As the economic, environmental, and social effects of biofuels are widely debated, they need to be carefully assessed before extending public support to large-scale biofuel programs. Those effects depend on the type of feedstock, the production process used, and the changes in land use.

Global production of ethanol as a fuel in 2006 was around 40 billion liters. Of that amount, nearly 90 percent was produced in Brazil and the United States. In addition, about 6.5 billion liters of biodiesel were produced in 2006, of which 75 percent was produced in the European Union. Current biofuel policies could, according to some estimates, lead to a fivefold increase in the share of biofuels in global transport—from just over 1 percent today to around 6 percent by 2020.

*Are biofuels economically viable—and what is their effect on food pric*es?
Governments provide substantial support to biofuels so that they can compete with gasoline and conventional diesel. Such support includes consumption incentives (fuel tax reductions); production incentives (tax incentives, loan guarantees, and direct subsidy payments); and mandatory consumption requirements.

Rising agricultural crop prices caused by demand for biofuels have come to the forefront in the debate about a potential conflict between food and fuel. Rising prices of staple crops can cause significant welfare losses for the poor, most of whom are net buyers of staple crops. But many other poor producers, who are net sellers of these crops, benefit from higher prices. For example, biofuel production has pushed up feedstock prices.

Nonmarket benefits and risks are context-specific. The possible environmental and social benefits of biofuels are second only to energy security as the most frequently-cited arguments in support of public funding and policy incentives for biofuel programs. But these come with risks also.

Potential environmental benefits. Environmental benefits need to be evaluated on a case-by-case basis because they depend on the greenhouse gas (GHG) emissions associated with the cultivation of feedstocks, the biofuels production process, and the transport of biofuels to markets. Changes in land use, such as cutting forests or draining peatland to produce feedstock such as oil palm, can cancel the GHG emission savings for decades. Similarly, land use changes arising from a need to replace land for food crops that is now used for biofuel production, can eliminate GHG savings and irreversibly damage wildlife and wild lands.

Benefits to smallholders. Biofuels can benefit smallholder farmers by generating employment and increasing rural incomes, but the scope of those benefits is likely to remain limited with current technologies. Ethanol production requires fairly large economies of scale and vertical integration because of the complexity of the production process in the distilleries. Small-scale production of biodiesel could meet local energy demand, but rising food and feedstock prices could negate any gains in cheaper energy.

Source: World Bank, 2008b.

Chapter 3. Ecosystem-based Adaptation: Reducing Vulnerability

During the course of human history, societies have often needed to cope with managing the impacts of adverse weather events and climate conditions. Nevertheless, the pace of global change is now so rapid that additional measures will be required to reduce the adverse impacts of projected global climate change in the near and long-term. Moreover, vulnerability to climate change can be exacerbated by other stresses, including the loss of habitats and natural resources, reduced ecosystem services, and land degradation.

Adaptation is becoming an increasingly important part of the development agenda, especially in developing countries most at risk from climate change. An essential component of adaptation is the protection and restoration of ecosystems and the habitats, natural resources and the services they provide. The multiple benefits in terms of goods and services afforded by biodiversity and healthy ecosystems are largely unrecognized and unrecorded in natural accounting. Enhanced protection and management of natural ecosystems and more sustainable management of natural resources and agricultural crops can play a critical role in adaptation strategies. Ecosystem-based approaches can contribute to adaptation strategies through:

- Maintaining and restoring natural ecosystems and the goods and services that they provide.
- Protecting and enhancing vital ecosystem services, such as water flows and water quality.
- Maintaining costal barriers and natural flood control and pollution reduction mechanisms.
- Reducing land and water degradation through actively preventing, and controlling, spread of invasive alien species.
- Managing habitats that maintain nursery, feeding and breeding grounds for fisheries, wildlife and other species on which human populations depend.
- Providing reservoirs for wild relatives of crops and other agrobiodiversity to increase genetic diversity and resilience for crop improvements.

Ecosystem-based adaptation complements other climate change responses in two ways. Natural ecosystems are resistant and resilient and provide a full range of goods and ecosystem services, including natural resources such as water, timber and fisheries on which human livelihoods depend. Secondly, natural ecosystems provide proven and cost-effective protection against some of the threats that result from climate change. For example, wetlands, mangroves, oyster reefs, barrier beaches and sand dunes all provide coastal protection from storms and flooding. Such ecosystem-based approaches can complement, or substitute for, more expensive infrastructure investments to protect coastal settlements.

Conserving Biodiversity under Climate Change

Conservation biology confirms the need to protect large areas of habitat and maintain landscape connectivity between natural habitats and across altitudinal gradients. Many threatened and charismatic species will not survive without adequate protection of large and connected landscapes. This is especially true for wide-ranging and migratory species—such as elephants, large herbivores, and many birds—and for the large carnivores at the head of the food chain. Corridors of natural habitats within transformed production landscapes or remaining habitat links between protected areas provide opportunities for species to move and maintain viable populations. Maintaining connectivity between natural habitats, and along altitudinal gradients, is a key strategy to allow plant and animal species to adapt to climate change (Box 1.1). In Colombia, a GEF project in the Andes has a specific component dedicated to building ecological corridors through the highly devastated cloud forests and paramo habitats of the mountain chain. More than 70 percent of Colombia's 41 million inhabitants reside in the high Andes plateaus and mountains, transforming the original habitats into agriculture and pasturelands. The project has already identified new areas for conservation through private reserves and is currently working with farmers to raise awareness of the need to establish biological corridors.

Many Bank projects are already contributing to improved biodiversity conservation across large landscapes through improved management across mosaics of different land use. Bank-support for biological corridor projects is ensuring protection of large landscapes and biological corridors, promoting connectivity in the Maloti-Drakensberg Transfrontier region in Lesotho and South Africa; mega-reserves from mountains to the sea in the Cape Region; corridors in the Vilicabamba-Amboró region in Venezuela, Colombia, Ecuador, Peru, Bolivia, and northern Argentina; and through a network of corridors in Bhutan – Box 3.1. Transboundary conservation efforts in the West Tien Shan in Central Asia foster international collaboration and cooperation across national boundaries, reduce disturbance on fragile mountain grasslands and promoting conservation of wide-ranging species. A new Tien Shan Ecosystem Development Project will promote further protection for the juniper and walnut forests and other key mountain habitats. The project covers the Kyrgyz Republic and Kazakhstan and benefits from funds through the GEF and BioCarbon Fund in recognition of the important role that mountain ecosystems play in regulating ecosystem services and carbon sequestration

Box 3.1. Biological Corridors in a Changing World

The MesoAmerican Biological Corridor (MABC) is a natural corridor of tropical rainforests, pine savannas, montane forests, and coastal wetlands that extends from Mexico to Colombia. Within the corridor, the Bank is supporting a number of national interventions in Guatemala, Mexico, Panama, Nicaragua, and Honduras to conserve the Atlantic forests of Central America. In Nicaragua, for instance, a GEF grant supported the incremental costs of protected areas and conservation-based land use in the corridor as part of an integrated development and conservation project. Management was strengthened in three key protected areas along the Caribbean coast: Cerro Silva natural reserve (339,400 ha), Wawashan natural reserve (231,500 ha), and the Cayos Miskitos biological reserve, which protects nesting grounds of five of the world's seven species of marine turtles. Within the corridor, indigenous communities were assisted to gain tenure over indigenous lands and to develop livelihoods based on sustainable management of natural habitats and resources. Significantly, recent studies have shown that the MABC forests are areas of high carbon storage.

The Atlantic Forest of Brazil is one of the most threatened ecosystems in Latin America, where only 7 percent of the original habitat remains in a few isolated forest patches. The area has an extraordinarily high level of endemism. The Bank, through the Pilot Program for the Brazilian Rain Forest and G8 donors, is working on increasing the connectivity of these patches through an ecological corridors project, which brings together states, municipalities, NGOs, and academic institutions. Similarly, in the highly threatened Chaco Andean system in Ecuador, a Bank-funded project has strengthened biological corridors through funding for private reserves and innovative conservation models.

The Critical Ecosystem Partnership Fund is supporting civil society activities to address threats to biodiversity across landscapes that include a matrix of uses, from protected areas to high-value conservation sites in production landscapes. A critical ecosystem profile identifies the priorities for each hotspot. Many of those priority activities are targeted toward key biological corridors, which overlay areas of high carbon. CEPF has already supported activities in the Sierra Madre in the Philippines, Barisan Selatan in Sumatra, key forest corridors in Madagascar, the West Guinea forests and Eastern Arc forests in Africa, mountain corridors in the Caucasus and eastern Himalayas, and the Choco-Manabi and Vilcabamba-Amboro corridors in the Tropical Andes. A new phase of funding will target important biological landscapes and corridors in Indochina, including the Mekong corridor, and the highly diverse tropical forests of the Western Ghats in India.

Maintaining and Restoring Natural Ecosystems

Within any given ecosystem, functionally-diverse communities are more likely to be resilient to climate change and climate variability than impoverished biological communities. Habitat conservation and protected areas play an important and cost-effective role in protecting biological resources and reducing vulnerability to climate change. The Bank already recognizes the important role that enhanced protection of natural forests can play in protecting development investments. Thus the Dumoga-Bone National Park in Indonesia was established to protect a major irrigation investment in North Sulawesi. Similarly, a new conservation area in Lao PDR protects the forests around the Nam Theun 2 Dam and its watersheds (Box 2.11), reducing sedimentation in the reservoirs and extending the lifespan of the hydropower generation facility. Coastal protected areas in Croatia, Bangladesh, Indonesia, Honduras, and Lithuania are protecting coastal forests, swamps, floodplains, and mangroves, important for shelter belts and flood control. The role of natural habitats in providing services such as coastal protection and nursery grounds for quality fisheries are increasingly being recognized as essential to these countries' coastal economies and the livelihoods of the communities who depend upon them.

Improved management of natural habitats and reducing threats such as habitat conversion, overharvesting, pollution, and alien species invasions contribute to healthier and more resilient ecosystems. For example, reducing the pressures from coastal pollution, overexploitation and destructive fishing practices, improves the health of coral reefs increasing their resilience to increased water temperatures and bleaching. Similarly, countering habitat fragmentation through the protection and/or establishment of biological corridors between protected areas increases forest resilience. More generally, mosaics of interconnected terrestrial, freshwater, and marine multiple-use areas and protected reserves are better adapted to meet conservation and livelihood needs under changing climate conditions. Such ecosystem-based approaches are low cost, long proven and low technology solutions to many of the anticipated adverse impacts arising from climate change.

Wetlands are some of the most threatened ecosystems on Earth, yet they provide many vital ecosystem functions. Montane wetlands, and freshwater rivers and lakes serve as vital water recharge areas and important sources of water for irrigation and domestic and industrial use. Freshwater and coastal wetlands downstream are also productive fisheries on which many of the world's poorest communities depend. Wetlands can also act as filters removing pollutants and improving water quality. In Bulgaria, the Bank is working with WWF and other partners to restore natural wetlands along the Danube River as filter beds to remove pollutants and provide habitat for native wildlife – Box 3.2.

Box 3.2. Restoring the Lower Danube Wetlands

Conversion of floodplains for farming and other development has led to 95 percent of the upper Danube, 75 percent of the lower Danube and 28 percent of the delta's floodplains cut off by dykes. This has increased flood risks and pollution in the region, threats which are expected to rise with climate change.

In 2000 WWF secured agreement from the heads of state of Bulgaria, Romania, Moldova and Ukraine to restore 2,236 km^2 of floodplain to form a 9,000 km^2 "Lower Danube Green Corridor." This Corridor is intended to attenuate floods, restore biodiversity, improve water quality, and enhance local livelihoods. As of 2008, 469 km^2 of floodplain, 14.4 percent of the area pledged, has been or is undergoing restoration. In Romania, the Babina and Cernovca polders have been reflooded, and in Ukraine, the Tataru polder has been flooded to link 68 km^2 of the Katlabuh Lake to the river. Restoration of the pilot polders has seen a diversification in livelihood strategies to fishing, tourism, reed harvesting and livestock grazing on seasonal pastures, activities that earn an average €40 ($56) per hectare per year. At Babina and Cernovca polders, the restored fisheries provide jobs for 20-25 people.

Restoration activities at Katlabuh Lake have improved water quality for 10,000 local residents. The value of ecosystem services, like restored floodplains for fisheries, forestry, animal feed, nutrient retention and recreation is estimated at €500 ($698) ha/yr, or around €85.6 ($119) million per year for the 2,236 km^2 restoration area. Following restoration, the number of resident breeding bird species increased from 34 to 72. As a result of its EU accession, Romania has now an additional 5,757 km^2 as Natura 2000 protected areas. Restoration of the 37 sites that make up the Lower Danube Green Corridor is estimated to cost €183 ($299) million, but will likely lead to additional earnings of €85.6 ($120) million per year. Before the restoration, the 2005 flood cost €396 million in damages, proving the cost effectiveness of ecosystem-based approaches.

Source: WWF, 2008

As climate change exacerbates the impacts of environmental stresses, many of these free goods and services provided by natural habitats will become ever more valuable. Enhanced protection of natural wetlands and, increasingly, restoration of wetland habitats will become an important adaptation strategy – see Box 3.3.

Box 3.3. Rebuilding Resilience in Wetland Ecosystems

The Gulf of Mexico possesses one of the richest, most extensive, and productive ecosystems on earth—coastal wetlands that cover an area of over 14,000 square kilometers. The coast is flanked by 27 major systems of estuaries, bays, and coastal lagoons that serve as shelter, feeding, and breeding areas for numerous species of important riverine and marine fishes. Moreover, the coastal swamps of Tabasco and Campeche are home to 45 of the 111 endemic species of aquatic plants in Mexico. These coastal wetlands play an important role in the water cycle.

Climate change is already beginning to impact these ecosystems. Sea-level rise in the Gulf of Mexico is leading to saltwater intrusion. Anticipated modifications in rainfall patterns in northern Mexico will affect natural drainage systems, further deteriorating the natural water balance of these coastal wetland systems. Degraded marshlands and mangroves will be less likely to withstand extreme weather events in the Gulf of Mexico. The number of high-intensity hurricanes that have reached landfall in the Gulf of Mexico has increased by more than 40 percent compared to the 1960s. These storms often cause serious disruption with loss of property and human life. The ecological and economic consequences can be staggering.

The Bank is preparing a project to address these concerns through improved water resource and wetland management. The project will pilot several measures, including:

- Restoring wetlands, taking into account sand dynamics and hydrology – initial activities will include the removal of soil or sand sediments obstructing water flows and the maintenance of waterways that feed wetland restoration.
- Integrating climate change adaptation measures into resource management programs.
- Restoring mangrove swamp ecosystems by establishing permanent/seasonal closed areas as well as by reducing and preventing changes in land use, promoting more efficient water management strategies, and reintroduction of native mangrove species in areas degraded by economic activities.
- Maintaining water supply for production sectors.
- Developing mechanisms to promote sustainable land-use patterns that maintain the functional integrity of wetland ecosystems in the region.

Reducing Vulnerability

Natural ecosystems can also reduce vulnerability to natural hazards and extreme climatic events. Protecting forests and other natural ecosystems can provide social, economic, and environmental benefits, both directly through more sustainable management of biological resources and indirectly through protection of ecosystem services. Mountain habitats, for instance, bestow multiple ecosystem, soil conservation, and watershed benefits. They are often centers of endemism, Pleistocene refuges, and source populations for recovery of more low-lying habitats. Mountain ecosystems play a role in influencing rainfall regimes and climate at local and regional levels, helping to contain global warming through carbon sequestration and storage in soils and plant biomass. Wetlands are nature's kidneys, providing indispensable ecosystem services that regulate nutrient loading and water quality.

Over the last decade, an increasing number of Bank projects have been making explicit linkages between sustainable use of natural ecosystems, biodiversity conservation, carbon sequestration and watershed values associated with erosion control, clean water supplies, and flood control. Bank watershed projects in the Middle East incorporate natural forests and endemic riparian woodlands as part of micro-catchment vegetation management with local communities, including the Lakhdar watershed in Morocco, the northern Yemen wadis, and Turkey's Eastern Anatolia Basin. In China, mountain forests are being increasingly recognized for their role in clean water supply, water regulation, and flood control. The China Forest Protection Project is focusing on mountain and upper watershed forests and reallocating forests for their watershed and biodiversity protection functions as well as more sustainably managed production.

The Bank has been a leader in piloting payments for ecosystem services (PES). In Mexico, Bank projects have helped to establish PES systems to reduce logging in the Monarch Butterfly Reserve to protect important butterfly habitat. With support from the Mexican Nature Conservation Fund, an endowment has been established for El Triunfo Reserve in the Sierra Madre in Chiapas to support activities that protect the area's ecosystem services, especially water production. In Ecuador an integrated watershed management project is being prepared with a specific component to capture payment for environmental services provided by Andean forests. Meanwhile, Costa Rica is launching a second Bank GEF project to build on the experience and success of the Ecomarkets projects in promoting biodiversity conservation and PES schemes on privately-owned lands – Box 3.4.

Box 3.4. Ecomarkets in Costa Rica

Costa Rica's program of payments for environmental services (PSA) is an innovative and highly successful effort to voluntarily enlist private landholders to maintain and protect their forests. Since its inception in 1997, the PSA Program has been applied to a total of nearly 500,000 ha of privately owned forests.

Since 2001, the program has received funding under the Bank/GEF Ecomarkets Project. More than 130,000 ha of priority biodiversity areas in Costa Rican portion of the Mesoamerican Biological Corridor (MBC) have been included in the program, Another 70,000 ha have been contracted on privately owned lands within other priority conservation areas thus further contributing to the achievement of conservation and sustainable management goals. In 2000, only 22 female landholders participated in the program; by 2005 there were 474 women participating. In 2000, there were 2,850 ha of indigenous-community-owned lands in the program; by 2005 this figure had risen to 25,125 ha, an eight-fold increase.

The PSA Program has been funded primarily by allocating 3.5 percent of the national fuel tax to FONAFIFO. The PSA Program has also attracted significant co-financing from bilateral donors, including KfW, NORAD, and the Government of Japan. The Ecomarkets project has not only provided additional financing to expand the PSA Program, but also led to the re-focusing of the entire PSA Program on global and regional biodiversity conservation priorities, as well as on national social goals. National benefits include the maintenance of privately owned forests in important biological corridors; local conservation of biological diversity; major increases in the involvement of women landholders and indigenous communities with the PSA Program; direct payments to a relatively greater number of small rural landholders; and, most importantly, broad-scale public recognition that intact forests and their environmental services have value.

The success of the Ecomarkets Project is based on a strong institution (FONAFIFO) that is capable of effectively and efficiently managing a complex system of payments for environmental services; the strong legal framework, and wide political support for the PSA Program through three successive administrations; and the nationwide support from civil society, particularly small- and medium-size landholders, as well as local and regional organizations (e.g., NGOs, cooperatives). The PSA Program and the Ecomarkets Project have attracted widespread international interest, spurring several replication efforts. FONAFIFO has hosted official delegations from many countries wanting to study the PSA Program. The project has led to more effective conservation by creating linkages between geographically isolated protected areas through privately-owned lands where biodiversity is legally protected through PSA contracts.

Adopting Indigenous Knowledge to Adapt to Climate Change

Indigenous Peoples can play a key role in climate change mitigation and adaptation. Many territories of indigenous groups have been better conserved than the adjacent agricultural lands, including in Brazil, Colombia and Nicaragua. Satellite maps clearly show that the area of the Amazon covered by indigenous lands represents one of the largest remaining reserves of intact tropical forest. As a result of the project, these indigenous groups are now in a better position to participate in the various private and public carbon payments from avoided deforestation. A climate change agenda fully involving Indigenous Peoples has many more benefits than if only government and/or the private sector are involved. Indigenous peoples are some of the most vulnerable groups to the negative effects of climate change, but they are also a source of knowledge and adaptation strategies. For example, ancestral territories often provide excellent examples of a landscape design that can resist the negatives effects of climate change. Over the millennia, Indigenous Peoples have cultivated genetic varieties of medicinal and useful plants and animal breeds with a wider natural range of resistance to climatic and ecological variability. They have also evolved farming and water management strategies to cope with climate change – Box 3.5.

Box 3.5. Measures to Address Climate Change in the Salinas and Aguada Blanca National Reserve in Peru

The GEF has supported the project, Participatory Management of Protected Areas, in Peru since 2005. The Salinas and Aguada Blanca National Reserve is one of the protected areas supported under the project. Located north of Arequipa city, at an altitude between 3,600 and 6,000 meters, the Salinas and Aguada Blanca National Reserve is the habitat to wild cameloids, such as vicuña and guanaco, and the home to a wide range of migratory and sedentary birds that breed around various mountain lakes, dams and rivers. Created in 1979 to preserve the endangered flora and fauna of the area, it recently has been extended to 366,936 hectares. The volcanoes Misti, Chachani, and Pichu Pichu are also within the limits of the reserve, as well as the beautiful Salinas lagoon that create an ideal habitat for a number of flamingos, and the Indio lagoon, as another important refuge for aquatic birds. The Salinas and Aguada Blanca National Reserve is the habitat to 169 animal species (of which 23 mammals and 138 birds). Some of the most representative are the vizcacha, the Andean huemul, the culpeo fox, the vicuña (which goes through a repopulation program), the flamingo and the guanaco.

The reserve protects a large source of water that supplies the city of Arequipa as well as other smaller towns. The natural ecosystems are threatened from deforestation by the 14 local communities that inhabit the reserve. Around 8,000 inhabitants live within the reserve and many of them are engaged in cameloid farming. Water resources are scarcer everyday due to the melting of the glaciers and because the area receives less precipitation than in the past. This water decrease can be attributed to climate change. The GEF project has supported sub-projects to help the local communities adapt to climate change. Several of these sub-projects have supported water conservation and management activities that in turn, have had a positive impact on biodiversity conservation. The project has supported water retention terracing to collect water during the raining season and to improve infiltration and conservation. The technology that they are using include: infiltration ditches, small barrages, water mirrors (small lakes) and rustic canals and was developed and used by the ancestral indigenous peoples that occupied these areas. This traditional knowledge stopped being used then the Spanish conquistadors came and only recently has been brought back. In a few years of implementation, water availability has improved especially during the summer season and the vegetation has recovered in some parts of the reserve.

Over the last two decades, 109 Bank projects have supported, or are, supporting Indigenous Peoples' programs and needs. Several of these projects have supported the conservation of tropical forests and reforestation activities that are directly linked to avoided deforestation; a few have supported direct benefits from carbon payments. The following activities supporting climate change and indigenous objectives are common components in these projects (a) Indigenous Peoples Reserves and protected-areas co-management; (b) titling and demarcation of indigenous lands; (c) indigenous life plans; (d) establishment of indigenous conservation areas; (e) indigenous community management and zoning plans; (f) indigenous community mapping and conservation; (g) community sustainable livelihood; and, (h) capacity building and training.

Adaptation in Coastal Areas

Coastal wetlands act as natural barriers protecting coastal settlements from storms and other natural hazards, reducing the risk of disaster. Mangroves and other coastal wetlands are especially vulnerable to climate change and rising sea levels. The loss of mangroves in turn makes coastal communities vulnerable to extreme events such as hurricanes, cyclones and tsunamis. Inland areas protected by healthy mangroves have generally suffered less than more exposed communities from extreme weather events such as the 2008 Cyclone Nargis that hit southern Myanmar and the dramatic 2004 tsunami that hit Southeast Asia. As well as providing coastal defenses, mangroves are important nurseries for fish, prawns and other marine invertebrates, critical resources for local livelihoods. Restoration of degraded mangroves in the Mekong Delta in Vietnam for example has improved management of coastal forests, improving coastal protection and safeguarding important nursery grounds for local fisheries and food security.

Box 3.6. Investing in Mangroves.

The destruction of mangroves has a strong economic impact on local fishing communities and on food production in several regions. Maintenance or restoration of mangroves can reduce vulnerability of coastal areas to sea level rise and extreme weather events while also contributing to food security. Often such ecosystem-based approaches are highly cost-effective.

Other examples of the way restoring and protecting mangroves can reduce vulnerability include:

- Mangrove forests have been estimated to have an economic value of 300,000 USD per km as coastal defenses in Malaysia, when compared to engineered alternatives (Ramsar Convention on Wetlands, 2005).

- Since 1994, communities have been planting and protecting mangrove forests in Vietnam as a way of buffering against storms. An initial investment of US$1.1 million saved an estimated US$7.3 million a year in sea dyke maintenance; and appeared to significantly reduce losses of life and property from typhoon Wukong in 2000, in comparison with other areas (IFRC, 2002).
- Loss of mangrove area has been estimate to increase in expected storm damages on the coast of Thailand by US$585,000 or US$187,898 per km2 (in 1996 $), based on damage data from 1979-96 and 1996-2004 respectively (Stolton et al, 2008).
- Recent studies in the Gulf of Mexico suggest that mangrove-related fish and crab species account for 32 percent of the small-scale fisheries landings in the region and that mangrove zones can be valued at $37,500 per hectare annually (Aburto-Oropeza et al., 2008).
- In Surat Thani, Thailand, the sum of all measured goods and services of intact mangroves exceeded that of shrimp farming from aquaculture by around 70 percent ($60,400) (Balmford et al., 2002).

Rising sea levels cause significant change to ecosystems and losses of marine resources. The construction of dikes and sea walls, as well as other coastal development and infrastructure may further degrade natural habitats and increase the stress on coastal resources. Small-island states are especially vulnerable to climate change. Accordingly, some of the first Bank projects on adaptation focused on small-island states in the Pacific (Kiribas) and the Caribbean. The Caribbean Planning for Adaptation to Climate Change (CPACC) Project, a regional enabling activity, focused on the vulnerability of the island nations of the Caribbean to the impacts of climate change. Potential economic impacts for the Caribbean Community (CARICOM) countries, for instance, are estimated at between $1.4 and $9 billion, assuming no adaptation measures. The largest category of impacts is the loss of land, housing, other buildings, and infrastructure due to sea-level rise. Impacts on agriculture are also potentially significant for CARICOM countries. Most of the remaining impacts are due to reduced tourism demand, caused by rising temperatures and loss of beaches, coral reefs, and other ecosystems (15–20 percent), and damage to property and life due to the increased intensity of hurricanes and tropical storms (7–11 percent) (Vergara, 2005).

The CPACC project provided information on the bleaching of corals caused by exposure to high temperatures and explored the ecological and economic consequences for the economies of the Caribbean through monitoring stations in the Bahamas, Belize, and Jamaica. Project data confirmed the deteriorating state of coral reefs in the Caribbean and the need to set up marine protected areas. Similarly the global Coral Reef Targeted Research Project (Box 3.7) is providing the scientific underpinning for management practices to adapt reef and fisheries management to address the threats arising from global warming. Regional working groups have been established to monitor coral reefs and investigate the impacts of climate change and appropriate management responses.

Fish form the primary source of protein for nearly 1 billion people and constitute a significant part of the diet for many more. Increasing demand for food has left half of wild marine fisheries fully exploited, with a further quarter already overexploited. Apart from the direct effects of over-fishing, fish populations are threatened by higher ocean temperatures, lower water flows, changing salinity, change of stream flow seasonality, loss of habitat and declining water quality. Over-fishing causes change in the structure of the food web; for example, jellyfish have replaced fish as the dominant planktivores in several areas such as the UK, and there is some concern that these community shifts may not be easily reversible, since the jellyfish also eat the eggs of their fish competitors. There is increasing evidence that species diversity is important for marine fisheries, both in the short term, by increasing productivity, and in the long term, by increasing resilience.

Box 3.7. Addressing the Impacts of Climate Change on Ocean Ecosystems and Coastal Communities.

The International Year of the Reef 2008 saw **a** worldwide campaign to raise awareness about the value and importance of coral reefs and threats to their sustainability, and to motivate people to take action to protect them. These threats include climate change, which is leading to widespread coral damage. The year 1998 witnessed an unprecedented climatic event in the world's oceans when a strong El Niño-Southern Oscillation episode caused abnormally high sea surface temperatures and affected more than 16 percent of the world's coral reefs. These events emphasized the urgent need to better protect natural resources and to prepare coastal-dependent people to adapt to climate change. At the same time human population growth in tropical coastal zones is causing tremendous use and transformation pressure that degrades and threatens coral reefs and associated resources.

The Coral Reef Targeted Research and Capacity Building for Management (CRTR) program is a proactive research and capacity building partnership designed to improve the scientific knowledge needed to strengthen management and policy to protect coral reefs. The CRTR is filling crucial knowledge gaps in targeted research areas such as Coral Bleaching, Connectivity, Coral Diseases, Coral Restoration and Remediation, Remote Sensing and Modeling and Decision Support. The CRTR partnership was formed to build national capacity for management-driven research and to use this information to improve the management effectiveness of coral reefs and the welfare of the human communities that depend on them. The Program is working with stakeholders and local governments through its regional Centers of Excellence to increase awareness of the growing risks facing coral reefs from local and global sources, and the implications in economic and social terms for the tens of millions of people who depend on them for livelihoods, food security and coastal protection.

While policy-makers in the international arena grapple with formulae and cost-effective means to bring down CO_2 emissions to well below 1990 levels over the next 50 years, the CRTR is putting local marine resource managers in a position to buy time for coral reefs. A number of interventions are addressing immediate threats to reef ecosystem health to increase resilience to changing ocean conditions associated with climate change.

Marine Protected Areas

Like terrestrial protected areas, marine protected areas (MPAs) are created to achieve long-term biodiversity conservation but may also maintain coastal and marine resources, sustain fisheries and provide opportunities for recreation, tourism and research. There are approximately 5000 MPAs globally covering about 2.2 million square kilometers of the marine environment (Laffoley, 2008). When effectively designed and managed, marine protected areas can deliver many ecological and socio-economic benefits as well as mitigate the effects of increasing carbon emissions.

The Protected Area Program of Work of the CBD has emphasized the need to expand the global MPA network to reach the target of protecting 10 percent of marine habitats in effectively managed MPAs by 2012. Such networks, especially when they link source and sink areas, can help to maintain functional marine ecosystems and mitigate carbon fluxes. All marine habitats are currently under-represented in marine protected area networks but there is a particular need to ensure that protection is extended to offshore and deep-sea areas as well as coastal reserves. The high seas beyond the legal jurisdiction of nations cover nearly 50 percent of the earth's surface but accounts for 90 percent of the planet's biomass (Corrigan and Kershaw, 2008). Ecosystems in the high seas provide valuable functions and services, including regulating services like carbon sequestration and storage, and access to scientific research, exploration, and tourism.

Bank-led sector work on marine management determined that MPAs provide the following benefits to marine conservation, fisheries stocks and carbon-sequestration, including:

- Increases in density, biomass, individual size, and diversity in all fish functional groups in communities ranging from tropical coral reefs to temperate kelp forests.
- 20-30 percent increase in diversity and average size of fish in MPAs relative to unprotected areas.
- Conservation of fish populations and their habitats, thereby enhancing the marine carbon sink.
- Reducing the need for engineered structural defenses, which do not provide ecosystem service benefits nor sequester carbon.

The Bank has invested in a range of marine conservation and resource management projects. Programs such as the MesoAmerican Barrier Reef Project and Coral Reef Management Project (COREMAP) in Indonesia have recognized the important links between sources and sinks, and are helping to protect some of the world's most biodiverse coral reefs through strengthened protection and management, and community engagement in resource management – Box 3.8. Similarly, the Namibian Coast Conservation and Management project aims to mainstream biodiversity conservation into sectoral policies and programs by providing defined incentives to stakeholders. Elsewhere, projects in Central America, Tanzania, and Vietnam have focused on integrating coastal zone management with enhanced protection of mangroves, coastal wetlands, and off-shore reefs that sustain local fisheries and thriving tourism industries.

Box 3.8. COREMAP: Coral Reef Rehabilitation and Management in Indonesia

The Indonesian archipelago is a center of coral and marine diversity with some of the most species-rich reef ecosystems in the world. The fisheries they support are an important source of food and economic opportunities for about 67,500 coastal villages throughout the country which has been increasingly threatened and overexploited in the last decade. For this reason, the Government of Indonesia initiated a multi-donor Coral Reef Rehabilitation and Management Program (COREMAP) in 1998, as a 15-year national program over three phases. As one of the main donors, the World Bank helped to finance efforts to improve the management of coral reef ecosystems in several pilot sites, including the marine protected area at Taka Bone Rate, the world's third largest atoll. Other pilot efforts in the Padeido islands, Papua, and Nusa Tenggara focused on supporting community management of coral reefs.

The first phase of COREMAP highlighted some of the challenges facing coral reefs and the communities that depend upon them. Many of the coral reef ecosystems in Indonesia, and the small-scale fisheries they support, have reached a level and mode of exploitation where the only way to increase future production and local incomes is to protect critical habitats and reduce fishing effort. There is now a growing body of empirical evidence suggesting that marine reserves can rejuvenate depleted fish stocks in a matter of years when they are managed collaboratively with the resource users, and form the core of a wider multi-use marine protected area. For the second phase of COREMAP, the Government of Indonesia has made an important policy shift toward marine conservation and protected areas as an important tool in sustainable management of coral reef ecosystems and small-scale fisheries.

COREMAP II will help to establish marine reserves within larger MPAs through a participatory planning process with communities, to ensure rejuvenation of coral reefs and reef fisheries. This six year, US$ 80 million program will be implemented in 12 coastal districts, including 1,500 coastal villages with more than 500,000 residents. The centerpiece of these efforts will be collaboratively-managed marine reserves, many within existing national parks and MPAs of recognized global value. The Government of Indonesia has committed to a target of 30 percent of the total area of coral reefs in each participating district being set aside as collaboratively-managed and fully-protected marine reserves by the year 2030. A key component of the program will be a learning network linking key marine sites and conservation efforts throughout the archipelago to exchange lessons learned and expertise. This is an ambitious program which places Indonesia as a global leaders in marine and coral reef conservation efforts. These lessons will be integrated into capacity building efforts to prepare local government and communities to manage coral reefs and their associated ecosystems, under the Coral Triangle Initiative.

These Bank efforts in coastal and marine management are complemented by new engagement in partnerships with other donors and major NGOs. The Coral Triangle Initiative (CTI) in the Indo-Pacific region (Box 3.9), for instance, aims to balance coastal protection and strengthened biodiversity conservation with improved fisheries management and local livelihoods. Such projects contribute to maintenance of healthy oceans by promoting protection and sustainable management of biologically diverse ecosystems.

Box 3.9. Coral Triangle Initiative on Coral Reefs, Fisheries and Food Security

The Coral Triangle region in the Indo-Pacific Ocean is a global hotspot of marine life abundance and diversity covering the Economic Zones of Indonesia, Papua New Guinea, Malaysia, Philippines, Timor Leste and the Solomon Islands. Destructive fishing practices and overexploitation of coastal and marine fisheries for local and export markets are leading to a loss of marine resources affecting the welfare of the coastal population who are heavily dependent on the sea and its resources for livelihoods. The loss of marine resources could affect more than 200 million people. In response, the governments of the six countries have launched the Coral Triangle Initiative (CTI).

The CTI is a multi-donor effort centered around high-level political commitments and proactive implementation by governments of the Coral Triangle area, and supported and carried forward by the private sector and civil society partners. It will help to safeguard the region's marine and coastal biological resources for the sustainable growth and prosperity of current and future generations.

The Initiative's main objective is to advance integrated ecosystem-based management of ocean and coastal areas at global, regional and national levels through coordinated planning processes building on lessons gleaned from management of large marine ecosystems, MPAs and community management. As part of the Initiative, the project aims to establish two large MPAs in the Sulu Sea, Indonesia, and in the Kimbe Bay-Bismarck Sea area of Papua New Guinea. to increase the regions' resilience to climate change. A network of smaller MPAs will combine science-based marine protection with community-based measures matching the socio-economic needs of the local populations. Lessons learned in the process of designing and implementing the resilient network of protected sites will be applicable to other large marine ecosystems and benefit local communities through improved coral reef conservation and more sustainable fisheries.

Investing in Ecosystems versus Infrastructure

Adaptation to climate change is likely to involve more investment in dams and reservoirs to buffer against increased variability in rainfall and runoff. Investments in water resource infrastructure, especially dams for storage, flood control or regulation may be essential for economic development, enabling hydropower generation, food security and irrigation, industrial and urban water supply, and flood and drought mitigation. Nevertheless, traditional engineered solutions may work against nature, especially when they lead to loss of habitat or are poorly planned, designed or operated and cause problems for downstream ecosystems and communities through impacts on the volume, pattern, and quality of flow (Hirji and Davis, 2009). Instead, in Ecuador and Argentina, flood control projects utilize the natural storage and recharge properties of critical forests and wetlands by integrating them into "living with floods" strategies that incorporate forest protected areas and riparian corridors – Box 3.10.

Box 3.10. Protecting Natural Forests for Flood Control

The irregular rainfall patterns prevailing in Argentina cause floods and droughts. Under all climate change scenarios, these boom-and-bust cycles will be exaggerated. Currently, about one-fourth of the country is repeatedly flooded. This is particularly true for north eastern Argentina, which has three major rivers— the Paraná, the Paraguay, and the Uruguay—and extensive, low-lying plains. The seven provinces of this area (Entre Ríos, Formosa, Chaco, Corrientes, Misiones, Buenos Aires, and Santa Fe) make up nearly 30 percent of the country. Nearly half of Argentina's population inhabits the latter two provinces, and an additional 12 percent live in the remaining five.

Flooding is the major regulating force in the ecosystems around these rivers; virtually all ecological events in the floodplains are related to its extent and regularity. Typical habitats include the Pampas grasslands, Mesopotamia savannah, Paraná forests, Chaco estuaries and forests, and the Paraná River islands and delta. The Paraná forests in the province of Misiones have the highest level of faunal biodiversity, followed by the Chaco estuaries and forests. Overall, 60 percent of Argentina's birds and more than 50 percent of its amphibians, reptiles, and mammals are found in the floodplains.

The first phase of a two-stage Flood Protection Program was aimed at providing cost-effective flood protection coverage for the most important economic and ecological areas, and developing a strategy to cope with recurrent floods. The project included the development and enforcement of flood defense strategies, the maintenance of flood defense installations, early flood warning systems, environmental guidelines for flood-prone areas, and flood emergency plans. Extensive areas of natural forest were protected as part of the flood defense system. This incorporation of natural habitats into flood defenses provided a low-cost solution as an alternative to costly infrastructure, with the added benefit of high biodiversity gains. As changing climate increases the likelihood of extreme weather events and flooding, the Argentina case provides some useful lessons on how to best harness natural habitats to reduce vulnerability of downstream communities.

Strengthening protection of cave systems and natural forests can safeguard important aquifers and freshwater supplies. For example, in the Lužnice floodplain – one of the last floodplains with an unaltered hydrological regime in the Czech Republic quantified the value per ha at $27,068, because of a range of ecosystem services including flood mitigation, water retention and carbon sequestration. Similarly, the value of forests for preventing avalanches is estimated at around $100 per ha per year in open lands in the Swiss Alps, and more than $170,000 per ha per year in built-up areas (ProAct Network, 2008).Elsewhere, improved ecosystem management can reduce vulnerability and protect against natural disasters – Table 3.1.

Table 3.1. Ecosystem-based Approaches to Defend against Natural Disasters

Natural hazard	Types of ecological protection	Examples
Flood	Dense vegetation cover within upper watershed areas increases infiltration of rainfall reduces surface run-off, reducing peak flow rates except when soils are already fully saturated. Vegetation also protects against erosion, reducing soil loss and transport of mud and rock which greatly increase the destructive power of floodwaters. Dense vegetation also protects river banks and adjacent land and structures from erosion by floodwaters. Wetlands and floodplain soils absorb water, reducing peak flow rates downstream.	Hurricane Jeanne hit several Caribbean islands, but the number of flood-related deaths was over 3,000 in Haiti vs. a few dozen in all other impacted countries, due in large part to Haiti's highly degraded and flood responsive watersheds. The pattern of economic losses was similar during the 2008 hurricane season, although the loss of life was far lower. A study around Mantadia National Park, Madagascar, concluded that conversion from primary forest to swidden can increase downstream storm flow by as much as 4.5 times. Communities have successfully planted bamboo to protect channel embankments from annual floods in Assam. Canalization and drainage in the Mississippi floodplain were estimated to have reduced flood storage capacity by 80 percent, and have been subsequently linked to subsidence of large areas and to the severity of the impact from Hurricane Katrina.
Tsunami / Storm surge	Coral reefs and sand dunes (which in coastal areas typically depend on associated plant communities for maintenance) provide a physical barrier against waves and currents. Salt marshes and lagoons can divert and contain floodwaters. Mangroves and other coastal forests can absorb wave energy and trap floating debris, reducing the destructive power of waves.	Modeling for the Seychelles suggests that wave energy has doubled partially as a result of changes in coral species structure due to bleaching and changes in coral species composition. In the Caribbean, more than 15,000 km of shoreline could experience a 10-20 percent reduction in protection from waves and storms by 2050 as a result of reef degradation. Re-establishment of salt-marshes forms part of coastal defense measures in the UK. Data from two villages in Sri Lanka that were hit by the devastating Asian tsunami in 2004 show that while two people died in the settlement with dense mangrove and scrub forest, up to 6,000 people died in the village without similar vegetation. In Japan, where good historical records exist, the role of forests in limiting the effects of tsunami damage have been demonstrated.
Landslide	Dense and deep-rooted vegetation helps to bind soil together, resisting slippage of surface layers.	China's grain for green program bans logging and agriculture on steep slopes and prohibits forest clearing for shifting agriculture in the mountains of Southwest China. In exchange the local communities get grain provisions and cash subsidies, as well as resilience against flooding events.
Avalanche	Forests form a physical barrier against avalanches, and pin down the snow pack, reducing the chance of a slide beginning.	Re-forestation has been used for avalanche protection in Switzerland, complementing and in some cases substituting for engineered barriers.

Source: World Bank, in prep.

The Bank already has good experience integrating protection and improved management of natural ecosystems into infrastructure projects as part of sustainable development. Such projects have included active measures to mitigate environmental impacts but have also harnessed natural forests as part of overall flood abatement, irrigation and coastal defense measures – Table 3.2.

Table 3.2. Exploring the Impacts and Offsets of Infrastructure Projects to Protect Carbon Sinks and Ecosystem Services

Environmental impacts	*Mitigation/ conservation actions*
Sectors: Energy, Hydropower	
Flooding of natural habitats near reservoirs; displacement/loss of wildlife; loss of biodiversity; deterioration of water quality; accumulation of vegetation before reservoir filling; upstream and downstream hydrological changes; alteration of fish communities and other aquatic life; invasion of aquatic vegetation and its associated disease vector species; sedimentation of reservoirs; generation of quarries and borrow pits; construction of multiple dams in one river; human resettlement; changes in hydrodynamics	Creation of compensatory protected areas; species conservation in situ and ex situ; minimization of flooded habitats; water pollution control/vegetation removal; water release management; minimum (ecological) stream flow maintenance year round; construction of fish passages and hatchery facilities; application of fishing regulations; physical removal of containments; biological and mechanical pest control; draw-down of reservoir water levels; watershed management; sediment management techniques; landscape treatment; environmental assessment of cumulative impacts
Sectors: Energy–Pipelines; Transportation–Roads; Telecommunications–Access Corridors	
Barriers to species dispersal; habitat loss, fragmentation, and simplification; spread of tree diseases: insect infestation; introduction of invasive species; human and domestic animal intrusions; runoff, erosion, and landslides; fire generation and/or natural fire frequency alteration; land use changes; wetlands and stream deterioration; water quality alterations; modifications of indigenous peoples' and local communities' ways of life	Generation of wildlife corridors to connect habitats; minimization of project footprint; creation of compensatory protected areas; management plans; use of native plant species as barriers to avoid or reduce undesirable intrusions; minimization of access roads and right of way (ROW) width for pipelines; minimization of forest edges; implementation of management and maintenance plans for all routes; revegetation along all routes; ROW maintenance; improvement of land use management; elaboration and implementation of zoning plans; environmental education and awareness programs
Sector: Water and Sanitation/Flood Protection	
Coastal erosion downstream from river breakwaters; pollutant removal by dredging bottom sediment; pollution of water supply sources; deterioration of wetlands; loss of connectivity between rivers/wetlands/riparian zones; displacement/loss of wildlife; generation of artificial wetlands; invasions of aquatic weeds and disease vectors; worsening of water quality due to sewage disposal water bodies; encroachment; land use changes; storm-induced floods within enclosed areas protected by dikes	Land use management; zoning; execution of pollution controls; water quality monitoring; elaboration and implementation of environmental education and awareness programs; implementation of management plans for wetland areas; maintenance of wildlife corridors, channels, and flooded areas; mechanical control of aquatic weeds; biological control of disease vectors; adequate site selection and engineering design; establishment of physical barriers; adoption of design criteria aimed at discouraging encroachment into natural habitats

Source: Quintero, 2007.

Chapter 4. Biodiversity Conservation and Food, Water and Livelihood Security: Emerging Issues

For some years, the World Bank has recognized that climate change poses a threat to achieving poverty reduction and development goals. Three of the world's greatest challenges over the coming decades will be biodiversity loss, climate change, and water shortages. These three issues are closely linked to agricultural productivity and food security. These impacts on agriculture and water availability will have the greatest potential to negatively affect the livelihoods of the poor, as well as national economic growth in the least-developed countries, especially in Africa. Recent studies show that farming, animal husbandry, informal forestry and fisheries make up only 7.3 percent of India's GDP, but these activities constitute 57 percent of GDP of the poor who are most reliant on natural resources and ecosystem services (Sukhdev, 2008). In many such poor regions with chronic hunger, achieving the MDG to reduce poverty will require harnessing ecosystem services as well as the rehabilitation of degraded lands and natural resources critical for increases in agricultural productivity and food security.

Agriculture and Biodiversity

Agriculture is already one of the greatest threats to natural ecosystems worldwide. Climate change, reduced rainfall, land degradation and rising human population pressure for lands and livelihoods are all likely to lead to agricultural expansion. Expanding agriculture will lead to further habitat loss and fragmentation, drainage of wetlands, and impacts on freshwater and marine ecosystems through sedimentation and pollution. The Millennium Ecosystem Assessment confirmed that agriculture is the dominant terrestrial influence on ecosystems and that without major changes in current farming practices and agricultural landscape management, the agricultural frontier is likely to expand and many important biological habitats will be lost. By 2050, almost 40 percent of the land currently under low impact forms of agriculture could be converted to more intensive agriculture use with poor farmers being forced to open up ever more marginal lands, with further loss of biodiversity and ecosystem services (Sukhdev, 2008).

While some natural habitats have been successfully converted in the past to productive and sustainable agricultural lands (e.g. conversion of temperate forests in Europe to fertile farm lands), other ecosystems have much less fertile soils and cannot support long-term agriculture. Clearance of tropical forests on low-nutrient soils, for instance, provides new land for short-term crops but after a few years such lands lose their productivity and farmers are forced to clear more forests to open up new fields. Expanding agricultural encroachment in such regions is likely to lead to further cycles of land degradation and abandonment.

Although agriculture is the greatest threat to biodiversity, it is also highly dependent on soil biodiversity, agrobiodiversity (crop varieties) and the ecosystem services and benefits that natural habitats provide. Collectively, ecosystem services to agriculture include:

- Regulation of water flow for downstream agriculture.
- Nutrient cycling, such as decomposition of organic matter.
- Nutrient sequestration and conversion, as in nitrogen-fixing bacteria.
- Regulating soil organic matter and soil water retention.

- Regulation of pests and diseases.
- Maintenance of soil fertility and biota.
- Pollination by bees and other wildlife.

Understanding the contribution to agricultural productivity of ecosystem services generated by natural habitats and integrating protection of such wild areas into agriculture planning can contribute to sustained production even under uncertain climatic conditions – Box 4.1.

Box 4.1. Insects and Orange Juice: Paying for Ecosystem Services in Costa Rica

In Costa Rica, the Del Oro Company, a large producer of citrus juices, is leading the way in maintaining a balance between agriculture and nature. Its collaboration with the government of Costa Rica in conserving tropical Guanacaste National Forests ensures provision of essential forest ecosystem services to the plantations.

The Area de Conservacion Guanacaste (ACG) includes a range of tropical forest habitats including a belt of transition forests between the dry forests of Guanacaste and the wetter Caribbean rainforests. Approximately 1200 ha of the dry-wet transition forests form a wide peninsula extending into the Del Oro plantations, and adjoin the ACG forests at the southern boundary of Del Oro lands. Del Oro recognizes that the ACG provides essential ecosystem services, in the form of pollination and pest control, to the citrus plantations and its juice production industry. Through an agreement with the Ministry of Environment and Energy signed in August 1998, Del Oro agreed to pay for a number of such services listed below:

- Biological control agents, primarily parasitic wasps and flies of importance to integrated pest control, were valued at $1 /ha/yr for the 1685 ha of adjacent Del Oro orange plantations, for a total of $1,685/yr.
- Water from the upper Rio Mena basin, in the ACG, services Del Oro farms, and was valued at $5 /ha/yr for the 1169 ha totaling $5,885 /yr.
- Biodegradation of the orange peels from Del Oro on ACG lands was valued at $11.93/truckload, for a minimum payment of 1000 truckloads per year, for a total of $11,930/yr.

In addition, the agreement also leaves room for possible carbon fixation program in these 1200 ha of wild lands and stipulates that any carbon credits will be divided equally between Del Oro and the ACG. Under the contract, the plantation agrees to maintain good agricultural practices in its plantations according to the standards and legislation of Costa Rica and the US Food and Drug Administration. The Del Oro-ACG agreement provides an interesting model, illustrating how recognition of ecosystem services can play a valuable role in conservation and adaptation.

Source: Janzen, 1999.

Impacts of Climate Change on Agriculture

Changing climate and rainfall patterns are expected to have significant impacts on agricultural productivity, especially in arid and semi-arid regions. One study estimates that climate change could lead to a 50 percent reduction in crop yields for rain-fed agricultural crops by 2020. Most climate modeling scenarios indicate that the dry lands of West and Central Asia and North Africa, for instance, will be severely affected by droughts and high temperatures in the years to come. A greater frequency of droughts and flash floods has already been observed in recent years in these regions. These largely rain-fed agricultural areas are the most vulnerable to the impact of climate change.

According to crop-climate models, in tropical countries even moderate warming can reduce yields significantly (1°C for wheat and maize and 2°C for rice) because many crops are already at the limit of their heat tolerance. For temperature increases above 3°C, yield losses are expected to occur everywhere and be particularly severe in tropical regions (WDR, 2008b). Areas most vulnerable to climate change—centered in South Asia and Sub-Saharan Africa—also have the largest number of rural poor and rural populations dependent on agriculture. Global warming, and less predictable rainfall patterns, will impact especially on arid and semi-arid lands, many of which are already marginal for agriculture. Climate change will lead to water scarcity, increased risk of crop failure, pest infestation, overstocking and permanent degradation of grazing lands and livestock deaths. Such impacts are already imposing severe economic and social costs and undermining food security, and they are likely to get more severe as global warming continues. This makes climate change a core development problem, and ecosystem-based approaches a critical part of the solution – Box 4.2.

Box 4.2. Water Tanks for Irrigation in Andhra Pradesh, India.

In the Godavari River basin in India, home to 63 million people, nearly all rain falls in the monsoon from June to October, making storage essential for year-round water access. Poverty, limited water supplies, drought, costs of seed and farm chemicals, and iniquitous financing by suppliers jeopardizes the lives of many farmers, resulting in a wave of farmer suicides. Climate change adds uncertainty to the precipitation frequency and rate in the region, putting an immense additional burden on these farmers.

Ancient village earth dams (1-10 ha in size) which functioned as storage tanks in the past have now deteriorated due to sharp population rise, mismanagement and full diversion of river water. Loss of surface waters has driven over-exploitation of ground waters, further threatening security of supply. To meet the increasing demand for water in the region, the Andhra Pradesh Government proposed a US$ 4 billion Polavaram Dam on the lower Godavari River, that would displace 250,000 people, inundate key habitats – including 60,000 ha of forest – to supply irrigation water.

A WWF pilot project developed in 2004 in collaboration with a local NGO and villages assessed the costs and benefits of restoring the old water tanks. Between 2005-2006, in Sali Vagu sub catchment, on a tributary of the Godavari, 12 tanks with an area of 11 ha and serving 42,000 people were restored through de-silting. To capture and store more monsoon runoff, 73,000 tons of silt were removed from these tanks. The $103,000 intervention was undertaken with funding of merely $28,000 in cash from WWF and $75,000 from farmers in cash inputs and labor. The increased water supply and groundwater recharge resulted in less groundwater pumping. Water tables rose, reactivating some wells that had dried up, wells worth an average value of $2,330 each. An additional 900 ha was irrigated and the nutrient rich silt was spread over 602 ha. This increased crop yields significantly, increasing total production by Rs 5.8 million ($69,600) per annum. Irrigation of additional lands decreased the need for electricity for groundwater pumping, and wages paid for de-silting the tanks supplemented farmers' incomes. In addition, use of some ponds for fish production provided a further net profit of Rs 160,000 ($3,700). The tank restoration project also created artificial habitats for migratory and water birds.

The pilot project demonstrated the potential for tank restoration to meet India's soaring water demands, where feasible, in place of proposals for large-scale water infrastructure developments. In the Maner River basin there are 6,234 water tanks covering 588 km^2 that could be de-silted at an estimated cost of Rs 25.5 billion (US$635 million). These could store an extra 1,961 Mm^3 of water (compared to estimated water use in the basin today of 2,000 Mm^3 pa) at a cost of US$0.32/$m^3$. Further, this water would be stored widely across the basin where more people could access it. By contrast, the government's proposed $4 billion Polavaram Dam would store 2,130 Mm^3 irrigation water but at a cost of US$1.88/$m^3$.

Source: WWF, 2008.

The Bank's response to the threats presented by climate change to agriculture focus on both mitigation and adaptation efforts and can be divided into four strategic objectives:

- Monitoring impacts of climate change on crops, forests, livestock and fisheries (adaptation).
- Providing risk management strategies for farmers and lenders against climate change impacts (adaptation).
- Preventing crop and livestock losses due to changing climatic factors and increased pest pressure through improved management techniques and tolerant crop varieties/livestock breeds (adaptation).
- Improving land and resource management to prevent degradation of the sustainable production base (mitigation).

The Bank has a large and expanding agriculture portfolio. Few projects explicitly target biodiversity conservation or ecosystem services, although many promote more sustainable agricultural practices, such as rotational cropping, reduced tillage and soil conservation measures, which are more ecologically friendly and are designed to increase harvest yields. During the last decade the Bank has become engaged in developing a suite of pilot conservation projects that target agriculture in, and around, protected areas or in larger landscapes of conservation interest. Such projects usually try to change production practices to provide greater biodiversity benefits (such as promotion of shade coffee) or attempt to substitute other income-earning opportunities for harmful agricultural practices. A few projects have also promoted more ecosystem-friendly policies in the agricultural sector, such as promotion of integrated pest management in Indonesia to reduce dependence on high levels of pesticides.

In response to climate change, the Bank is encouraging more sustainable agriculture to avoid overgrazing and land degradation and promoting new agroforestry systems and multi-species cropping. Increased attention is also being paid to conserving agrobiodiversity in crop gene banks and to traditional agricultural practices, which maintain diversity of varieties and crops for food security – Box 4.3.

Box 4.3. Adaptation to Climate Change: Exploiting Agrobiodiversity in the Rain-fed Highlands of Yemen

Communities in the highlands in Yemen retain old crop varieties and traditional knowledge related to the utilization of these agrobiodiversity resources. This knowledge and practice has evolved over more than 2,000 years to increase agricultural productivity in areas of limited rainfall. The construction and management of terraces, for instance, helps to improve water use efficiency and minimize land degradation. Most of the landraces and local crop varieties have been selected to meet local needs and have adaptive attributes for coping with adverse environmental and climatic conditions. Yemen is considered an important primary and secondary center of diversity for cereals, so these crops are important genetic resources. This local agrobiodiversity is, however, threatened by global, national, and local challenges, including land degradation, climate change, globalization, anthropogenic local factors, and loss of traditional knowledge.

A $4 million GEF-supported project, currently under preparation, aims to enhance coping strategies for adaptation to climate change for farmers who rely on rain-fed agriculture in the Yemen highlands. The project focuses on the conservation and utilization of biodiversity important to agriculture (particularly the local landraces and their wild relatives) and associated local traditional knowledge. This GEF project will complement the Bank-IDA supported Rainfed Agriculture and Livestock Project. Since women do much of the farm work in Yemen the project will have a strong gender emphasis. The project will have four components:

- Agrobiodiversity and local knowledge assessment: Document farmers knowledge on (adaptive) characteristics of local landraces and their wild relatives in relation to environmental parameters to develop vulnerability profiles for the crops.
- Climate modeling assessment: Develop initial local predictive capacity of weather patterns, climatic changes, and longer term climate change scenarios for these rain-fed areas.
- Enhancement of coping mechanisms: Identify a menu of coping mechanisms (such as *in-situ* conservation, improved terracing with soil and water conservation practices, choice of crops and cropping patterns) designed and piloted to increase resilience of farmers to climate variability and reduce vulnerability to climatic shifts.
- Enabling policies, institutional and capacity development: Improve the capacity of key line agencies and stakeholders to collect and analyze data, improve climate predictions, and systems of information and information flow for enhanced uptake of coping mechanisms in the agricultural sector.

Sustainable Land Management

Land degradation diminishes biological diversity and many of the ecosystem goods and services on which human societies depend. Up to 75 percent of Africa's poor live in rural areas with livelihoods critically dependent on efficient use of increasingly scarce land, water, and nutrients. Land degradation marginalizes efforts to secure long-term food security, rural productivity, and development. Climate change is likely to put further stress on already fragile ecosystems. Desertification in some regions is already triggering large-scale migrations, instability, and violent conflicts over scarce resources.

As one of the leading financiers of measures aimed at combating land degradation and desertification, the Bank continues to invest in activities that promote appropriate sustainable land management (SLM) practices and protection of biodiversity and ecosystem. Regional and national investments planned under the TerrAfrica umbrella are expected to improve land use practices and carbon sequestration while promoting more sustainable land management and biodiversity. The Bank is already assisting several countries in sub-Saharan Africa, including Burundi, Ethiopia, Madagascar, Mauritania, Senegal and Senegal to integrate sustainable land management into poverty reduction strategies and investments to address land degradation. New carbon markets may also afford opportunities to invest in land rehabilitation, as well as more sustainable agricultural practices to restore productive agricultural systems and alleviate poverty. Studies have shown that ecosystem-based agriculture not only improves soil fertility and has fewer detrimental effects on the environment but can also produce equivalent crop yields to conventional methods – Box 4.4.

Box 4.4. **Conservation Farming in Practice in South Africa**

A GEF-funded MSP showed that conservation farming on some South African farms reduced input costs, increased profits, and improved sustainability. These farming practices also conserve biodiversity, contribute to carbon sequestration, and improve the quantity and quality of water flow.

Farming for flowers on the Bokkeveld Plateau

From the western rim to the eastern margin of the Bokkeveld Plateau, rainfall decreases from 500 mm to 200 mm per year over a distance of 15 km. Over this transition, the vegetation changes from fynbos on infertile sandy soils through renosterveld to succulent Karoo. The area supports about 1,350 plant species, 97 of which are endangered. The small village of Nieuwoudtville on the Bokkeveld Plateau is the “bulb capital of the world,” with a staggering 241 bulb species. The richest concentration of bulbs, both in terms of species and individuals, occurs on the highly fertile clays. Unfortunately, large areas of bulb-rich veld have been ploughed up and replaced with cereals and pasture crops.

About 30 years ago, one farmer—Neil McGregor, on the farm Glen Lyon,—decided that this form of agriculture was not sustainable. Instead, he began to nurture the indigenous veld to provide better plant cover. With the diversity of indigenous plants, McGregor was able to maintain productivity for much longer through the dry summer season than his neighbors did with their planted crops. By using biodiversity-friendly practices, and refraining from the use of pesticides, he was able to boost sheep productivity and reduce his inputs. Moreover, he found that aardvark and porcupine, considered troublesome on crop farms, actually promoted the proliferation of bulbs and hence forage for his livestock. Therefore, he abandoned attempts at controlling these so-called problem animals. One consequence of this conservation farming was unparalleled displays of wild flowers with a profusion of bulb species flowering from mid-winter through to late spring. These displays draw tourists to Namaqualand, catalyzing additional tourist income to the farm and district. Glen Lyon has become a role model in the region and many farmers are now following conservation farming practices. Recently Glen Lyon farm has been declared a national botanical garden in recognition of its biodiversity values.

Getting the most out of the veld

The semi-arid summer rainfall area of South Africa known as the Nama Karoo is characterized by highly variable rainfall from year to year. The natural veld comprises a very diverse flora of palatable shrubs and grasses, interspersed with unpalatable shrubs. This area also supports an extremely important livestock industry, based mainly on wool and mutton production. Over the last century, the condition of ranch land over much of the Nama Karoo has deteriorated, with proliferation of a few unpalatable species replacing more palatable species.

One farm in Elandsfontein in the Beaufort West district instituted a grazing regime that simulated pre-farming natural conditions when the veld was grazed by migrating herds of ungulates. Livestock were separated into small units and kept in one area until that area was well-grazed before being moved on. The condition of the veld improved. Livestock were forced to eat both palatable and unpalatable plant species. Since the unpalatable plants are not adapted to being grazed, they lose their competitive edge, become weakened, and their numbers reduced. The higher number of small management areas ensured a lengthened period between grazing, thereby enabling much of the range land to recover. Studies show that implementation of this system resulted in the highest productivity in the district, as well as ecological buffering and greater resilience of the veld against drought, with benefits both for biodiversity and production.

Source: Pierce et al., 2002.

As agricultural programs take account of climate change and changing rainfall patterns, there is an increasing emphasis on community-driven development. In Karnataka, India, farmers rely on rain-fed agriculture and a narrow range of two to five crops. Frequent droughts, and poor agriculture and watershed management has led to deterioration of lands further reducing their productivity. The Bank funded a project in 2001 in five districts to promote better management of the watershed and the associated natural resources. The project focused on soil and water conservation over 432,000 ha of arable and non arable land by introducing new approaches for community-based participatory planning. Project results included an increase in groundwater availability from four to six months and an increase in crop diversity and crop yield by 24 percent.

In Central America, the Bank has been supporting improved livestock management linked to payments for ecosystem services. The large-scale conversion of forests to pastures in Central America has resulted in the loss of biodiversity and the disruption of ecological processes. Pastures are often poorly managed and quickly become degraded, with reduced pasture productivity. Currently, at least 30 percent of the region’s pastures are considered to be degraded and are of little economic and ecological value. A Bank-funded project (Box 4.5), is exploring the relationships between silvopastoral systems, ecosystem services and farmer livelihoods to determine how silvopastoral systems contribute to both conservation and development goals. This research provides important information on more sustainable land management that can contribute to biodiversity conservation and carbon storage while improving farmers’ livelihoods.

Box 4.5. Payments for Environmental Services to Protect Biodiversity and Carbon in Agricultural Landscapes

Protecting biodiversity in agricultural landscapes is important both in its own right and as a means to connect protected areas, thus reducing their isolation. The challenge is finding ways to do so. The GEF -financed project, Regional Integrated Silvopastoral Approaches to Ecosystem

Management was implemented in Costa Rica, Nicaragua and Colombia from 2002-2008 as a pilot project to demonstrate and measure the effects of the introduction of payment incentives for environmental services to farmers. By the time it closed in January 2008, the project had clearly demonstrated that silvopastoral practices generate substantial benefits in terms of biodiversity conservation, carbon sequestration and water services, and that PES can induce substantial land use changes which are beneficial environmentally.

Silvopastoral production systems (SPS), which combine trees with cattle production, provide an alternative to current livestock production practices and can help improve the sustainability of cattle production and farmer income, while providing an environment that is also more hospitable to biodiversity. SPS supported by the project resulted in substantial carbon sequestration, both directly (by sequestering carbon in trees) and indirectly (by inducing lower applications of nitrogen fertilizers and, through improved nutrition, reducing methane emissions from livestock). SPS can also act as an adaptation measure to climate change, as they incorporate deeply-rooted, perennial, native and naturalized, multi-purpose and timber tree species that are drought tolerant and retain their foliage in the dry season. As such, they provide large amounts of high quality fodder and shade that results in stable milk and beef production, maintain the animals condition and secure farmers' assets. Under extreme climate change conditions affecting temperatures and rainy seasons, cattle ranching in pastures without trees would be more vulnerable than in those with trees.

Based on the documented results of this pilot project, new projects are under preparation in Colombia and Nicaragua, to scale up and adopt biodiversity-friendly SPS at a larger scale. The program will help to address climate change and its consequences in the livestock sector, among other environmental and socioeconomic benefits.

Managing Invasive Alien Species

Changing land use patterns and global warming will affect species distributions, exacerbate other environmental stresses, and may facilitate the establishment and spread of invasive alien species (IAS). IAS are now widely regarded as the second greatest threat to biodiversity after direct habitat destruction and fragmentation. Most introductions of exotic species to new environments have been facilitated by human agency either deliberately, for example, through agricultural introductions, or accidentally, for example, in the ballast water of ships. The spread of IAS is on the increase globally, facilitated by increasing trade, tourism, international traffic and even development assistance. Although IAS may provide some immediate short-term benefits, often there are long-term environmental and economic costs.

The threats to agricultural productivity posed by IAS (weeds, pests, and diseases of crops and livestock) have long been recognized. In recent years, understanding of the impacts of IAS on natural ecosystems, ecosystem services and wider human livelihoods has increased. For example, exotic plants can come to dominate freshwater bodies and waterways, affecting nutrient dynamics, oxygen availability, food webs, and fisheries. Other IAS, from microbes to mammals, poses a major threat to human health and livelihoods. The economic impacts of IAS are expensive, costing an estimated $140 billion annually in the United States. Water hyacinth in Lake Victoria costs around $150 million per year for control and removal, and threatens local fisheries; eradication of donkeys and goats that cause soil degradation from parts of the

Galapagos Islands to protect fragile ecosystems, endemic species and the local tourist economy costs more than $8 million annually (Murphy and Cheesman, 2006).

The introduction of new and adaptable exotic species for agriculture and to meet increasing demands for biofuels, mariculture, aquaculture, and reforestation presents a particular challenge. Ironically, in some cases, the very characteristics that make a species attractive for introduction under development assistance programs (fast-growing, adaptable, high reproductive output, tolerant of disturbance and a range of environmental conditions, are the same properties that increase the likelihood of the species becoming invasive. Development programs for agriculture, especially agroforestry programs and aquaculture, have thus facilitated both deliberate, and unintentional, spread of IAS. Such events are costly; indeed, their negative effects may be far greater, and longer lasting, than the positive impacts of the aid programs from which they arose. Invasives accidentally introduced through development assistance programs include itch grass, a major weed in cereals in South and Central America, and a range of nematode pests. Problems resulting from intentional introductions under development assistance programs include *Tilapia* fish for aquaculture in Central America and a number of agroforestry trees and shrubs.

The impacts of IAS on land and water management and agriculture will be greatest in some of the poorest countries, including those in Africa, where land degradation and food security are already major concerns. The Bank is working with the Global Invasive Species Programme (GISP) to better understand the implications of IAS on food production, food security and health, including assessment of best practice guidelines for avoiding the introduction of species known to be invasive. These capacity building efforts have been complemented by specific projects to control, manage, and eradicate IAS in South Africa (wattles and pines), Lake Victoria (water hyacinth), India, the Seychelles, and South and Central America.

Climate change is likely to exacerbate the spread of IAS, with serious environmental and economic consequences. Already, invasives are a serious problem in some vulnerable habitats such as the Cape Floristic Region (CFR) in South Africa. It is estimated that 43 percent of the Cape Peninsula alone is covered in alien vegetation, consuming up to 50 percent of the region's river runoff. The availability of freshwater is a key limiting factor to development in the Western Cape; where water is available, it is already fully utilized for agriculture, industrial and domestic use. It has been estimated that the spread of exotic trees in the mountain catchment areas surrounding Cape Town could reduce water resources for this rapidly-growing city by another 30 percent. These losses could mean that more (and expensive) dams have to be built to meet water demands. Economic studies have shown that clearing invasive species in the catchment areas will increase water production and deliver water supplies at much less cost than building a new reservoir – see Box 4.6 .

Box 4.6. Removing Invasive Species in South Africa: A Cost-Effective Solution for Increasing Water Supply

South Africa has a serious invasive alien plants problem that affects 10 million hectares (8.28 percent) of the country. These invasions come at a significant ecological and economic cost. Invasive species, with their high evapotranspiration rates, are an immense burden to already water scarce regions. A number of studies have analyzed the role of invasive alien plants in decreasing the amount of water available to reservoirs. In 2002, the South African government approved R 1.4-billion ($173.5 m) for the proposed Skuifraam Dam project on the Berg River near Franschhoek to help the looming water crisis in the Western Cape and Cape Town. A feasibility study for the planned dam demonstrated that water delivery would cost 3 cents **less** per kiloliter if invasive species are managed in the catchment area. It was estimated that clearing invasive plants from the Theewaterskloof catchment would deliver additional water at only 10.5 percent of the cost of delivery from the new Skuifraam scheme if no clearance was carried out. Accordingly, large-scale programs to clear invasive trees are being undertaken as part of management for the new Berg dam.

Source: Pierce et al., 2002.

Additionally, invasive plants in indigenous grasslands and scrublands increase fuel loads and fire risk, which leads to increased soil erosion, degradation and loss of biodiversity and ecosystem services in mountain catchments. The South African government has taken serious action to address these threats through the Working for Water and Working for Fire programs, which are collaborating with the Bank GEF CAPE program to better manage and control IAS in the CFR. Working for Water brings additional benefits in terms of increased employment opportunities for disenfranchised groups. Support to the Working for Water Program from the Bank's Development Marketplace has increased employment opportunities for marginalized people through small-scale industries that utilize the alien trees after harvesting.

Protecting Natural Ecosystems for Water Services

Water is essential for all life on Earth. Climate change impacts can be expected to have serious consequences on the availability and quality of water resources. Melting glaciers, higher intensity and more variable rainfall events, and increasing temperatures will contribute to increased inland flooding, water scarcity and decreasing water quality. Restoration and maintenance of watersheds, including management of soils, can contribute to reducing the risk of flooding and maintaining regular water supplies. Natural ecosystems such as wetlands and forests act as natural water recharge areas, storing runoff, recharging aquifers, and replenishing stream flows. This reduces flood risks associated with heavy rainfall or a glacier melt event. A study of upland forests in a watershed in Madagascar has estimated the annual flood protection value of these forests at $126,700 (Kramer et al., 1997) – Box 4.7.

Box 4.7. The Downstream Benefits of Forest Conservation in Madagascar

Economic analysis can be a useful tool for demonstrating the social benefits of protected areas and conservation. A World Bank study showed that the economic benefits of biodiversity conservation far outweigh costs in Madagascar. Sustainable management of a network of 2.2 million hectares of forests and protected areas over a 15-year period was estimated at $97 million (including opportunity costs forgone in future agricultural production) but would result in total benefits of $150–180 million. About 10–15 percent of these benefits are from direct payments for biodiversity conservation, 35–40 percent from ecotourism revenues, and 50 percent from watershed protection, primarily from maintaining water flows and averting the impacts of soil erosion on smallholder irrigated rice production.

The study considered potential winners and losers from forest conservation and pointed to the needs for equitable transfer mechanisms to close this gap, but emphasized that conservation will help to maintain or improve the welfare of at least half a million poor peasants. The study contributed to a government decision to increase forest protected areas to more than 6 million hectares in Madagascar. The Bank and other donors are helping to fund the expanded protected area network through the Third Environment Program, including capitalization of a conservation trust fund to provide sustainable financing. Carbon finance will also provide support to protect Madagascar's rich forests and the unique lemurs and other endemic fauna for which the island is famed.

Similarly, Sri Lanka's Muthurajawela marsh, a coastal peat bog covering some 3,100 hectares, is an important part of local flood control. The marsh significantly buffers floodwaters from the Dandugam Oya, Kala Oya and Kelani Ganga rivers and discharges them slowly into the sea. The annual value of these services was estimated at more than $5 million, or $1,750 per hectare of wetland area (Emerton and Bos 2004). Natural wetlands are also part of water treatment and flood control strategies in the Yangtze Basin in Hubei Province – Box 4.8.

Box 4.8. Lakes in the Central Yangtze River Basin, China

In 2000, the central Chinese government ordered all cities of more than 500,000 people to treat at least 60 percent of their wastewater. As part of that order, the government endorsed a $4.5 billion scheme to build 150 new wastewater treatment plants along the Yangtze River by 2009. A pilot plant for this project is located in Chongqing, in Sichuan Province. Chongqing, lies in the basin of Yangtze River and is the largest municipality in China, generating nearly 1 billion tons of untreated wastewater a year. The pilot plant has been operational for a year and provides primary treatment to more than 50,000 cubic meters of water per day. This treatment involves multiple screens that remove large debris and a UV disinfection mechanism that reduces microorganisms. Due to relatively high installation costs, the treatment plant does not include systems for removal of organic pollutants, or dissolved nitrogen and phosphorus, which increases the risk of nutrient pollution in the surrounding waters.

In the same river basin, water quality in the neighboring province, Hubei, has been deteriorating over the last 50 years. Within Hubei, however, natural ecosystems have been integrated into water treatment strategies. Previously, 757 out of 1,066 lakes had been converted to polders reducing wetlands area by 80 percent and flood retention capacity by 75 percent. Application of fertilizers to aquaculture pens had contributed to the lakes pollution. The loss of connection to the Yangtze River prevented diluting flows and migration of fish. Damage from four major floods between 1991 and 1998 resulted in up to thousands of deaths and billions of dollars in damages. To ameliorate these conditions, government agencies and NGOs have been restoring the wetlands in the basin, reconnecting the flows between the lakes and the Yangtze River. From 2004-2005 the sluice gates at lakes Zhengdu, Hong and Tien'e zhou have been seasonally re-opened and illegal and uneconomic aquaculture facilities and other infrastructure removed or modified. Now these 448 km^2 wetlands can store up to 285 Mm^3 of floodwaters, reducing vulnerability to flooding in the central Yangtze region. Cessation of unsustainable aquaculture, better agricultural practices, and reconnection to the Yangtze River has reduced pollution levels in these lakes. Pollution fell at Lake Hong from national pollution level IV (fit for agricultural use only) to II (drinkable) on China's five point scale. Healthy wetlands can also naturally remove organic and inorganic pollutants and supply clean water. Restoration of these wetlands provided more services than constructing wastewater treatment plants and at a considerably cheaper cost.

Rehabilitation of these wetlands has also considerably enhanced the biodiversity of the lakes. It has brought back twelve migratory fish species to the lakes. Hong Lake that supported only 100 herons and egrets when polluted, after restoration started supporting 45,000 wintering water birds, 20,000 breeding birds and the endangered Oriental White Stork. Similar positive results were seen in Tian'e zhou and Zhangdu lakes as well.

Source: WWF, 2008.

Rising temperatures and the increasing need for irrigated agriculture will all increase the pressure on scarce water resources. Overall, the greatest human requirement for freshwater resources is for crop irrigation, particularly for farming in arid regions and in the great paddy fields of Asia. In Asia, irrigated lowland agriculture in the large basins receiving their runoff from the Hindu Kush-Himalayan system is projected to suffer negatively from lack of dry season water. In South Asia, hundreds of millions of people depend on perennial rivers such as the Indus, Ganges, and Brahmaputra – all fed by the unique water reservoir formed by the 16,000 Himalayan glaciers. The current trends in glacial melt suggest that low flows will become substantially reduced as a consequence of climate change. In addition, an increase in agricultural water demand by 6 to 10 percent or more is projected for every 1 ˚C rise in temperature. As a result, and even under the most conservative climate projections, the net cereal production in South Asian countries is projected to decline between 4 to 10 percent by the end of this century (IPCC, 2007).

Retreating glaciers are also a serious concern in the Andes. As a part of the Adaptation to the Impact of Rapid Glacier Retreat in the Tropical Andes project that started in May 2008, the Bank is implementing, a water management plan in Peru that includes improvement of water storage infrastructure and improved water use practices in the agricultural and livestock sectors. In Bolivia, the project is incorporating the impact of rapid glacier retreat into integrated watershed management, devising an integrated pilot catchment management plan for watersheds, and mainstreaming adaptive river defenses for Huayhuasi and El Palomar settlements. The tropical Andes project, is including specific adaptation measures such as improved streamside conservation and management, and improved management of glacier buffer zones, adopting an ecosystem-based approach to adaptation. In Peru and Ecuador adaptation measures include forest protection, reforestation and forest regeneration activities aimed mostly at conserving natural ecosystems, to increase the resilience of forest ecosystems to the impacts of climate change. By restoring and harnessing ecosystem services, the project will decrease the risks of sudden floods due to glacier melt, provide alternative water storage options, and reduce erosion and siltation.

Natural Water Towers

Growing concern over water scarcity provides a powerful argument for protection of natural habitats and protected areas. Ecosystem-based approaches can form an integral part of strategies to maintain water supplies for agriculture and domestic use. Municipal water accounts for less than a tenth of human water use, but clean drinking water is a critical need.

Today, half of the world's population lives in towns and cities and one-third of this urban population live without clean drinking water. These billion have-nots are unevenly distributed: 700 million city dwellers in Asia, 150 million in Africa, and 120 million in Latin America and the Caribbean. With expanding urban needs, cities face immediate problems of access to clean water and mounting problems of supply.

Among the world's largest cities, 33 out of 105 obtain a significant proportion of their drinking water directly from protected areas (Dudley and Stolton, 2003). The cities include Jakarta, Mumbai (formerly Bombay), Karachi, Tokyo, Singapore, Mexico City, New York, Bogota, Rio de Janeiro, Los Angeles, Cali, Brasilia, Vienna, Barcelona, Nairobi, Dar Es Salaam, Johannesburg, Sydney, Melbourne, and Brisbane. Elsewhere, half of Puerto Rico's drinking water comes from the last sizable area of tropical forest on the island, which is in the Puerto Rico National Park. Quito, the capital of Ecuador, draws its water from a system of protected areas. Mount Kenya, the second highest mountain in Africa, is one of Kenya's five main "water towers" and provides water to over 2 million people.

In recent years, governments and city councils began to take an increasing interest in the opportunities for offsetting or reducing some of the costs of maintaining urban water supplies—and, perhaps even more importantly, water quality—through management of natural resources, particularly forests and wetlands. The Government of Spain is promoting reforestation of the Pyrenees to improve the quality of downstream water resources. Similarly, the values of watershed protection functions have been estimated in the Philippines at $223-455/ha/yr (Paris and Ruzicka, 1991). In Riverside, California, the local authorities have invested in rehabilitation of a natural wetland in lieu of building a denitrification facility at a considerable cost savings (Box 4.9).

Box 4.9. Wastewater Treatment with Wetlands

The Hidden Valley treatment wetland in Riverside, California, is an example of a treatment wetland. A regulatory revision required the city of Riverside to remove nitrogen from its wastewater. The cost of a conventional denitrification facility at the treatment plant was estimated at $20 million. After investigating alternatives, the city decided to employ a wetland system for nitrogen removal. A low-grade wetland infested with invasive, non-native vegetation near the treatment plant was cleared of invasives and rehabilitated to provide the treatment along with ecosystem benefits. The cost of constructing the 28 ha wetlands project was only $2 million, a savings of $18 million, 90 percent less than a conventional facility. The operation and maintenance costs of the wetland system are also more than 90 percent less than a conventional system. In operation since May 1995, the system has proven effective at nitrogen removal and has met all permit requirements. Furthermore, the wetland provides important ancillary benefits that could not be provided by a conventional facility. The wetland includes an interpretive center for environmental education and trails for recreational use that attract more than 10,000 visitors a year. It also supports wildlife habitat that is home to 94 bird species.

Source: Barrett, 1999.

Many mountain protected areas can be justified through provision of ecosystem services, such as clean water, soil conservation, and protection of downstream and vulnerable communities from natural hazards such as floods and unstable hillsides. A number of Bank projects have provided funding to protected areas in forest watersheds, which safeguard the drinking supplies for some of the world's major cities Panda reserves in the Qinling Mountains, China, protect the drinking water supplies for Xi'an. The Gunung Gede-Pangrango in Indonesia safeguards the drinking water supplies of Jakarta, Bogor, and Sukabumi and generates water with an estimated value of $1.5 billion annually for agriculture and domestic use. Similarly, Kerinci National Park in Sumatra safeguards water supplies for more than 3.5 million people and 7 million hectares of agricultural land, while two of the Andean protected areas in Ecuador provide drinking water supplies for 80 percent of Quito's population. The La Visite and Pic Macaya national parks in Haiti safeguard water supplies for the cities of Port au Prince and Les Cayes respectively. In Mexico, the Monarch Butterfly Reserve protects an amazing biological phenomenon and the drinking water of Mexico City. The Aberdare Mountains and Mount Kenya national parks in Kenya provide critical water to Nairobi, while the Udzungwas in the eastern arc mountains of Tanzania supply Dar es Salaam. Similarly a recent study in Mongolia has demonstrated that maintaining natural ecosystems in the Ulaanbaatar watershed to protect the city's water supplies makes more economic sense than allowing urban development to expand into the former reserve – Box 4.10.

Box 4.10. Protected Areas as Water Towers: Mongolia's least costly solution.

The wells that supply Ulaanbaatar with drinking and industrial water have almost reached their limits. Demand for water is fast outstripping supply. Seasonal water shortages are growing ever more common, and at some time within the next 10 years the city will face a critical shortfall in water availability. Ulaanbaatar derives its water from the Tuul Basin, which supplies water to Ulaanbaatar, has a catchment area of almost 50 thousand square kilometres, through which the river runs for a length of more than 700 kilometres. The Tuul River, its main tributary the Terelj, and another 40 smaller rivers, streams and lakes, are fed by rainfall, snowmelt and groundwater and drain the southern slopes of the Baga Khentii to the north east of the city.

Ecological conditions in the upper watershed have a direct link to the availability of surface water and groundwater downstream in Ulaanbaatar. Natural vegetation cover is particularly critical, as it influences rainfall interception, runoff and water discharge over the course of the year. The extent and quality of forests, grasslands and soil cover affect the Tuul River's mean flow and flow duration, influence the timing and intensity of peak and low flows, and determine the extent and rate of groundwater recharge. They also impact on the silt and sediment loads which are carried downstream. Basically, a healthy upstream ecosystem helps to ensure clean, regular and adequate river flow and groundwater resources for Ulaanbaatar.

A recent study shows that as the ecosystem is degraded and land cover is lost, average runoff will increase and the river's mean annual maximum and low flows will be intensified. Diminished discharge would lead to a lowering of the groundwater table of between 0.24 metres (under a continuation of the status quo) and 0.4 metres (under a scenario of rapid degradation). In 25 years' time, daily water supply in Ulaanbaatar would be reduced by some 32,000 and 52,000 cubic metres respectively. In contrast, conservation and sustainable use of the upper watershed would protect current river flow and groundwater levels. Weighing up the gains (sustained water supplies to Ulaanbaatar) and losses (reduced land values in the upper watershed) conservation of natural habitats in the Upper Tuul is the most economically beneficial future management scenarios. The conservation and sustainable use scenario yields a net present value, over 25 years, of $560 million. This is higher than the net present values generated under either a continuation of the status quo or a scenario of rapid ecosystem degradation.

Source: Emerton et al., 2009.

Chapter 5. Implementing Ecosystem-based Approaches to Climate Change

Climate change has become the key environmental concern of the decade. Much attention is rightly focused on reducing carbon emissions and greenhouse gases from transport and energy sectors through reduction in fuel use and improved technologies. Nevertheless, as countries look to medium and longer-term mitigation and adaptation measures, protection of natural habitats must be a key part of climate change strategies. The world's poorest people, who depend directly on the services that various ecosystems provide, are also the most vulnerable to the effects of climate change. This makes conservation of biodiversity, and the services that healthy ecosystems provide, a triple-A investment. Healthy ecosystems can reduce vulnerability to climate shocks; protect the web of life on which people depend for goods and services; and increases local and national resilience to the impacts of climate change.

The Bank has access to several instruments and financing mechanisms which can assist client countries to incorporate ecosystem-based solutions into climate mitigation and adaptation strategies. These include Bank programs and projects, DPLs, the Bank's Strategic Framework for Climate Change and Development (SFCCD) and new Environment Strategy (under preparation) as well as assistance to countries for economic sector work, strategic environmental assessments (SEA), Poverty Reduction Strategy Papers and National Adaptation Strategies. In addition to Bank lending and GEF grants the Bank is also facilitating the development of market-based financing mechanisms and piloting new avenues to deepen the reach of the carbon market.

Looking Forward: The Strategic Framework for Climate Change and Development

The Bank recognizes that global efforts to overcome poverty and advance sustainable development must address climate change and its economic, environmental and social implications. In order to efficiently address these questions, the SFCCD seeks to examine climate change from a multi-sectoral and multi-faceted perspective, institution-wide. The SFCCD consists of the following six action pillars:

- Support climate actions in country-led development processes;
- Mobilize additional concessional and innovative finance;
- Facilitate the development of market-based financing mechanisms;
- Leverage private sector resources;
- Support accelerated development and deployment of new technologies;
- Step up policy research, knowledge, and capacity building.

In addition to focusing on immediate actions to promote cleaner and renewable energy, the SFCCD recognizes that ecosystems and biodiversity provide essential services that underpin every aspect of human life, including food security, carbon storage, climate regulation, livelihoods, ethnic diversity, and cultural and spiritual enrichment. Enhanced protection and management of natural habitats and biological resources can contribute to climate change mitigation; they also provide *effective* and *low-cost* options to reduce vulnerability and adapt to climate change.

Bank projects and programs are already supporting biodiversity conservation and protecting natural habitats and ecosystem services, thereby contributing to effective mitigation and adaptation strategies. Nevertheless the Bank could, and should, support a stronger focus on ecosystem management as part of an explicit response to climate change, including:

- Protecting terrestrial, freshwater, and marine ecosystems and ecological corridors to conserve terrestrial and aquatic biodiversity and ecosystem services.
- Integrating protection of natural habitats into strategies to reduce vulnerability and disaster risks (including protection from natural hazards such as floods, cyclones and other natural disasters).
- Scaling up country dialogue and sector work on valuation of ecosystem services and the role of natural ecosystems, biodiversity and ecosystem services in underpinning economic development.
- Emphasizing the linkages between protection of natural habitats and regulation of water flows and quality of water, essential for agriculture, food security, and domestic and industrial supplies.
- Scaling up investments for protected areas and natural ecosystems linked to sector lending, such as infrastructure, agriculture, tourism, water supply, fisheries, forestry.
- Promoting greater action on management of invasive alien species, which are linked to land degradation, and impact negatively on food security, and water supplies.
- Emphasizing the multiple benefits of forest conservation and sustainable forest management (carbon sequestration, water quality, reducing risks from natural hazards, poverty alleviation, biodiversity conservation).
- Promoting investments in natural ecosystems as a response to mitigation (avoided deforestation) and adaptation (wetland services).
- Integrating indigenous crops and traditional knowledge on agrobiodiversity and water management into agricultural projects as part of adaptation strategies.
- Promoting more sustainable natural resource management strategies linked to agriculture, land use, habitat restoration, forest management and fisheries.
- Developing new financing mechanisms and integrating ecosystem benefits into new adaptation and transformation funds.
- Using strategic environment assessments as tools to promote protection of biodiversity and ecosystem services.
- Monitoring investments in ecosystem protection within mainstream lending projects and documenting good practices for dissemination and replication.
- Developing new tools to measure the benefits of integrated approaches to climate change (ecosystem services, biodiversity conservation, carbon sequestration, livelihood co-benefits and resilience).

Growing Forest Partnerships

In collaboration with FAO and IUCN and with technical support from the International Institute for Environment and Development (IIED), the Bank is supporting the implementation of the Growing Forest Partnerships (GFP) initiative, which was informed by an independent, global consultation of over 600 forest stakeholders, including a special survey of Indigenous Peoples. The GFP aims to facilitate bottom-up, multi-stakeholder partnership processes in developing countries to identify national priorities, to better access the increasing forest financing being made available through a wide variety of international means and mechanisms, for example, carbon finance, private sector investments, and overseas development assistance (ODA). The

GFP aims to provide a platform to ensure that marginalized, forest-dependent groups can participate in the formulation of national priorities and be included in the international dialogue on forests. The GFP will work through locally-based institutions and will build on existing partnership structures. The Bank is supporting this initiative with start-up funding from the Development Grant Facility.

The GFP will provide a platform to achieve progress in the following target areas by the year 2015: (a) creating an enabling environment for carbon-based forestry activities (b) promoting the use of forests for poverty alleviation under conditions of climate change; (c) significant growth in sustainably managed, and legally traded, forest products and the expansion of the area of responsibly managed forests; (d) an increase in the establishment, management, and financial sustainability of protected forest areas; and (e) a decrease in area of primary forest converted to alternative land uses. The GFP will facilitate and scale up activities associated with the implementation of the Bank's Forest Strategy. It will link existing and new partnership programs that promote enabling conditions in the forest sector (for example, the Forest Law Enforcement and Governance Initiative, the Multi-donor Program on Forests) with the Bank's existing lending and financial instruments, as well as new sources of concessional financing .

Developing Financing Mechanisms to Support Ecosystem-based Approaches

There is growing consensus between the Parties to the international conventions on Climate Change (UNFCC) and Biological Diversity (CBD) for strengthened conservation and management of natural ecosystems as part of climate change response strategies. The Ad Hoc Technical Group (AHTEG) on Biodiversity and Climate Change was established to provide biodiversity-relevant information to the UNFCCC through the provision of scientific and technical advice and assessment on the integration of the conservation and sustainable use of biodiversity into climate change mitigation and adaptation activities. The AHTEG has emphasized the key roles that natural ecosystems can play in mitigation and adaptation to climate change and in protecting ecosystem services. Nevertheless a key challenge remains – how to reward countries that conserve these natural ecosystems and provide global services.

Currently very few markets exist to provide financial benefits for improved management of natural ecosystems in the context of climate change and most opportunities have come about through the voluntary carbon markets. The Clean Development Mechanism (CDM) under the Kyoto Protocol, for instance, gives carbon credits for forestation and re-forestation projects (including natural forest regeneration) but makes no provision for protecting standing forest and other intact natural habitats. The Bank has been a leader in promoting innovative new financing mechanisms to protect natural ecosystems for carbon sequestration and biodiversity benefits. Initiatives, such as the BioCarbon Fund and the Forest Carbon Partnership Facility, afford opportunities to protect forests for carbon sequestration and other multiple benefits, including conservation of biologically-rich habitats, and greater community benefits from forest management and watershed protection. New opportunities also exist through the GEF Adaptation Fund and linkages to new Bank programs such as the Global Facility for Disaster Reduction and Recovery.

Under the ***BioCarbon Fund****,* the Bank is working through existing carbon markets to bring new revenue streams to rural communities through reforestation, currently the only land use or forestry activity allowed under the CDM. Through the BioCarbon Fund, the Bank has committed to purchase emissions reductions from 17 reforestation projects in developing countries, all of them expected to also generate biodiversity benefits. The BioCarbon Fund is also pioneering carbon credits for soil and agriculture carbon. This is currently an activity that is not allowed under the CDM but is being discussed by the UNFCCC. This would further the penetration of the carbon markets to rural communities. At the same time the BioCarbon Fund is working on the methodologies to allow a robust system of carbon payments and is piloting activities in Kenya.

Climate Investment Funds

Recognizing that a future financial architecture still has to be developed and agreed for climate change interventions post 2012, the World Bank, jointly with the Regional Development Banks and in consultation with developed and developing countries and other stakeholders, has developed the Climate Investment Funds (CIFs). These are an interim measure to scale up assistance to developing countries to address climate change and to strengthen the knowledge base in the development community. The World Bank Board of Executive Directors formally approved the creation of the Climate Investment Funds (CIFs) in July 2008.

The CIF umbrella covers two funds, the Clean Technology Fund and the Strategic Climate Fund (SCF). Two of the pilot programs under the SCF are the Forest Investment Program and the Pilot Program for Climate Resilience (PPCR). The PPCR will be implemented in eight vulnerable countries. It will demonstrate ways of integrating climate risk and resilience into core development planning. The PPCR will be country-led, and will enable pilot countries to transform country-specific plans and investment programs to address climate risks and vulnerabilities. For most of these selected countries, improved management of ecosystems and natural resources are important components of building resilience and reducing vulnerability in targeted sectors – see Table 5.1.

Table 5.1 shows how PPCR countries can benefit from ecosystem protection to achieve resilience to climate change

	Food Security	Infrastructure	Carbon Sequestration	Water Security	Coastal Zone Management
Bangladesh	√	√	√		√
Bolivia	√			√	
Cambodia	√	√	√		√
Mozambique	√			√	√
Nepal	√		√	√	
Niger	√				
Tajikistan	√			√	
Zambia	√		√		

Food Security: Ecosystem-based approaches include agroforestry practices; implementing crop rotations; choosing crops with less intensive in nutrient and water requirements; controlling invasive alien species; maintaining local landraces and crop varieties; and protecting reefs and mangroves for sustainable fisheries.

*Infrastructure***:** planning to protect natural habitats and ecological connectivity; incorporate protection of natural ecosystems into coastal defences and flood control rather than rely solely on infrastructure such as sea walls and drainage canals; accommodate ecological flows and ecosystem functions in reservoir and dam design.

*Carbon Sequestration***:** Reduction of carbon emission through ecosystem-based approaches e.g. establishment of new protected areas and improved management of existing reserves; protection of old growth and swamp forests and wetlands; natural regeneration of forests, reforestation and Afforestation.

*Water Security***:** Ecosystem-based approaches including watershed and forest protection; incorporation of wetlands in water treatment and water quality improvement initiatives; wetlands for water storage and flood control purposes.

Coastal Zone Management: Incorporate mangroves and other coastal wetlands into storm protection and coastal defence; protect mangroves, sea grass beds and coral reefs for sustainable fisheries; promote Integrated coastal management that prevents pollution of marine and coastal environment.

Reducing Emissions from Deforestation and Degradation

Forestry, land use change, and agriculture are major issues for climate change, accounting for almost 45 percent of emissions in developing countries. Reducing emissions from deforestation and forest degradation (REDD) has been identified as one of the most cost-effective ways to lower emissions (Stern, 2006). Under the CDM of the Kyoto Protocol, countries currently cannot receive credits for REDD. However, REDD holds promise for linking carbon to improved biodiversity conservation and other co-benefits since it relies on protection and improved management of natural forests.

There is some controversy over how REDD should be funded and how emissions will be measured and monitored. Ascertaining deforestation trends is difficult, especially if payments are linked to incremental reductions in deforestation rates. The IPCC has provided guidelines for monitoring and measuring GHG emissions from deforestation and forest degradation and more recently the World Bank and UNEP have presented a concept paper to GEF to develop standard measures and models for carbon sequestration and storage. A trading mechanism would allow developing countries to sell carbon credits on the basis of successful reductions in emissions from deforestation; such credits would probably relate to national scale emissions rather than being linked to individual sites. Any such mechanisms could generate significant additional funding for forest protection, perhaps as much as $1.2 billion a year. This is considerably more than the estimated $695 million annually spent on all protected areas (not only in forest ecosystems) in developing countries annually. In contrast forestry exports from the developing world were worth over $3.9 billion in 2006. REDD could provide strong incentives for forest conservation but is unlikely to benefit all forests equally. For REDD to make a successful contribution to combating climate change, countries would need to target threatened forests with a high volume of carbon in their biomass and soils. Priority sites for tackling deforestation to reduce emissions may not always reflect other forest values e.g. biodiversity conservation, livelihood benefits, or water delivery (Miles and Kapos, 2008).

One obvious risk associated with REDD is the displacement of pressures resulting from continuing demand for land for agriculture, timber, and even biofuels, to ecosystems with low carbon values, either less carbon-rich forests or non-forest ecosystems such as savananas or wetlands. Another key issue is the question of "who owns carbon?" and who should benefit from any carbon credits, national governments or the local communities and indigenous groups who manage and protect those forest and are dependent on them for their livelihoods. Assuring the equitable distribution of revenues gained from carbon credits to communities affected by improved forest protection may prove to be a key challenge of REDD implementation – Box 5.1. Implementing REDD successfully will require agreement on clear goals, eligibility criteria and prioritization as well as strong national and international capacity to monitor, manage and evaluate performance over time.

Box 5.1. Principles for Leveraging Co-Benefits from REDD for the Poor

1. Information provision
Basic details of how REDD mechanisms work, realistic expectations of benefits and possible implications of different approaches are required.

2. Provision of upfront finance and use of mechanisms for reducing costs
Provision of upfront finance would significantly improve equity of benefit distribution; for example, at community levels, some options for self-financing could be explored such as improved agricultural production, non-farm employment and revolving credit programmes.

3. Use of 'soft' enforcement and risk reduction measures
'Hard' enforcement measures such as financial penalties are likely to affect the poor disproportionately. Instead, 'soft' measures such as non-binding emissions reduction commitments should be applied where possible.

4. Prioritize 'pro-poor' REDD policies and measures and long time horizons
Stable and predictable benefits would provide increased security to the poor.

5. Provide technical and legal assistance
To ensure 'voice and choice', improved access to appropriate legal support is crucial for poor people.

6. Maintain flexibility in the design of REDD mechanisms
Flexibility is crucial in order to minimize risks such as communities being locked into inappropriate long-term commitments.

7. Clear definition and equitable allocation of carbon rights
Rights to own and transfer carbon will be essential, and such rights are likely to govern land management over long timescales.

8. Development of social standards
Social standards would improve benefits for the poor by ensuring that processes are transparent. Standards should also be developed for ongoing social impact assessments.

9. Applying measures to improve the equity of benefit distribution

Issues such as baseline setting, risk aversion and cost effectiveness can lead to variable benefit distribution.

10. Alignment with international and national financial and development strategies
Aligning REDD schemes with existing development processes such as Poverty Reduction Strategies (PRSPs) would help to raise the profile of the poor.

Source: Peskett et al., 2008.

Forest Funds

Recognizing the importance of the REDD mitigation strategy, the World Bank established the Forest Carbon Partnership Facility (FCPF)to build the capacity of developing countries in the tropics to tap into financial incentives for REDD under future regulatory or voluntary climate change regimes. The FCPF has dual objectives: to build capacity for REDD in developing countries, and to test performance-based incentive payments on a relatively small scale in some pilot countries. The FCPF became operational in June 2008 with the start of operations of the Readiness Mechanism, which was triggered by the Readiness Fund having been capitalized at the required minimum ($20 million); today donors have contributed $55 million to the Readiness Fund and $21 million to the Carbon Fund. The Readiness Fund will finance activities designed to (a) establish a national reference scenario for emissions; (b) adopt national REDD strategies; and (c) design national monitoring systems.

Initially 25 countries were accepted into the Facility: Cameroon, the Democratic Republic of Congo, Ethiopia, Gabon, Ghana, Kenya, Liberia, Madagascar, Republic of Congo, Uganda (Africa); Argentina, Bolivia, Colombia, Costa Rica, Guyana, Mexico, Nicaragua, Panama, Paraguay, Peru (LAC) ; Lao PDR, Nepal, Papua New Guinea, Vanuatu and Vietnam (Asia). As of March 2009, 12 more countries have been added to the list, bringing the total number of REDD country participants to 37.

Box 5.2. Can Carbon Markets Save Sumatran Tigers and Elephants?

Riau Province in central Sumatra harbors populations of the critically endangered Sumatran tiger and the endangered Sumatran elephant within a high-priority Tiger Conservation Landscape. Riau has lost 65 percent of its original forest cover and has one of the highest rates of deforestation in the world, due to loss and conversion of forest for agriculture, pulpwood plantations and for expanding industrial oil-palm plantations to serve the surging biofuels market. If the current rate of deforestation continues, estimates suggest that Riau's natural forests will decline from 27 percent today to only 6 percent by 2015. All of this comes at a global cost. The average annual CO_2 emissions from deforestation in Riau exceed the emissions of the Netherlands by 122 percent and are about 58 percent of Australia's annual emissions. Between 1990 and 2007, Riau alone produced the equivalent of 24 percent of the targeted reduction in collective annual greenhouse gas emissions set by the Kyoto Protocol Annex I countries for the first commitment period of 2008–12.

Can carbon trading provide a new economic incentive to protect Riau's forests, especially the carbon-rich peat swamp forests? At present, countries do not get rewarded for retaining forest canopy (avoided deforestation)—the emphasis is on afforestation. Second, although there are new programs under consideration to provide incentives for conserving forests, the prevailing price of carbon may be too low to shift incentives from clearing for biofuels or pulp to conservation. Third, even if the price of carbon rises sufficiently, Riau's forests may not get priority over other forests with higher carbon sequestration potential since the proposed new systems pay only for carbon with little attention to the biodiversity value of forests.

Yet carbon markets may have potential to promote conservation in less productive lands. In parts of South Asia the returns (present value) of arable land are often as low as $100 to $150 per hectare. Clearing a hectare of tropical forest could release 500 tons of CO_2. At an extraordinarily low carbon price of even $10 per ton of CO_2, an asset worth $5,000 per hectare is being destroyed for a less valuable land use. A modest payment through avoided deforestation schemes could be sufficient to shift incentives in some of the unproductive arable land in South Asia.

Source: Damania et al., 2008.

Within the framework of the Strategic Climate Fund, targeted programs can be established to provide financing to pilot new development approaches or scaled-up activities aimed at a specific climate change challenge or sectoral response. The Forest Investment Program, proposed at the June 2008 CIF design meeting in Potsdam, Germany is a program under the SCF that will mobilize significantly increased investments to reduce deforestation and forest degradation, and promote improved sustainable forest management, leading to emission reductions and the protection of carbon reservoirs. The FIP will take into account country-led priority strategies for the containment of deforestation and degradation and build upon complementarities between existing forest initiatives.

Apart from carbon and climate funds administered through the WBG, the Bank is collaborating with the *Congo Basin Forest Fund* led by the African Development Bank (AfDB) to build national and local capacity for sustainable forest management in the Congo Basin and with the *Norwegian International Climate and Forest Initiative* launched in December 2007 to reduce GHG from deforestation of tropical forests in developing countries. The Bank is also represented on the steering committee of UN REDD. The first phase of UN REDD, with financial contributions from Norway, will help develop national strategies, establish systems for monitoring forest cover and biomass and report on emission levels and general administrative capacity building in selected pilot countries (Bolivia, Democratic Republic of Congo, Indonesia, Panama, Papua New Guinea, Paraguay, Tanzania, Vietnam and Zambia). The Bank is also collaborating with The Prince of Wales Rainforest Trust on proposed REDD initiatives and the creation of green bonds to fund future investments in tropical forest conservation.

This wide range of forest initiatives and new financing mechanisms provide exciting opportunities for improving conservation and management of natural ecosystems, especially tropical forests, with expected associated benefits for many species, habitats and ecosystem services. Nevertheless it is unlikely that any international mechanism linked to the UNFCCC will explicitly support forest ecosystem services other than carbon storage. Under such circumstances it may be more efficient to focus limited conservation funds on non-forest ecosystems or forests with low carbon content rather than on high biodiversity forests that could be covered by REDD mechanisms.

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Annex 2. Securing Carbon Finance @ the World Bank: Minimum Project Requirements

Type of Project

- Greenhouse gases targeted should be those covered under the Kyoto Protocol (CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6).
- The Carbon Finance Unit, in accordance with the Marrakesh Accords, can support afforestation and reforestation projects in non-Annex I countries, and a whole range of land use, land-use change and forestry projects in Annex I countries.

Adequate Emission Reductions (ERs) Volume

- The ER volume must be big enough to make a project viable under the CDM -- for example, a small-scale project should generate a minimum threshold of 50,000 tCO_2e/year.

Demonstration of Additionality and Determination of Baseline Scenario and Emission Reductions

- Why the project should not happen on its own? (does project have significant barriers, or is not the most economically attractive)
- What could have happened in the absence of the project?
- Sources of emission reductions and total ER volume

Competent Project Participants and Clear Institutional Arrangement

- Technically experienced and sound project developers with clear division of functions.
- Demonstration of sound legal arrangement -- for example, who owns, who operates, and what type of agreement between project participants as well as with third party (e.g. power purchase agreement, ownership agreement, water right)

Viable Business and Operation Model that Helps Reduce Transaction Costs

- Potential for scale-up
- Involvement of intermediaries who can invest, bundle, and implement project-related CDM services locally

Ratification of Kyoto Protocol by the Host Country

- Has the host country ratified the KP or expressed its intention to ratify the KP in due course?
- Project should identify specific locations for its implementation.

Financing Sought

- The World Bank Carbon Finance Unit will not provide debt and/or equity finance for the baseline component of the project. The baseline component of the project should be financed by other sources;
- Payment on delivery of Emission Reductions.

Sound Financing Structure

- Sound financial health of project sponsors and co-financiers.
- The sooner the project can achieve financial closure, the better the chances of selection are

Technical Summary of Project

- Project should be replicable and/or facilitate technology transfer for the country;
- Technology to be applied must be an established and commercially feasible one in somewhere other than the country in consideration; and
- Project proposal should contain sample cases of the technology applied in the past in order to show its commercial feasibility.

Expected Environmental Benefits

- Evidence should be given that the project is additional to the baseline or reference scenario, which represents the most likely or business-as-usual scenario in the country.

Safeguard Policies of the World Bank Group

- The Bank Group has a body of well-developed, mandatory Safeguard policies which apply to all World Bank operations, as well as an extensive set of good practices. These are applied to CFU operations to ensure that they are environmentally and socially sound, whether baseline financing is from the Bank Group or from a third party project supplier. The project must be consistent with these safeguard policies and the host country's overall sustainable development framework.

Contribution to Sustainable Development

- As defined by the host country. For some end-of-pipe type projects, contribution to sustainable development can be manufactured through re-investment in host community of some revenues from carbon finance.