UNITED
NATIONS

EP

United Nations
Environment
Programme

UNEP

UNEP (DEPI)/RS.10 /INF.7.RS

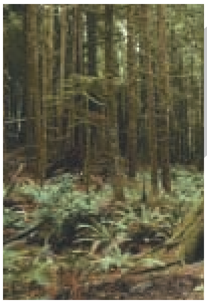
Original: ENGLISH

10th Global Meeting of the Regional Seas
Conventions and Action Plans
Guayaquil, Ecuador, 25th– 27th November 2008

INTERLINKAGES BETWEEN BIOLOGICAL DIVERSITY AND CLIMATE CHANGE

Secretariat
of the Convention on
Biological Diversity

CBD Technical Series No. 10



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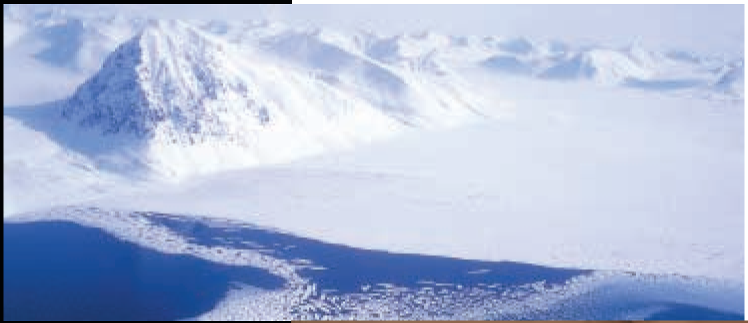

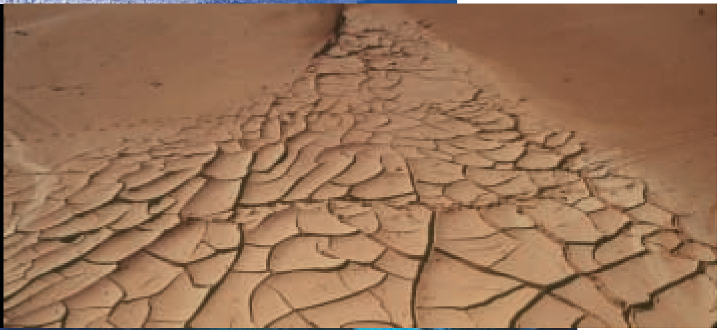

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Ad hoc **Technical Expert Group on Biological Diversity and Climate Change**

October 2003

Published by the Secretariat of the Convention on Biological Diversity. ISBN: 92-807-2389-8

Citation
Secretariat of the Convention on Biological Diversity (2003). Interlinkages between biological diversity and climate change. Advice on the integration of biodiversity considerations into the implementation of the United Nations Framework Convention on Climate Change and its Kyoto protocol. Montreal, SCBD, 154p. (CBD Technical Series no. 10).

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FOREWORD BY THE EXECUTIVE SECRETARY

The human pressure on our planet's natural systems is unprecedented. Loss of biological diversity threatens to unravel the intricate ecosystems that life of Earth depends. Climate change is having profound and long-term impacts on human welfare and adds yet another pressure on terrestrial and marine ecosystems that are already under threat from land-use change, pollution, over-harvesting, and the introduction of alien species.

At the 2002 World Summit on Sustainable Development (WSSD), the world's leaders reaffirmed the need to tackle these issues and endorsed the target set by the Convention on Biological Diversity's Conference of the Parties to achieve, by 2010, a significant reduction in the rate of loss of biological diversity. The World Summit also reaffirmed the central importance of the Convention on Biological Diversity and the United Nations Framework Convention on Climate Change—the conventions adopted at the Rio Earth Summit 10 years earlier—in addressing these issues.

The objectives of these two conventions are closely inter-related:

- Climate change is a major cause of biodiversity loss and one of the obligations under the Convention on Biological Diversity (CBD) is to identify and address such threats. At the same time, the ultimate objective of United Nations Framework Convention on Climate Change (UNFCCC) includes the stabilization of greenhouse gas concentrations within a timeframe sufficient to allow ecosystems to adapt to climate change;
- Biodiversity management can contribute to climate change mitigation and adaptation and to combating desertification. Indeed, the UNFCCC calls for the conservation and enhancement of terrestrial, coastal and marine ecosystems as sinks for greenhouse gases;
- Both conventions, as well as the United Nations Convention to Combat Desertification, are intended to contribute to sustainable development.

The impacts of climate change on biodiversity are of major concern to the Convention on Biological Diversity. The Conference of the Parties has highlighted the risks, in particular, to coral reefs and to forest ecosystems, and has drawn attention to the serious impacts of loss of biodiversity of these systems on people's livelihoods. More recently, the Conference of the Parties has also turned its attention to the potential impacts on biodiversity and ecosystems of the various options for mitigating or adapting to climate change and requested the Convention's Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA) to develop scientific advice on these issues.

SBSTTA established an ad hoc technical expert group to carry out an assessment of the inter-linkages between biodiversity and climate change. The results are contained in the present report, which draws upon best available scientific knowledge, including that provided by the Intergovernmental Panel on Climate Change.

The report concludes that there are significant opportunities for mitigating climate change, and for adapting to climate change while enhancing the conservation of biodiversity. However, these synergies will not happen without a conscious attention to biodiversity concerns. The report identifies a wide range of tools that can help decision makers assess the likely impacts and make informed choices.

The report provides the scientific basis for the development of recommendations, as appropriate, under each Convention, for setting priorities for future research. I hope that it will also be used widely by countries as they seek to implement policies, programmes and activities under the Convention on Biological Diversity and the United Nations Framework Convention on Climate Change.

This report is a tangible product of cooperation among the Rio conventions. I trust that it will prove to be a useful step in promoting implementation of the three Rio Conventions in a mutually supportive manner.

Hamdallah Zedan
Executive Secretary

Acknowledgements

First of all, I wish to thank all members of the Ad Hoc Technical Expert Group on Biological Diversity and Climate Change whose expertise contributed to the preparation of this report, as well as those persons from major agencies and institutes, intergovernmental and non-governmental organizations who also provided with substantial inputs in various chapters. I also want to thank the Group co-chairs, Ms. Outi Berghäll and Mr. Robert Watson for their valuable efforts, as well as to the coordinators of the substantive chapters: Mr. Braulio Dias, Ms. Habiba Gitay, Mr. Horst Korn, Mr. Phocus Ntayombya, Mr. Robert Watson, and Ms. Kanta Kumari. The Secretariat also wishes to thank the Government of Finland for its financial support to carry out the first and third meetings of the Group, which also benefited from the gracious cooperation of the staff of the Finnish Environment Institute in Helsinki.

I also express my gratitude to those Governments, intergovernmental and non-governmental institutions, and scientists who contributed their time to the review of a draft version of this report. The following experts provided comments on the draft report: Rosemarie Benndorf, Pam Berry, Lenny Bernstein, David Cooper, John Dixon, Peter C. Frumhoff, Sandy Gauntlett, Mike Harley, Lee Hannah, Mikael Hildén, Floyd Homer, Lesley Hughes, Bryan Huntley, Joy Kim, Jyrki Luukkanen, J. Piers Maclaren, Anita Mäkinen, Petra Mahrenholz, John Parrotta, Lucio Pedroni, Hannah Reid, M. J. Sanz, Ernst-Detlef Schulze, John Stone, Gijs van Tol, Jussi Uusivuori, Liette Vasseur, Henry Venema, Markus Vinnari, Clive Wilkinson, Edgard Yerena, Lewis Ziska. Also, the Governments of Argentina, Austria, Brazil, Canada, Finland, Germany, Italy, Japan, New Zealand, Norway, Spain, Sweden, Switzerland, The Netherlands, United Kingdom, United States of America, and Uzbekistan reviewed the draft report. Finally, valuable observations were provided by the following organizations: FAO, Forests and the European Union Resource Network (FERN)-U.K. and Belgium, Friends of the Siberian Forests, Greenpeace, SOLJUSPAZ, Pacific Indigenous Peoples Environment Network, Center for Environmental Law and Community Rights, FOA PAC, Friends of the Earth Japan, and Friends of the Earth International.

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EXECUTIVE SUMMARY

A. Biodiversity and linkages to climate change

Biological diversity includes all plants, animals, microorganisms, the ecosystems of which they are part, and the diversity within species, between species, and of ecosystems [1]. No single component of biodiversity (i.e., genes, species or ecosystems) is consistently a good indicator of the overall biodiversity as these components can vary independently. Functional diversity describes the variety of ecological functions of species or groups of species in an ecosystem. It is a biodiversity descriptor that provides an alternative way of understanding biological diversity, and the effects of disturbances caused by human activities, including climate change, on ecosystems.

Biodiversity is determined by the interaction of many factors that differ spatially and temporally. Biodiversity is determined for example, by a) the mean climate and climate variability; b) the availability of resources and overall productivity of a site; c) the disturbance regime and occurrence of perturbations of cosmic (e.g. meteorites), tectonic, climatic, biological or anthropic origin; d) the original stock of biodiversity and dispersal opportunities or barriers; e) spatial heterogeneity of habitats; f) the intensity and interdependency of biotic interactions such as competition, predation, mutualism and symbiosis; and g) the intensity and kind of sexual reproduction and genetic recombination. Biodiversity at all levels is not static, as the dynamics of natural evolutionary and ecological processes induces a background rate of change.

Biodiversity underlies the goods and services provided by ecosystems that are crucial for human survival and well being. These can be classified along several lines. *Supporting services* maintain the conditions for life on Earth including, soil formation and retention, nutrient cycling, primary production; *regulating services* include regulation of air quality, climate, floods, soil erosion, water purification, waste treatment, pollination, and biological control of human, livestock and agriculture pests and diseases; *provisioning services* include providing food, fuelwood, fibre, biochemicals, natural medicines, pharmaceuticals, genetic resources, and fresh water; and *cultural services* provide non-material benefits including cultural diversity and identity, spiritual and religious values, knowledge systems, educational values, inspiration, aesthetic values, social relations, sense of place, cultural heritage, recreation, communal, and symbolic values.

Ecosystem goods and services have significant economic value, even if some of these goods and most of the services are not traded by the market and carry no price tags to alert society to changes in their supply or in the condition of the ecosystems that generate them. Many ecosystem services are largely unrecognized in their global importance or in the crucial role that they play in meeting needs in particular regions. For example, to date there have been no markets that recognize the important contribution of terrestrial and oceanic ecosystems and their biodiversity in absorbing at least half of the carbon that is currently emitted to the atmosphere from human activities, thereby slowing the rate of global climate change.

Past changes in the global climate resulted in major shifts in species ranges and marked reorganization of biological communities, landscapes, and biomes. The present global biota was affected by fluctuating Pleistocene (last 1.8 million years) concentrations of atmospheric carbon dioxide, temperature, and precipitation, and coped through evolutionary changes, species plasticity, range movements, and/or the ability to survive in small patches of favourable habitat (refugia). These changes, which resulted in major shifts in species ranges and marked reorganization of biological communities, landscapes, and biomes, occurred in a landscape that was not as fragmented as it is today, and with little or no pressures from human activities. Anthropogenic habitat fragmentation

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[1] This is a contraction of the definition in the Convention on Biological Diversity.

has confined many species to relatively small areas within their previous ranges, with reduced genetic variability. Warming beyond the ceiling of temperatures reached during the Pleistocene will stress ecosystems and their biodiversity far beyond the levels imposed by the global climatic change that occurred in the recent evolutionary past.

The current levels of human impact on biodiversity are unprecedented, affecting the planet as a whole, and causing large-scale loss of biodiversity. Current rates and magnitude of species extinction, related to human activities, far exceed normal background rates. Human activities have already resulted in loss of biodiversity and thus may have affected goods and services crucial for human well being. The main indirect human drivers (underlying causes) include: demographic; economic; sociopolitical; scientific and technological; and cultural and religious factors. The main direct human drivers (proximate causes or pressures) include: changes in local land use and land cover (the major historical change in land use has been the global increase in lands dedicated to agriculture and grazing); species introductions or removals; external inputs (e.g., fertilizers and pesticides); harvesting; air and water pollution; and climate change. The rate and magnitude of climate change induced by increased greenhouse gases emissions has and will continue to affect biodiversity either directly or in combination with the drivers mentioned above, and might outweigh them in the future.

For a given ecosystem, functionally diverse communities are more likely to adapt to climate change and climate variability than impoverished ones. In addition, high genetic diversity within species appears to increase their long-term persistence. It must be stressed, however, that the effect of the nature and magnitude of genetic and species diversity on certain ecosystem processes is still poorly known. The ability of ecosystems to either resist or return to their former state following disturbance may also depend on given levels of functional diversity. This can have important implications for the design of activities aimed at mitigating and adapting to climate change. Therefore, conservation of genotypes, species and functional types, along with the reduction of habitat loss, fragmentation and degradation, may promote the long-term persistence of ecosystems and the provision of ecosystem goods and services.

B. Climate change and biodiversity: observed and projected impacts

Changes in climate over the last few decades of the 20th century have already affected biodiversity. The observed changes in the climate system (e.g., increased atmospheric concentrations of carbon dioxide, increased land and ocean temperatures, changes in precipitation and sea level rise), particularly the warmer regional temperatures, have affected the timing of reproduction of animals and plants and/or migration of animals, the length of the growing season, species distributions and population sizes, and the frequency of pest and disease outbreaks.

Projected changes in climate during the 21st century will occur faster than in at least the past 10,000 years and combined with land use change and exotic/alien species spread, are likely to limit both the capability of species to migrate and the ability of species to persist in fragmented habitats. The projected impacts due to changes in mean climate, extreme climatic events and climate variability include:

(a) **The climatic range of many species will move poleward or upward in elevation from their current locations.** Species will be affected differently by climate change; some will migrate through fragmented landscapes whilst others may not be able to do so.

(b) **Many species that are already vulnerable are likely to become extinct.** Species with limited climatic ranges and/or with limited geographical opportunities (e.g., mountain top species, species on islands, peninsulas (Cape Flora)), species with restricted habitat requirements and/or small populations are typically the most vulnerable.

(c) **Changes in the frequency, intensity, extent, and locations of climatically and non-climatically induced disturbances will affect how and at what rate the existing ecosystems will be replaced by new plant and animal assemblages.** Species in an ecosystem are unlikely to all migrate at the same rates; long-lived species will persist longer in their original habitats leading to new plant and animal assemblages. Many ecosystems will be dominated by opportunistic, 'weedy' species, i.e., species well adapted to dispersal and rapid establishment, especially if the frequency and intensity of disturbance is high.

(d) **Some ecosystems are particularly vulnerable to climate change,** such as coral reefs, mangroves, high mountain ecosystems, remnant native grasslands and ecosystems overlying permafrost. Some ecosystems will often be slow to show evidence of change, e.g., those dominated by long-lived species (e.g., long-lived trees), whilst others, e.g. coral reefs, will show rapid response.

Net primary productivity of many species (including crop species) will increase due to the elevated concentrations of atmospheric carbon dioxide, however, there may be losses in net ecosystem and biome productivity. The changes in the net primary productivity will result in changes in the composition and functioning of ecosystems. Losses in net ecosystem and biome productivity can occur e.g., in some forests, at least when significant ecosystem disruption occurs (e.g., loss of dominant species or a high proportion of species due to changes in the disturbances, such as wildfires, pest and disease outbreaks).

The livelihood of many indigenous and local communities, in particular, will be adversely affected if climate and land-use change lead to losses in biodiversity. These communities are directly dependent on the products and services provided by the terrestrial, coastal and marine ecosystems, which they inhabit.

Changes in biodiversity at ecosystem and landscape scale, in response to climate change and other pressures (e.g., deforestation and changes in forest fires, introduction of invasive species), would further affect global and regional climate through changes in the uptake and release of greenhouse gases and changes in albedo and evapotranspiration. Similarly, changes in biological communities in the upper ocean could alter the uptake of carbon dioxide by the ocean or the release of precursors for cloud condensation nuclei causing either positive or negative feedbacks on climate change.

C. Climate change mitigation and adaptation options: links to, and impacts on, biodiversity

Terrestrial and oceanic ecosystems play a significant role in the global carbon cycle and their proper management can make a significant contribution to reducing the build up of greenhouse gases in the atmosphere. Each year about 60 gigatons[2] (Gt) of carbon (C) are taken up and released by terrestrial ecosystems and about another 90 Gt C are taken up and released by ocean systems. These natural fluxes are large compared to the approximately 6.3 Gt C currently being emitted from fossil fuels and industrial processes, and about 1.6 Gt C per year from deforestation, predominantly in the tropics. Terrestrial ecosystems appear to be storing about 3 Gt C each year and the oceans another about 1.7 Gt. The result is a net build up of 3.2 Gt of atmospheric C per year.

There are significant opportunities for mitigating climate change, and for adapting to climate change, while enhancing the conservation of biodiversity. Mitigation involves reducing the greenhouse gas emissions from energy and biological sources or enhancing the sinks of greenhouse gases. Adaptation is comprised of activities that reduce a system's (human and natural) vulnerability to climate change. Carbon mitigation and adaptation options that take into account environmental (including biodiversity), social and economic considerations, offer the greatest potential for positive synergistic impacts.

The ecosystem approach of the Convention on Biological Diversity provides a flexible management framework to address climate change mitigation and adaptation activities in a broad perspective. This holistic framework considers multiple temporal and spatial scales and can help to balance ecological, economic, and social considerations in projects, programmes, and policies related to climate change mitigation and adaptation. "Adaptive management", which allows for the re-evaluation of results through time and alterations in management strategies and regulations to achieve goals, is an integral part of the ecosystem approach.

Land-use, land-use change and forestry activities can play an important role in reducing net greenhouse gas emissions to the atmosphere. Biological mitigation of greenhouse gases through land use, land-use change and forestry (LULUCF) activities can occur by three strategies: (a) conservation of existing carbon pools, i.e., avoiding deforestation (b) sequestration by increasing the size of carbon pools, e.g., through afforestation and reforestation, and (c) substitution of fossil fuel energy by use of modern biomass. The estimated upper limit of the global potential of biological mitigation options (a and b) through afforestation, reforestation, avoided deforestation, and agriculture, grazing land, and forest management is on the order of 100 Gt C (cumulative) by the year 2050, equivalent to about 10–20% of projected fossil-fuel emissions during that period,[3] although there are substantial uncertainties associated with this estimate. The largest biological potential is projected to be in subtropical and tropical regions. When LULUCF activities are used to offset emissions from fossil fuels, there is a net shift of carbon from fossil storage to more labile storage—but potentially long term—in terrestrial ecosystems.

Within the context of the Kyoto Protocol, additionality, leakage, permanence, and uncertainties, are important concepts for carbon storage in relation with the implementation of mitigation activities. A project credited under the Clean Development Mechanism is additional only if it would not have occurred without the stimulus of the Mechanism and if it removes more greenhouse gases from the atmosphere than would have occurred without the project. Leakage refers to the situation where activities related to carbon sequestration or conservation of existing carbon pools triggers an activity in another location, which leads in turn, to carbon emissions. Permanence refers to the longevity and stability of soil and vegetation carbon pools, given that they will undergo various management regimes and be subjected to an array of natural disturbances. Uncertainties result from lack of information or disagreement about what is known or even knowable.

Afforestation[4] and reforestation [5] can have positive, neutral, or negative impacts on biodiversity depending on the ecosystem being replaced, management options applied, and the spatial and temporal scales. The value of a planted forest to biodiversity will depend to a large degree on what was previously on the site and also on the landscape context in which it occurs. The reforestation of degraded lands will often produce the greatest benefits to biodiversity but can also provide the greatest challenges to forest management. Afforestation and reforestation activities that pay attention to species selection and site location, can promote the return, survival, and expansion of native plant and animal populations. In contrast, clearing native forests and replacing them with a monoculture

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[2] 1 gigaton equals 10^9 tons

[2] The emission of carbon from the combustion of fossil fuels is projected to increase from the current level of 6.3Gt C per year to between 10 and 25 Gt C per year

[4] Afforestation requires planting trees on land that has not contained a forest for over 50 years

[5] Reforestation requires planting trees on land that was not forested in 1990

forest of exotics would clearly have a negative effect on biodiversity. Afforestation of other natural grasslands and other native habitat types would also entail significant loss of biodiversity.

Short rotation plantations will not sequester and maintain carbon as much as long rotation plantations in which vegetation and soil carbon is allowed to accumulate. 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. Short rotation forests, with their simpler structure, foster lower species richness than longer-lived forests. However, products from short rotation plantations may alleviate the pressure to harvest or deforest longer-lived or primary forests.

Plantations of native tree species will support more biodiversity than exotic species and plantations of mixed tree species will usually support more biodiversity than monocultures. Plantations of exotic species support only some of the local biodiversity but may contribute to biodiversity conservation if appropriately situated in the landscape. Planting of invasive exotic species, however, could have major and widespread negative consequences for biodiversity. Tree plantations may be designed to allow for the colonization and establishment of diverse under-storey plant communities by providing shade and by ameliorating microclimates. Specific sites may make better candidates for implementing such activities than others, based on past and present uses, and the local or regional importance of their associated biodiversity, and proximity to other forests across a landscape. Involvement of local and indigenous communities in the design and the benefits to be achieved from a plantation may contribute to local support for a project and hence contribute to its longevity. Plantations may contribute to the dispersal capability of some species among habitat patches on a formerly fragmented landscape. Even plantations of a single species can confer some benefits to local biodiversity, especially if they incorporate features such as allowing canopy gaps, retaining some dead wood components, and providing landscape connectivity.

Slowing deforestation and forest degradation can provide substantial biodiversity benefits in addition to mitigating greenhouse gas emissions and preserving ecological services. In temperate regions, deforestation mainly occurred, when it did, several decades to centuries ago. In recent decades, deforestation has been most prevalent in the tropics. Since the remaining primary tropical forests are estimated to contain 50–70 percent of all terrestrial plant and animal species, they are of great importance in the conservation of biodiversity. Tropical deforestation and degradation of all types of forests remain major causes of global biodiversity loss. Any project that slows deforestation or forest degradation will help to conserve biodiversity. Projects in threatened/vulnerable forests that are unusually species-rich, globally rare, or unique to that region can provide the greatest immediate biodiversity benefits. Projects that protect forests from land conversion or degradation in key watersheds have potential to substantially slow soil erosion, protect water resources, and conserve biodiversity.

Forest protection through avoided deforestation may have either positive or negative social impacts. The possible conflicts between the protection of forested ecosystems and ancillary negative effects, restrictions on the activities of local populations, reduced income, and/or reduced products from these forests, can be minimized by appropriate stand and landscape management, as well as using environmental and social assessments.

Most of the world's forests are managed, hence improved management can enhance carbon uptake or minimize carbon losses and conserve biodiversity. Humans manage most forests for conservation purposes and to produce goods and services. Forest ecosystems are extremely varied and the positive or negative impact of any forest management operation will differ according to soil, climate, and site history, including disturbance regimes (such as fire). Because forests are enormous repositories of terrestrial biodiversity at all levels of organization (genetic, species, population, and ecosystem), improved management activities have the potential to positively affect biodiversity. Forestry practices that enhance biodiversity in managed stands and have a positive influence on carbon retention within forests include: increasing rotation length, low intensity harvesting, leaving woody debris, post-harvest silviculture to restore the local forest types, paying attention to landscape structure, and harvesting that emulates natural disturbance regimes. Management that maintains natural fire regime will usually maintain biodiversity and carbon storage.

Agroforestry systems have substantial potential to sequester carbon and can reduce soil erosion, moderate climate extremes on crops, improve water quality, and provide goods and services to local people. Agroforestry incorporates trees and shrubs into agricultural lands to achieve conservation and economic goals, while keeping the land in production agriculture. The potential to sequester carbon globally is very high due to the extensive agricultural land base in many countries. Agroforestry can greatly increase biodiversity, especially in landscapes dominated by annual crops or on lands that have been degraded. Agroforestry plantings can be used to functionally link forest fragments and other critical habitat as part of a broad landscape management strategy.

There are a large number of agricultural management activities (e.g., conservation tillage, erosion control practices, and irrigation) that will sequester carbon in soils, and which may have positive or negative effects on biodiversity, depending on the practice and the context in which they are applied. Conservation tillage denotes a wide range of tillage practices, including chisel-plow, ridge-till, strip-till, mulch-till, and no-till that can allow for the accumulation of soil organic carbon and provide beneficial conditions for soil fauna. The use of erosion control practices, which include water conservation structures, vegetative strips used as filters for riparian zone management, and agroforestry shelterbelts for wind erosion control can reduce the displacement of soil organic carbon and provide opportunities to increase biodiversity. The use of irrigation can increase crop production, but has the potential to degrade water resources and aquatic ecosystems. Where feasible, it is important to include farmer-centred participatory approaches and consideration of local or indigenous knowledge and technologies, promote cycling and use of organic materials in low-input farming systems, and use a diverse array of locally adapted crop varieties.

Improved management of grasslands (e.g., grazing management, protected grasslands and areas set-aside, grassland productivity improvements, and fire management) can enhance carbon storage in soils and vegetation, while conserving biodiversity. The productivity, and thus the potential for carbon sequestration of many pastoral lands is restricted mainly by availability of water, nitrogen and other nutrients, and the unsuitability of some native species to high-intensity grazing by livestock. Introduction of nitrogen-fixing legumes and high-productivity grasses or additions of fertilizer can increase biomass production and soil carbon pools, but can decrease biodiversity. Introduction of exotic nitrogen fixers poses the risk of them becoming invasive. Irrespective of whether a grazing land is intensively managed or strictly protected, carbon accumulation can be enhanced through improvement practices, especially if native species are properly managed to enhance the biodiversity associated with the system.

Avoiding degradation of peatlands and mires is a beneficial mitigation option. Peatlands and mires contain large stores of carbon, however, in recent decades, anthropogenic drainage and climate change has changed peatlands from a global carbon sink to a global carbon source. Draining peatlands for afforestation and reforestation activities may not lead to a net carbon uptake and in the short term would lead to carbon emissions.

Revegetation activities that increase plant cover on eroded, severely degraded, or otherwise disturbed lands have a high potential to increase carbon sequestration and enhance biodiversity. Sequestration rates will depend on various factors, including revegetation method, plant selection, soil characteristics and site preparation, and climate. Soils of eroded or degraded sites generally have low carbon levels and therefore a high potential to accumulate carbon; however, revegetation of these types of such sites will pose technical challenges. An important consideration is to match the plant species to the site conditions and to consider which key ecological functions need to be restored. Biodiversity can be improved if revegetation aids recruitment of native species over time or if it prevents further degradation and protects neighboring ecosystems. In certain instances, where native species may now be impossible to grow on some degraded sites, the use of exotic species and fertilizers may provide the best (and only) opportunity for reestablishing vegetation. However, care should be exercised to avoid situations where exotics that have invasive characteristics end up colonizing neighboring native habitats, thereby altering plant communities and ecosystem processes.

Marine ecosystems may offer mitigation opportunities, but the potential implications for ecosystem function and biodiversity are not well understood. Oceans are substantial reservoirs of carbon with approximately 50 times more carbon than is presently in the atmosphere. There have been suggestions to fertilize the ocean to promote greater biomass production and thereby sequester carbon and to mechanically store carbon deep in the ocean. However, the potential for either of these approaches to be effective for carbon storage is poorly understood and their impacts on ocean and marine ecosystems and their associated biodiversity are unknown.

Bio-energy plantations provide the potential to substitute fossil fuel energy with biomass fuels but may have adverse impacts on biodiversity if they replace ecosystems with higher biodiversity. However, bio-energy plantations on degraded lands or abandoned agricultural sites could benefit biodiversity.

Renewable energy sources (crop waste, solar- and wind-power) may have positive or negative effects on biodiversity depending upon site selection and management practices. Replacement of fuelwood by crop waste, the use of more efficient wood stoves and solar energy and improved techniques to produce charcoal can also reduce the pressure on forests, woodlots, and hedgerows. Most studies have demonstrated low rates of bird collision with windmills, but the mortality may be significant for rare species. Proper site selection and a case-by-case evaluation of the implications of windmills on wildlife and ecosystem goods and services can avoid or minimize negative impacts.

Hydropower has significant potential to mitigate climate change by reducing the greenhouse gas intensity of energy production but also can have potential adverse effects on biodiversity. In a few cases, emissions of carbon dioxide and methane caused by dams and reservoirs may be a limiting factor on the use of hydropower to mitigate climate change. Large-scale hydropower development can also have other high environmental and social costs such as loss of biodiversity and land, disruption of migratory pathways and displacement of local communities. The ecosystem impacts of specific hydropower projects vary widely and may be minimized depending on factors including type and condition of pre-dam ecosystems, type and operation of the dam (e.g., 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.

Adaptation is necessary not only for the projected changes in climate but also because climate change is already affecting many ecosystems. Adaptation activities can have negative or positive impacts on biodiversity, but positive effects may generally be achieved through: maintaining and restoring native ecosystems; protecting and enhancing ecosystem services; actively preventing and controlling invasive alien species; managing habitats for rare, threatened, and endangered species; developing agroforestry systems at transition zones; paying attention to traditional knowledge; and monitoring results and changing management regimes accordingly.. Adaptation activities can threaten biodiversity either directly—through the destruction of habitats, e.g., building sea walls, thus affecting coastal ecosystems, or indirectly—through the introduction of new species or changed management practices, e.g., mariculture or aquaculture.

Reduction of other pressures on biodiversity arising from habitat conversion, over-harvesting, pollution, and alien species invasions, constitute important climate change adaptation measures. Since mitigation of climate change itself is a long-term endeavour, reduction of other pressures may be among the most practical options. For example, increasing the health of coral reefs, by reducing the pressures from coastal pollution and practices such as fishing with explosives and poisons, may allow them to be more resilient to increased water temperature and reduce bleaching. A major adaptation measure is to counter habitat fragmentation through the establishment of biological corridors between protected areas, particularly in forests. More generally, the establishment of a mosaic of interconnected terrestrial, freshwater and marine multiple-use reserve protected areas designed to take into account projected changes in climate, can be beneficial to biodiversity.

Conservation of biodiversity and maintenance of ecosystem structure and function are important climate change adaptation strategies because genetically-diverse populations and species-rich ecosystems have a greater potential to adapt to climate change. While some natural pest-control, pollination, soil-stabilization, flood-control, water-purification and seed-dispersal services can be replaced when damaged or destroyed by climate change, technical alternatives may be costly and therefore not feasible to apply in many situations. Therefore, conserving biodiversity (e.g., genetic diversity of food crops, trees, and livestock races) means that options are kept open to adapt human societies better to climate change. Conservation of ecotones is also an important adaptation measure. Ecotones serve as repositories of genetic diversity that may be drawn upon to rehabilitate adjacent ecoclimatic regions. As an insurance measure such approaches can be completed by ex situ conservation. This might include conventional collection and storage in gene banks as well as dynamic management of populations allowing continued adaptation through evolution to changing conditions. Promotion of on-farm conservation of crop diversity may serve a similar function.

The protection, restoration or establishment of biologically diverse ecosystems that provide important goods and services may constitute important adaptation measures to supplement existing goods and services, in anticipation of increased pressures or demand, or to compensate for likely losses.

For example:
The protection or restoration of mangroves can offer increased protection of coastal areas to sea level rise and extreme weather events;

The rehabilitation of upland forests and of wetlands can help regulate flow in watersheds, thereby moderating floods from heavy rain and ameliorating water quality;

Conservation of natural habitats such as primary forests, with high ecosystem resilience, may decrease losses of biodiversity from climate change and compensate for losses in other, less resilient, areas.

D. Approaches for supporting planning, decision making and public discussions

There is a clear opportunity to implement mutually beneficial activities (policies and projects) that take advantage of the synergies between the United Nations Framework Convention on Climate Change and its Kyoto Protocol, the Convention on Biological Diversity and broader national development objectives. These opportunities are rarely being realized due to a lack of national coordination among sectoral agencies to design policy measures that exploit potential synergies between national economic development objectives and environmentally focused projects and policies. In addition, there is a lack of coordination among the multilateral environmental agreements, specifically among the mitigation and adaptation activities undertaken by Parties to the UNFCCC and its Kyoto Protocol, and activities to conserve and sustainably manage ecosystems undertaken by Parties to the Convention on Biological Diversity.

Experience shows that transparent and participatory decision-making processes involving all relevant stakeholders, integrated into project or policy design from the beginning, can enhance the probability of long-term success. Decisions are value-laden and combine political and technocratic elements. Ideally, they should combine problem identification and analysis, policy-option identification, policy choice, policy implementation, and monitoring and evaluation in an iterative fashion. Decision-making processes and institutions operate at a range of spatial scales from the village community to the global level.

A range of tools and processes are available to assess the economic, environmental and social implications of different climate-change-mitigation and adaptation activities (projects and policies) within the broader context of sustainable development. Environmental impact assessments (EIAs) and strategic environmental assessments (SEAs) are processes that can incorporate a range of tools and methods including decision analytical frameworks, valuation techniques, and criteria and indicators. Simple checklists, including indicative positive and negative lists of activities, can help guide consideration of when use of EIA or SEA is warranted.

Environmental impact assessments and strategic environmental assessments can be integrated into the design of climate change mitigation and adaptation projects and policies to assist planners, decision-makers and all stakeholders to identify and mitigate potentially harmful environmental and social impacts and enhance the likelihood of positive benefits such as carbon storage, biodiversity conservation and improved livelihoods. EIAs and SEAs can be used to assess the environmental and social implications of different energy and land-use, land-use change and forestry (LULUCF) projects and policies undertaken by Parties to the UNFCCC and the Convention on Biological Diversity and to choose among them. While the Convention on Biological Diversity explicitly encourages the use of EIA and SEA tools as a means to achieve its objectives there is no respective reference to them in the UNFCCC or its Kyoto Protocol. The operational rules for the Kyoto Protocol included in the Marrakesh Accords only stipulate that participants in the clean development mechanism (CDM) and in some cases joint implementation (JI) projects have to carry out an EIA in accordance with the requirements of the host Party if, after a preliminary analysis, they or host countries consider the environmental impacts of the project activities significant.

Decision-analytic frameworks are tools that can be used to evaluate the economic, social and environmental impacts of climate change mitigation and adaptation activities and those of biodiversity conservation activities. Decision-analytic frameworks can be divided into four broad categories, i.e., normative, descriptive, deliberative, and ethically and culturally based. These include decision analysis, cost-benefit analysis, cost-effectiveness analysis, the policy exercise approach and cultural prescriptive rules. The diverse characteristics of possible climate change mitigation and adaptation activities and biodiversity conservation activities imply the need for a diverse set of decision-analytic frameworks and tools so those most relevant to the decision-making can be selected and applied, e.g., if cost-effectiveness is the most important decision criteria this would suggest conducting a cost effectiveness analysis. Use of decision-analytic frameworks prior to implementing a project or a policy, can help address a series of questions that should be part of the project or policy design.

Methods are available to determine changes in the use and non-use values of ecosystem goods and services from climate-change-mitigation and adaptation activities. The concept of total economic value is a useful framework for assessing the utilitarian value of both the use and non-use values of ecosystem goods and services now and in the future. The use values arise from direct use (e.g., provisioning of food), indirect use (e.g., climate regulation) or option values (e.g., conservation of genetic diversity), whereas the non-use values include existence values.[6] Valuation techniques can be used to assess the "economic" implications of changes in ecological goods and services resulting from climate change mitigation and adaptation, as well as biodiversity conservation and sustainable use, activities. In contrast, the non-utilitarian (intrinsic) value of ecosystems arising from a variety of ethical, cultural, religious and philosophical perspectives cannot be measured in monetary terms. Hence, when a decision-maker assesses the implications of the possible alteration of an ecosystem, it is important that they are aware of the utilitarian and non-utilitarian values of the ecosystem. **Without a set of minimum common international environmental and social standards, climate-change-mitigation projects could flow to countries with minimal or non-existent standards, adversely affecting biodiversity and human societies.** If agreed internationally, such standards could be incorporated into national planning efforts. Furthermore, the Marrakesh Accords affirm that it is the host Party's prerogative to confirm whether a CDM project assists in achieving sustainable development.

National, regional and possibly international systems of criteria and indicators could be useful in monitoring and evaluating the impact of climate change and to assess the impacts of climate change mitigation and adaptation activities on biodiversity and other aspects of sustainable development. An important aspect of monitoring and evaluation is the choice of suitable criteria and indicators, which should be, whenever possible, meaningful at the site, national and possibly international level, as well as consistent with the main objectives of the project or policy intervention. Criteria and indicators consistent with national sustainable development objectives are to some degree available. For example, many international processes have developed or are currently developing specific biodiversity and sustainable development criteria and indicators in management guidelines for forestry that could be useful for afforestation, reforestation and conservation (avoided deforestation) projects and policies.

A critical evaluation of the current criteria and indicators developed under the Convention on Biological Diversity, and the many other national and international initiatives could assist in assessing their utility to evaluate the impact of activities undertaken by Parties to the UNFCCC and its Kyoto Protocol. Such an evaluation would allow the presentation of an array of eligible standards and procedures for validation and certification that could enable national and international

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[6] Where individuals are willing to pay to for the conservation of biodiversity

initiatives to select a scheme that best serves their project circumstances.

Monitoring and evaluation processes that involve the communities and institutions most affected by climate change mitigation and adaptation activities and recognize that different spatial and temporal scales will be required to assess the implications of these activities, are likely to be the most sustainable. Methods are available to monitor components of biodiversity at the local and regional scale, but few countries have an operational system in place. Determining the impact of climate-change projects and policies on biodiversity is, in some instances, likely to remain problematical given the long lag-time between the intervention and the response of the system.

E. Lessons learned from case-studies: harmonization of climate-change-mitigation and adaptation activities with biodiversity considerations

The individual and collective experience from several case-studies provides insights on key practical challenges and opportunities for improving the design of projects. There are some lessons learned for the harmonization of climate-change-mitigation and adaptation activities with biodiversity considerations, based on analyses of 10 case-studies being implemented at various scales (site, regional, national). Some of these case-studies were pilot projects launched in anticipation of the Kyoto Protocol; others preceded the Kyoto discussion.

Lesson 1: **There is scope for afforestation, reforestation, improved forest management and avoided deforestation activities to be harmonized with biodiversity conservation benefits.** It has to be noted that improved forest management and avoided deforestation are not eligible under the CDM. Improved conservation of biodiversity can occur through reforestation [case studies 1 and 10]; afforestation [case studies 6 and 10], avoided deforestation [case studies 2 and 5] and improved forest management [case study 5]. These projects included specific design features to optimize conservation benefits, including the use of native species for planting, reduced impact logging to ensure minimal disturbance; and establishment of biological corridors. In addition, sustainable use of forest products and services was also secured through various incentive measures, particularly in the cases of Uganda/Netherlands, Costa Rica and Sudan [case studies 1, 2 and 6]. Nevertheless, there is room for improvement in existing projects to further explore synergies between climate mitigation activities and biodiversity conservation; for example, the Mesoamerican Biological Corridor Project [case study 8], originally conceived as a regional strategy for biodiversity conservation, and not to address climate change, clearly has significant potential and scope for mitigation and adaptation options to be designed into the particular national-level implementation of projects.

Lesson 2: **The linkages between conservation and sustainable use of biodiversity with community livelihood options provides a good basis for projects supported under the Clean Development Mechanism to advance sustainable development.** In some cases, project "success" [case studies 2 and 6] stemmed from combining key local development and livelihood concerns with those relating to carbon sequestration and biodiversity conservation, where-as in one case [case study 1] the restrictions imposed on the livelihoods of the local communities almost led to project failure.

Lesson 3: **The neglect and/or omission of social, environmental and economic considerations can lead to conflicts which could undermine the overall success of carbon mitigation projects, and long-term biodiversity conservation.** For example, omission of social and environmental issues in the Uganda-Norway/private investor project [case study 9] during planning and negotiation of agreements resulted in losses to key stakeholders; land conflicts which undermined the security of carbon credits for the investor, livelihood loss for local communities, and unsustainable forest management for the Ugandan forest authorities. This was also initially the case in the Uganda-Netherlands/private investor project [case study 1], although later the project took a proactive approach to address these issues. Continued attention to economic and environmental considerations in Costa Rica [case study 2] has proved to be useful for balancing the carbon and biodiversity objectives; after an initial period reforestation contracts were excluded because the higher financial rewards for these contracts over those for forest conservation were serving as a disincentive for conservation.

Lesson 4: **Countries and key stakeholders need to have the necessary information, tools and capacity to understand, negotiate, and reach agreements under the Kyoto Protocol to ensure that the resulting projects are balanced with respect to environment, social and development goals.** The tensions between key stakeholders and wavering commitment to the agreement in the Uganda-Norway/private investor project [case study 9] can be partly attributed to the asymmetry of information and understandings of their roles and responsibilities at the time of finalizing the deal. It is critical that all stakeholders understand the benefits and the costs of proposed interventions to each partner, including the opportunities and synergies to be achieved with conservation. In this regard, Costa Rica's experience [case study 2] has been more positive in part due to the country's sound institutional and policy environment, and its capacity to deal with key project issues and key stakeholders as equal partners.

Lesson 5: **Some minimum environmental and social norms (or guiding frameworks) when purchasing carbon credits through CDM projects could avoid perverse outcomes.** Without such minimum norms, e.g., between 'private investors/parent countries', projects could still be able to claim carbon credits even when they have detrimental environmental and/or social impacts, as indicated by the Uganda-Norway/private investor project [case study 9].

Lesson 6: **The application of appropriate analytical tools and instruments can provide constructive frameworks for *ex ante* analysis to guide decision making; provide adaptive management options during implementation; and provide a basis for learning and replication through *ex post* evaluations.** In most cases, only a sub-set of the available tools was used in designing the projects. However, several of the case-studies reviewed illustrated the application of at least one of the various analytical tools and instruments, which in turn influenced processes at key stages of the project/programme. The application of cost-benefit analysis at a specific site in Madagascar [case study 4] provided the rationale for retaining the Masaola forest as a national park instead of converting it to a logging concession, but concluded that conservation would only succeed in the long term if the benefits outweigh costs at all scales. The application of the strategic environmental assessment at a national level in Finland [case study 3] revealed that the scenarios initially chosen for the climate change strategy had been too narrowly defined, and the Parliament has since requested more scenarios and longer-term analyses be undertaken. Similarly a strategic modelling approach to inform the adaptation of nature conservation policy and management practice to climate change impacts was undertaken in Britain and Ireland [case study 7]. The comprehensive approach taken by Costa Rica [case study 2] is also exemplary in that it combined various tools (valuation, strategic sector-level analysis, and decision analytical frameworks) to unleash the power of the market to meet multiple objectives of conservation, climate change mitigation, and hydrological services.

Lesson 7: **Measuring the impact of CDM and joint implementation projects on biodiversity requires baseline data, inventories and monitoring systems.** The Belize and Costa Rica projects [case studies 2 and 5] are simultaneously monitoring and measuring carbon and certain aspects of biodiversity, whereas the Sudan project [case study 6] discontinued the biodiversity inventory and monitoring component due to resource constraints.

Lesson 8: **The ecosystem approach provides a good basis to guide the formulation of climate change mitigation policies/projects and conservation of biodiversity.** Most of the case-studies analysed have not used the ecosystem approach as a guiding framework, but the overall analyses of the case-studies suggests that several projects benefited from the consideration of the intent of the various principles of the approach.

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CHAPTER 5. APPROACHES FOR SUPPORTING PLANNING, DECISION MAKING AND PUBLIC DISCUSSIONS

1. INTRODUCTION

Outi Berghäll, Kalemani J. Mulongoy

At its fifth meeting in 2000, the Conference of the Parties to the Convention on Biological Diversity (CBD) noted that there was a significant evidence that climate change[7] was a primary cause of the 1998 extensive coral bleaching[8] and made references to the possible interactions between climate change and the conservation and sustainable use of biological diversity in forests[9]. In order to draw to the attention of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) the need for reducing and mitigating the impacts of climate change on coral reefs and forest biological diversity, the Conference of the Parties to the Convention on Biological Diversity requested its Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA) to review the impacts of climatic change on forest biological diversity[10] and prepare scientific advice for the integration of biodiversity considerations into the implementation of the UNFCCC and its Kyoto Protocol[11].

The Conference of Parties to the CBD called for this work to be carried out in collaboration with the appropriate bodies of the UNFCCC and the Intergovernmental Panel on Climate Change (IPCC), bearing in mind that the objectives of both conventions are, to a large extent, mutually supportive: climate change is one of the threats to biodiversity, and the need for its rate to be reduced to allow ecosystems to adjust to climate change is recognized in the objective of the UNFCCC[12]. Strengthened collaboration between the two conventions has been called for by the CBD Conference of the Parties at its third, fourth and fifth meetings. At the latter meeting, the Conference of the Parties called for collaboration not only concerning forest biodiversity but also incentive measures[13] and the impact of climate change on coral bleaching and on dry and subhumid lands.

In response to the request of the Conference of the Parties to the CBD[14], the Subsidiary Body on Scientific, Technical and Technological Advice decided to carry out a wider assessment of the interlinkages between climate change and biodiversity and, as a first step, it established[15] in March 2001 an ad hoc technical expert group on biological diversity and climate change with the following mandate:

(a) Analyse possible adverse effects on biological diversity of measures that might be taken or are being considered under the United Nations Framework Convention on Climate Change and its Kyoto Protocol;

(b) Identify factors that influence biodiversity's capacity to mitigate climate change and

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[7] As defined in the reports of Inter Governmental Panel on Climate Change, climate change is described as the variation in either the mean state of the climate or in its variability, persisting for an extended period, typically decades or longer, encompassing temperature increases ("global warming"), sea-level rise, changes in precipitation patterns, and increased frequencies of extreme events. Article 1 of the United Nations Framework Convention on Climate Change (UNFCCC) describes "adverse effects of climate change" as changes in the physical environment or biota resulting from climate change which have significant deleterious effects on the composition, resilience or productivity of natural and managed ecosystems or on the operation of socio-economic systems or on human health and welfare.

[8] Decision V/3, paras. 3, 5 and annex

[9] Decision V/4, para. 11 and paras. 16-20.

[10] Decision V/4, para. 11

[11] Decision V/4, para. 18

[12] The ultimate objective of the UNFCCC is the stabilization of greenhouse gas concentrations "within a time-frame sufficient [inter alia] to allow ecosystems to adapt naturally to climate change" (art. 2). Thus, although the UNFCCC makes no specific reference to biological diversity, its objective contributes to the objectives of the Convention on Biological Diversity. Further, among their Commitments under the UNFCCC (art. 4), Parties shall "promote sustainable management, and promote and cooperate in the conservation and enhancement, as appropriate, of sinks and reservoirs of all greenhouse gases not controlled by the Montreal Protocol, including biomass, forests and oceans as well as other terrestrial, coastal and marine ecosystems" (art. 4.1(d)) and "cooperate in preparing for adaptation to the impacts of climate change (…)" (art. 4.1(e)). Particular attention is given to, inter alia, "fragile ecosystems" (art. 4.8(g)). Additionally, the Clean Development Mechanism of the Kyoto Protocol makes provision for a share of the proceeds from certified project activities to be used to assist developing country Parties that are particularly vulnerable to the adverse effects of climate change to meet the costs of adaptation (art. 12.8). The operational rules for the implementation of the Kyoto Protocol, included in the Marrakesh accords, recognize the requirement to contribute to the conservation of biological diversity.

[13] Under the Convention on Biological Diversity, "incentive measures" refer to any "economically and socially sound measures that act as incentives for the conservation and sustainable use of components of biological diversity" (Article 11).

[14] CBD COP Decision V/4, para. 11

[15] Paragraph 5 of SBSTTA recommendation VI/7

contribute to adaptation and the likely effects of climate change on that capacity;

(c) Identify options for future work on climate change that also contribute to the conservation and sustainable use of biological diversity.

In addition, the expert group was requested to develop recommendations based upon a review of possible approaches and tools such as criteria and indicators, to facilitate application of scientific advice for the integration of biodiversity considerations into the implementation of measures that might be taken under the United Nations Framework Convention on Climate Change and its Kyoto Protocol to mitigate or adapt to climate change.

For the purpose of ensuring synergy and avoiding unnecessary duplication, SBSTTA invited the United Nations Framework Convention on Climate Change, as well as the Convention on Migratory Species, the Convention on Wetlands of International Importance, especially as Waterfowl Habitat (Ramsar), the United Nations Convention to Combat Desertification, the Scientific and Technical Advisory Panel of the Global Environment Facility, the United Nations Forum on Forests, the Millennium Ecosystem Assessment and other relevant organizations to contribute to this work. Intergovernmental Panel on Climate Change (IPCC) was also invited to contribute to this assessment process inter alia by preparing a technical paper on climate change and biodiversity. The IPCC prepared the requested technical paper, which was approved in April 2002.

The ad hoc technical expert group comprised experts in the fields of biological diversity and climate change from all the United Nations regions, including scientists involved in the IPCC processes, and experts from indigenous and local communities. The group met three times; in Helsinki, Finland, in January 2002; in Montreal, Canada, at the seat of the Secretariat of the Convention on Biological Diversity in September 2002; and after a meeting of the lead authors organized in Washington in January 2003, again in Helsinki in May 2003. During these meetings and in the intersessional period, the expert group reviewed existing literature including the IPCC Third Assessment Review, the Special Report on Land Use, Land-Use Change and Forestry (LULUCF), the IPCC Technical Paper on Climate Change and Biodiversity and other available literature not covered by previous IPCC assessments. The experts compiled that information in a draft report that was then submitted between February and May 2003 for peer-review to Governments using the channels of both the Convention on Biological Diversity and the United Nations Framework Convention on Climate Change, and to the wider scientific community. At its third meeting, the expert group considered and took into account the comments of the reviewers to finalise its report.

Referring to the description of biodiversity in the Convention on Biological Diversity, chapter 2 introduces the concepts needed to understand the interlinkages between biodiversity and climate change, with a particular emphasis on ecosystem functioning. Building on the work of IPCC, chapter 3 summarises observed and projected changes in climate and their observed and projected impacts on biodiversity. Chapter 4 begins by presenting the key provisions of the UNFCCC and its Kyoto Protocol as well as the ecosystem approach which provides the CBD framework for the subsequent analysis. The chapter thereafter discusses climate change mitigation options, focusing on the Land Use, Land Use Change and Forestry (LULUCF) activities because of their particular relevance to biodiversity. The last section of the chapter considers adaptation options to reduce the impact of climate change on biodiversity. Chapter 5 introduces planning and analytical tools that can support decision-making as well as monitoring and evaluation of actions including methodologies that can be used for ex-ante impact assessments at various levels. Criteria and indicators to be used for monitoring and evaluation processes and decision analytical frameworks and tools are presented, as well as value and valuation techniques. Chapter 6 assesses how some of the methodologies and tools have been applied in selected case studies. The report provides information on biodiversity considerations in the ongoing discussions on afforestation and reforestation activities in the context of the UNFCCC and its Kyoto Protocol.

2. BIODIVERSITY AND LINKAGES TO CLIMATE CHANGE

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INTRODUCTION

The purpose of this chapter is to provide a conceptual and empirical base on the links between biological diversity (from now on referred to as biodiversity) and climate change. More specifically, the chapter addresses the following questions:

(a) How is biodiversity defined?

(b) How has biodiversity been affected by changes in past climate and what are the implications for both current and projected climate change, and climate variability?

(c) What are the main contemporary human impacts on biodiversity?

(d) How could biodiversity affect ecosystem functioning and what are the implications for climate-related management actions?

This chapter also summarises the complexity of biodiversity at all scales and how this affects our ability to forecast changes that may occur in any components of biodiversity. Biodiversity is not only affected by climate and climate change, but also many of the past and present human activities. These interacting pressures will be addressed in the chapter and put into the context of changes in biodiversity over longer (i.e., geological) time frames.

2.1 BIODIVERSITY: DEFINITIONS AND IMPORTANCE

The Convention on Biological Diversity defines biological diversity as the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems. This report adopts this definition, but refers to particular aspects of biodiversity as appropriate. Biodiversity, which includes all plants, animals and microorganisms, can be measured and expressed in different units such as genes, individuals, populations, species, ecosystems, communities and landscapes (Boyle and Boontawee 1995, Garay and Dias 2001, Gaston 1996, UNEP 1995). Functional diversity, which describes the ecological functions of species or groups of species in an ecosystem (e.g., relative abundance of shrub, tree, and grass species; annual species vs. perennial species), provides an additional way of measuring biodiversity. Differing levels of functional diversity may impact ecosystem functioning; using functional diversity as biodiversity descriptor provides an alternative way of understanding the effects of disturbances, including climate change, on the provision of ecosystem goods and services (Chapin et al. 1996, Hawksworth 1991, Mooney et al. 1996, Schulze and Mooney 1993, UNEP 1995; but see Schwartz et al. 2000).

Many factors determine the biodiversity present in a given area at a given time. The determinants of biodiversity include: a) the mean climate and its variability; b) the availability of resources and overall productivity of the site (measured in terms of the primary productivity and soil characteristics), including availability of adequate substrate, energy, water and nutrients; c) the disturbance regime and occurrence of perturbations of cosmic, tectonic, climatic, biological or anthropogenic origin; d) the original stock of biodiversity and dispersal opportunities or barriers; e) the level of spatial heterogeneity; f) the intensity and interdependency of biotic interactions such as competition, predation, mutualism and symbiosis and; g) the intensity and kind of sexual reproduction and genetic recombination (Huston 1994, Kunin and Gaston 1997, Ricklefs and Schluter 1993, Rosenzweig 1995, UNEP 1995). Biodiversity is therefore not a static concept, as the dynamics of evolutionary and ecological processes induces a background rate of change. Human induced climate change caused by increased greenhouse gases emissions is a new perturbation, introduced in the last century, that will impact biodiversity either directly or in synergy with the above determinants.

Ecosystems provide many goods and services essential for human survival and well being. Ecosystem services can be classified along functional lines, using categories of supporting, regulating, provisioning, and cultural services, as adopted by the Millennium Ecosystem Assessment (Box 2.1).

Box 2.1. Ecosystem services

The most crucial ecosystem services provided through biodiversity are:

Supporting Services (services that maintain the conditions for life on earth):
Soil formation and retention; nutrient cycling; primary production; pollination and seed dispersal; production of oxygen; provision of habitat;

Regulating Services (benefits obtained from regulation of ecosystem processes):
Air quality maintenance; climate regulation; water regulation; flood control; erosion control; water purification; waste treatment; detoxification; human disease control; biological control of agriculture and livestock pest and disease; storm protection;

Provisioning Services (products obtained from ecosystems):
Food; wood fuel; fiber; biochemicals; natural medicines; pharmaceuticals; genetic resources; ornamental resources; fresh water; minerals, sand and other non-living resources;

Cultural Services (non-material benefits obtained from ecosystems):
Cultural diversity and identity; spiritual and religious values; knowledge systems; educational values; inspiration; aesthetic values; social relations; sense of place; cultural heritage; recreation and ecotourism; communal; symbolic.

Source: Millenium Ecosystem Assessment 2003 Report "People and Ecosystems: A Framework for Assessment"

The provision of goods and services by ecosystems is underpinned by various aspects of biodiversity, although the relationship is a complex one. "Biodiversity" is a composite, multidimensional term and there is no simple relationship between biodiversity and ecosystem services. Ecosystem functioning may be sensitive to biodiversity at some levels and scales while being insensitive at other levels and scales. The relationship between species diversity per se and particular aspects of ecosystem productivity is debated. Most experiments show a positive relationship, but the interpretation of these experiments and their applicability to natural ecosystems is questioned (Loreau et al. 2001). Besides species diversity, genetic diversity within populations is important to allow continued adaptation to changing conditions through evolution, and ultimately, for the continued provision of ecosystem goods and services. Likewise, diversity among and between habitats, and at the landscape level, is also important in multiple ways for allowing adaptive processes to occur.

Goods and services provided by biodiversity have significant economic value, even if some of these goods and most of the services are not traded by the market. The value of biodiversity-dependent goods and services is difficult to quantify and may depend on the interests of stakeholder groups. Ecosystem services may be worth trillions of dollars annually (Costanza et al.1997), but most of these services are not traded in markets and carry no price tags to alert society to changes in their supply, or even their loss. The sustained of biodiversity-derived goods is a service provided to society at low cost by non-intensively managed ecosystems. An estimated 40 percent of the global economy is directly based on biological products and processes, and the goods provided by biodiversity represent an important part of many national economies. Ecosystems also provide essential services for many local and indigenous communities. For example, some 20 000 species are used in traditional medicine, which forms the basis of primary health care for about 80 per cent of the 3 billion people living in developing countries. Recent valuations by Balmford et al. (2002) have demonstrated the value of ecosystem services. Many ecosystem services are largely unrecognized in their global importance or in the pivotal role that they play in meeting needs in particular regions. For example, biodiversity contributes to the absorption by terrestrial and ocean ecosystems of nearly 60 percent of the carbon that is now emitted to the atmosphere from human activities, thereby slowing the rate of global climate change.

2.2 PAST AND CURRENT IMPACTS ON BIODIVERSITY

This section reviews how biodiversity has been affected by changes in past global climate. Observed and projected impacts of current and future climate change effects on biodiversity are discussed in Chapter 3. Nevertheless, by examining past trends here, the reader may be assisted in understanding likely future effects global climate change on biodiversity. It is important to note that past climate-driven changes in biodiversity were virtually uninfluenced by human activities. The Pleistocene record (last 1.8 million years) is most relevant to put into perspective future concerns for two main reasons: (1) the species that flourished during the Pleistocene are either identical or closely related to those of the present; and (2) there is a wealth of independent climate variation data for this period.

2.2.1 Past environmental impacts

While most discussion in this section refer to temperature changes as an indicator of past climate events, precipitation, changes in sea level, and extreme climate events also influenced the Pleistocene period. The Pleistocene was characterized by long (usually 100 000 year long) glacial periods with cool fluctuating climates interrupted by relatively brief (10 000 to 20 000 years) interglacial periods during which climates approximated those of the present (Lowe and Walker 1997). These glacial-interglacial cycles are understood to be ultimately caused by cyclical changes in the seasonal distribution of solar radiation (due to changes in the Earth's orbit), amplified by snow, ice, vegetation and naturally produced greenhouse gas feedbacks. Climate variation has not been uniform across the globe: high latitudes and the centers of continents tended to have the largest changes. The coolest glacial intervals had lowered global temperatures by around 5°C, while interglacials at their peak were as much as 3°C warmer than now (Kukla et al. 2002). Major alterations of precipitation occurred with most (but not all) areas being drier during glacials. Transitions between the coolest glacial intervals and interglacials tended to be rapid (Stocker 2000).

Global past climate change resulted in marked reorganizations of biological communities, landscapes, and biomes, and major shifts in species geographical ranges. During Pleistocene glacials, biomes, such as tundra, desert, steppe, grasslands, open boreal forest-parkland and savannas, expanded while closed temperate and moist tropical forest retreated towards the equator and became fragmented (Kohfeld and Harrison 2000). Many moist tropical forests in southeast Asia and the Amazon basin persisted intact through glacial-interglacial transitions, although dry, seasonal savannas were greatly expanded (Flenley 1979, Colinvaux et al. 2000). The negative effects on vegetation of low levels (ca. 180 ppm; parts per million) of atmospheric CO_2 on vegetation cover may have promoted these widespread biome changes (Levis et al. 1999). Rapid global expansion of woody vegetation and closed forest occurred during the glacial-interglacial transitions, and during interglacial peaks moist forest types reached their maximum abundance. Expansion and contraction of the northern ice sheets, and alternations of cooler and more arid glacial climates with warmer, wetter interglacials forced major changes in species geographic distributions, especially at high northern latitudes. Also the sea level and sea surface temperature have fluctuated greatly according to the glacial-interglacial cycles and caused rearrangements in the marine biota. However, over most of the globe, especially in the tropics and subtropics, southern latitudes and mountainous and desert regions, habitat reduction was the most common response (Colinvaux et al. 2000, Markgraf et al. 1995, Thompson et al. 1993).

After examination of past biological changes due to climate change, it is clear that present plant and animal communities do not resemble ancient ones. Repeated assembling and disaggregation of plant and animal communities and biomes has occurred in the past at all spatial and temporal scales (Andriessen et al. 1993, Marchant et al. 2002). Past biotic records indicate many alterations in community structure, even during periods of relatively stable climates. Non-analogue communities (past communities in which the dominant species do not presently occur together, or whose relative abundance is inconsistent with any known for present day communities) have formed frequently, most often during glacial periods, as species responded individualistically to environmental change. For example, during the late Pleistocene in North America, many mammals with currently non-overlapping ranges were in close proximity, while present day ranges show little resemblance to past ones (FAUNMAP Working Group 1996). An extensive northeastern United States pollen data network has demonstrated widespread, non-analogue plant communities, especially during the late Pleistocene (Webb et al. 1993). Similar changes have been documented in many tropical regions (Colinvaux et al. 2000).

Repeated movements of species due to climatic fluctuations have affected their genetic structures. Genetic studies have demonstrated how diverse the distributional pathways and origins of the genomes of current taxa are (Petit et al. 2002). In some cases these genetic studies have confirmed the inference--based on fossil records--that populations of some species have survived multiple glaciations in refugia which are thus centres of genetic diversity, while repeated expansion and contraction of populations in response to climate outside of these refugia have led to stochastic change of genetic diversity (Hewitt 1999). Glacial refugia and repeated expansions and contractions both north-south and east-west in relation to climate change have created complexly structured patterns of genetic diversity across the entire continent of Europe (Hewitt 1999).

During periods of rapid climate warming during the Pleistocene, many tree and shrub species excluded by ice or cold, and/or dry climates, migrated to more favourable site. Physical barriers seemed to have only a limited effect, in some regions, on migration (Davis 1989, Huntley and Birks, 1983, Webb et al. 1993, Pitelka et al. 1997). Whether tree species will presently be able to migrate the way the did in the past through presently fragmented landscapes is debatable (particularly when the species has a low abundance of individuals).

Species extinctions have occurred especially at the start of major climatic change episodes. Extinctions may be more likely to occur during periods of rapidly changing climates and vegetation cover (Webb and Barnosky 1989, Alroy 2001). Long-lived alterations in climate, either to a warmer or cooler state, have invariably resulted in adjustments in species numbers and types (Crowley and North 1988). The last great global readjustment of species numbers occurred during the initiation of the Pleistocene cooling; e.g., a major pulse of extinctions of marine organisms occurred in many ocean basins 1-2 million years ago (Jackson and Johnson 2000), and both northern and southern temperate floras suffered diversity loss (Lee et al. 2001, Huntley 1993, van der Hammen and Hooghiemstra 2000). Plant extinctions during the Pleistocene appear to have been low. To take trees as an example, only one species is documented to have gone extinct during the last glacial-interglacial transition in North America (Jackson and Weng 1999) despite massive readjustments of forest ecosystems over that period.

Widespread extinctions of large vertebrates over the last 50 000 years have often

occurred during periods of major climate and habitat alteration, but human hunting or introduced predators have also always been a factor. Widespread extinctions of large vertebrates have occurred throughout the globe during the last 50 000 years. In some areas, in particular on islands, humans and human-introduced predators have clearly been responsible (Steadman 1995, Millien-Parra and Jaeger 1999). In continental regions disruption of habitat through rapid changes at the end of the last glacial period have been often invoked as the primary agent, but even here, recent evidence at the very least implicates human hunting as a contributory agent (Cardillo and Lister 2002).

Implications for the present

The present global biota is adapted to changes in climate within the Pleistocene ranges of atmospheric concentrations of CO_2 temperature, and precipitation. Changes in climate per se are not necessarily damaging to biodiversity as most biotic communities have never been stable for any length of time in the past. Species have constantly adjusted their distributions and abundance in response to a number of factors, including atmospheric concentrations of CO_2, temperature, and precipitation. The present global biota therefore appears well adapted to fluctuating Pleistocene levels of atmospheric CO_2, temperature, and precipitation, and has coped in the past through species plasticity, range movements or ability to survive in small patches of favourable habitat (refugia). In the absence of other human disturbances (such as land use and land cover change, habitat fragmentation), even rapid warming over the next century, within the Pleistocene range, would be unlikely to cause major species extinctions.

Projected rate and magnitude of changes in climate during the 21st century are unprecedented compared to those in the last 1.8 million years and the ability of species to adjust given present human-dominated landscapes is questionable. While shifts in the average temperatures, for a given locality, in the range of 1-3°C above those of the pre-industrial present have been experienced from time to time during Pleistocene inter-glacials, increases beyond that range will create climates not encountered for millions of years. During the Pleistocene, atmospheric CO_2 levels have not reached those of the present day, let alone those of the near future. The rate of warming induced by greenhouse gas emission seems historically unprecedented (chapter 3), and there must be questions as to the ability of species to adjust to existing human-dominated landscapes, as many species exist in fragmented, weed and pest infested localities, confined to small areas within their previous ranges, reduced to small populations with reduced genetic diversity, and therefore constrained to any adjustment to climate change through migration. There is therefore no reliable model in the recent past of what to expect with sustained greenhouse driven global climate change. Warming beyond the Pleistocene temperature range can be expected to lead to large biotic turnover and extinctions, besides the expected substitution of present biotic communities by non-analogue communities. Species at the northern or southern limit of their distribution might be affected differently by climate change, and some could become extinct while others could become pests.

2.2.2 Current human impacts

The Earth is subjected to many human-induced and natural pressures that have significantly altered, degraded, displaced and fragmented terrestrial ecosystems, often leaving biologically impoverished landscapes. The pressures include those from increased demand for resources; selective exploitation or destruction of species; land-use and land-cover change; the accelerated rate of anthropogenic nitrogen deposition; soil, water, and air pollution; introduction of non-native species; diversion of water to intensively managed ecosystems and urban systems; fragmentation; and urbanization and industrialization (see Box 2.2). Among the most serious of land transformations is that of primary forest into degraded forest and outright deforested lands, because forests maintain the majority of terrestrial species. Where partial forest cover remains, fragmentation effects result in the loss of many species that would be associated with more continuous habitat (Bierregaard et al. 1992, Andren 1994). In drylands, more than 50% of the land has been converted to cropland in the past 90 years (Houghton 1994). As a result, a high proportion of grassland species are endangered and many are extinct. Worldwide, about 70% of the agriculturally-used drylands have been degraded, including through desertification (UNEP 1995) and some 40 percent of agricultural land has been strongly or very strongly degraded in the past 50 years by erosion, salinization, compaction, nutrient depletion, biological degradation, or chemical pollution. Even more significantly, we are increasingly undermining the productive capability of ecosystems to provide the services that we desire. Climate change constitutes an additional pressure on ecosystems and the goods and services they provide (IPCC 2002, UNEP 1995, Vitousek et al. 1997, Sala et al. 2000).

Current rates of species extinction, related to human activities, far exceed normal background rates and would tend to increase as climate change may add further stress on endangered species. The main causes of species extinctions as a result of human activities are introduction and competition from invasive exotic species, habitat destruction and conversion, over-exploitation, agricultural and urban expansion, over-grazing, and burning. Current rates of species extinction, related to human activities, far exceed normal background rates (Pimm et al. 1995, Lawton and May 1995). Current estimates suggest that 400-500 vertebrates, about 400 invertebrates, and approximately 650 plants have become extinct in the past 400 years (UNEP 1995). Currently, 12% of birds, 24% of mammals, 30% of fish, and 8% of plants are already threatened with extinction (UNEP 1995, SCBD 2001). Generally, rates of species extinction have been greatest on islands and lakes, largely owing to their biological uniqueness and endemic character. Although species have a certain level of resistance to change, and may continue to persist in isolated populations, many species have a high probability of eventually becoming extinct.

Box 2.2. Main drivers of biodiversity change

Major indirect drivers (underlying causes):

Demographic (such as population size, age and gender structure, and spatial distribution);
Economic (such as national and per capita income, macroeconomic policies, international trade, and capital flows);
Socio-political (such as democratisation, the role of women, of civil society, and of the private sector, and international dispute mechanisms);
Scientific and technological (such as rates of investments in research and development and the rates of adoption of new technologies, including information technologies); and
Cultural and religious (non-utilitarian values).

Major direct drivers (proximate causes or pressures):
Changes in local land use and land cover;
Species introductions or removals;
Technology adaptation and use;
External inputs (e.g., fertilizer use, pest control, irrigation);
Harvesting;
Natural physical and biological drivers
(e.g., volcanoes, landslides, floods, hurricanes);
Air and water pollution; and
Climate and climate change.

Source: Millenium Ecosystem Assessment 2003 Report "People and Ecosystems: A Framework for Assessment"

Human impacts have significantly altered, degraded, and displaced aquatic ecosystems leaving a mosaic of biologically impoverished waterbodies. There is no major commercial fishery in the world that has been managed sustainably and most world fisheries are now declining due to overfishing (FAO 1994, UNEP 1995). Other than through direct exploitation, humans have affected ocean and freshwater systems through agricultural runoff and sedimentation that has resulted in major impacts on coastal and shoreline ecosystems. Other impacts include pollution from waste disposal including radioactive residues, global climate change, and habitat (sea-floor) alteration. Pollution, warmer temperatures and human impacts seem to be causing extensive loss of coral reef ecosystems that in turn eliminates habitat for numerous other aquatic organisms (UNEP 1995, SCBD 2001). Damage to many freshwater systems has occurred as a result of pollution, acidification, invasion by exotic species, over-exploitation, and altered water flows from damming. Groundwater systems are also affected through the accumulation of nitrogen from fertilizers and unsustainable use, especially in arid areas. Humans now withdraw about 20 percent of the world's rivers' base flow and during the past century the rate of increase in withdrawals was more than twice the rate of population growth.

Human activities have affected the concentration of greenhouse gases in the atmosphere. During the period 1750 to 2000, the atmospheric concentration of CO_2 increased by 31±4%, primarily due to the combustion of fossil fuels, land use, and land-use change, most of it since 1900. Fossil-fuel burning released on average 5.4 Gt C yr-1 during the 1980s, increasing to 6.3 Gt C yr-1 during the 1990s. About three-quarters of the increase in atmospheric CO_2 during the 1990s were caused by fossil-fuel burning, with land-use change, including deforestation, responsible for the rest (Table 2.1). The atmospheric concentration of CH_4 increased by 151±25% from 1750 to 2000, primarily due to emissions from fossil-fuel use, livestock, rice agriculture, and landfills. Increases in the concentrations of tropospheric ozone, the third most important greenhouse gas, are directly attributable to fossil-fuel combustion as well as other industrial and agricultural emissions. CO_2 enrichment in the atmosphere has been shown to exert significant direct effects on biodiversity (the so called CO_2 fertilization effect), impacting growth rate, foliage quality and species abundance (Malhi and Grace 2000, Körner 2000, Niklaus et al. 2001, Shaw et al. 2002).

Human activities have also affected hydrological and biogeochemical cycles. Dams, impoundments, deforestation, and excessive

Table 2.1: **Changes in the atmospheric concentrations of greenhouse gases due to human activities (From IPCC 2001 – Synthesis Report and IPCC 2002)**

Concentration indicators	**Concentration indicators**
Atmospheric concentration of CO_2	280 ppm (parts per million) for the period 1000–1750 to 368 ppm in year 2000 (31±4% increase).
Terrestrial biospheric CO_2 exchange	Cumulative source of about 30 Gt C between the years 1800 and 2000; but during the 1990s, a net sink of about 14±7 Gt C.
Atmospheric concentration of CH_4	700 ppb (parts per billion) for the period 1000–1750 to 1,750 ppb in year 2000 (151±25% increase).
Atmospheric concentration of N_2O	270 ppb for the period 1000–1750 to 316 ppb in year 2000 (17±5% increase).
Tropospheric concentration of O_3	Increased by 35±15% from the years 1750 to 2000, varies with region.
Stratospheric concentration of O_3	Decreased over the years 1970 to 2000, varies with altitude and latitude.
Atmospheric concentrations of HFCs, PFCs, and SF_6	Increased globally over the last 50 years.

water use have altered the hydrological cycle. The nitrogen cycle has also been altered by increasing human fixing of N, up by a factor of 8 since 1950 and expected to rise by an additional 40% before 2030 (Galloway et al. 1994). All of these changes are having an effect on global, regional, and local climates, on the air quality, and on rainwater quality and quantity (UNEP 1995, Vitousek et al. 1997). Acidic precipitation continues to affect ecosystems especially in Europe, China, and eastern North America.

Climate change is likely to interact with land use change and other human impacts as a major factor impacting biodiversity. The major historical change in land use has been the global increase in lands dedicated to agriculture and grazing lands (Houghton 1994, WWF 2002). The majority of land use change in the past has been located in Europe, Asia and North America, where native forests have been deforested in a large scale. In the past few decades a high rate of deforestation and conversion of lands to either agriculture and/or degraded lands with low productivity has occurred in the tropics (Houghton 1994). Sala et al. (2000) developed scenarios of biodiversity change for the year 2100 based on changing scenarios of atmospheric carbon dioxide, climate, vegetation, land use, and the known sensitivity of biodiversity to these changes. They proposed that for terrestrial ecosystems, land-use change followed by climate change would probably have the largest effect on biodiversity while for freshwater ecosystems, biotic exchange (i.e., both unintentional and intentional introduction of organisms) will have the largest effect. The authors stressed that the level of change in biodiversity will depend on interactions among the different drivers of biodiversity change and that in turn, discerning these interactions represent one of the largest uncertainties for projecting the future of biodiversity (see also chapter 3).

2.3 BIODIVERSITY EFFECTS ON ECOSYSTEM FUNCTIONING: LINKS TO CLIMATE CHANGE

For a given ecosystem, high-diverse and/or functionally diverse ecosystems may be better able to adapt to climate change and climate variability than functionally impoverished ecosystems. As biodiversity is degraded or lost, communities and human society itself become more vulnerable because options for change may be diminished. Biodiversity is responsive to a range of external factors, but of interest here is that levels of biodiversity influence ecosystem functioning (Chapin et al. 2000, Purvis and Hector 2000). Experimental studies have indicated that intact, non-intensively managed ecosystems, as well as high-diversity agricultural and forestry systems, may cope better with long-term climatic variability than biologically impoverished and man-made low-diversity ecosystems. It must be stressed, however, that the nature and magnitude of the effect of biodiversity on many ecosystem processes is still poorly known. Although there is consensus that at least some minimum number of species is essential for ecosystem functioning and that a larger number of species is likewise essential for maintaining the stability of ecosystem processes in changing environments (Loreau et al. 2001), there is also growing evidence that the effects of biodiversity on ecosystem processes are heavily dependent on given levels of functional diversity rather than to total number of species (Chapin et al. 2000). This is because both the number and type of functional types present in a community largely affects ecosystem processes (reviewed in Díaz and Cabido 2001). In addition, the larger the number of functionally similar species within the ecosystem (e.g., several species of trees), the greater the probability that at least some of these species will survive changes in the environment and maintain its vital properties (Chapin et al. 1996). Nevertheless, ecosystem functioning may sometimes be determined by a few dominant species. So-called keystone species are examples of species whose ecosystem role is disproportionately high in relation to their relative biomass. Examples are some "ecosystem engineer" species (Jones et al. 1994), and plant species that form mutualisms with nitrogen fixing bacteria (Vitousek and Walker 1989).

Two essential elements of ecosystem functioning: resistance and resilience, are strongly influenced by key attributes of its dominant species. However, both elements cannot be concurrently maximized (Lepš et al. 1982). Resistance is the ability of a system to avoid change, or its capacity to stay in the same state in the face of perturbation. Resilience is the rate at which a system returns to its former state after being displaced by perturbation (Lepš et al. 1982). The ability of ecosystems to persist depends on their resilience, resistance to change, their capacity to 'migrate' due to changing environmental conditions (see chapter 3), and on the severity of the environmental variation (Pimm 1991). Functional diversity may also play a role; e.g., the dominance of short lived, fast growing plants (e.g., annual grasses) leads to high resilience and low resistance, whereas the dominance of long lived (e.g., trees) slow growing, stress-tolerant plants favors resistance. This can have important consequences for long-term carbon storage in ecosystems. Thus species attributes and types of species (e.g., trees, shrubs, grasses) may have important implications in climate change mitigation projects as it may determine the longevity, rate and direction of desired ecosystem processes (e.g., rate of atmospheric carbon uptake).

The degree of genetic variability within species can be important for maintaining ecosystem performance and for allowing continued adaptation to changing conditions. Therefore, the possibility exists that the loss of within-species genetic variation could also lead to instability in the face of a changing environment (Joshi et al. 2001). Grime et al. (2000) reported that in herbaceous communities, those composed of genetically uniform populations appear to lose more species over time, than those with more genetically heterogeneous populations. Evidence of this also comes from the field of agriculture, in particular subsistence agriculture practiced by traditional peoples. Genetic erosion often occurs during the process of selection to produce high-yielding crop varieties (Pretty 1995, Altieri 1995, Shiva 2000). Crops with high genetic diversity tend to be more resistant to pests (Zhu et al. 2000).

Mixed cropping systems can produce higher combined yields than those based on monocultures, especially if there are strong functional and morphological differences between crop species (Trenbath 1974, Vandermeer 1989). The ground cover of mixtures can be higher than that of monocultures, reducing water runoff (Pretty 1995). However, it is debatable whether a mixture necessarily results in better yields than the monoculture alternatives, except for legume + non-legume mixtures (Vandermeer 1989), and many production systems based on monoculture appear to be stable. Tropical rice systems for example, appear to be stable even though they are often genetically uniform monocultures. Stability may be due to high levels of diversity in crop-associated biodiversity including arthropods that provide homeostasis in terms of pest-predator dynamics (Settle et al. 1996). Pretty (1995) highlights that in traditional peasant societies (where most study cases come from), intercropping is practiced not as a way to maximize yield, but rather to spread risk in coping with a spatially and temporally variable environment. Ad-hoc experiments on the role of plant biodiversity in the functioning of forest ecosystems are much more rare, due to obvious operational difficulties. However, there are some experiments with low-diversity mixtures and reviews based on forest inventory data (Cannell et al. 1992) suggesting that multiple tree species mixtures can be more productive than monoculture stands, although this pattern is far from universal (Cannell et al.

1992, Wormald 1992, Caspersen and Pacala 2001). There is little consistent evidence of benefits of tree intercropping for belowground processes (Rothe and Binkley 2001).

2.4 RESEARCH NEEDS AND INFORMATION GAPS

Our knowledge is still insufficient to give detailed scientific advice on many aspects of interlinkages between biodiversity, human-induced climate change, and ecosystem function. Future research may want to assess: (1) which ecosystem functions are most vulnerable to species loss; and (2) the relationship between biodiversity and ecosystem structure, its functioning and productivity, and the delivery of ecosystem goods and services.

Further research is also needed on the interaction between climate change and land-use change impacts on biodiversity and on the effects of atmospheric CO_2 enrichment on the productivity, species composition and carbon dynamics in different ecosystems, and on ecosystem resistance and resilience.

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3. CLIMATE CHANGE AND BIODIVERSITY: OBSERVED AND PROJECTED IMPACTS

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INTRODUCTION

The Convention on Biological Diversity (CBD) has organized its work under the following thematic programs: agricultural biodiversity, dry and sub-humid lands biodiversity, forest biodiversity, inland waters biodiversity, mountain biodiversity, and marine and coastal biodiversity. This chapter summarizes the observed and projected changes in the climate system and the impacts of these changes on the above ecosystem types, and the potential impacts of large-scale changes in biodiversity on regional and global climates.

The majority of the material for this chapter is drawn from Intergovernmental Panel on Climate Change (IPCC)[16] reports; in particular, the Technical Paper V on climate change and biodiversity that summarized the material in IPCC reports of relevance to this chapter. Appendix A of the IPCC Technical Paper V provided a set of additional literature of some relevance to this chapter; in addition, a thorough literature search was conducted from 1999 to late 2002. Thus, there have been a number of publications of relevance to this chapter published post-IPCC Third Assessment Report and these have been assessed and are cited. Overall, the additional publications have supported the IPCC findings, often with specific examples of a particular taxa, ecosystem or region.

IPCC in its Working Group II (impacts, adaptation and vulnerability – IPCC 2001, IPCC 2002- section 1) provides definitions of concepts of importance to this chapter. The major concepts are impacts, adaptation, and vulnerability and their accepted definitions are as follows:

(a) The magnitude of the impact is a function of the extent of change in a climatic parameter (e.g., a mean climate characteristic, climate variability and/or the frequency and magnitude of extremes) and the sensitivity of the system to that climate-related stimuli. The impacts of the projected changes in climate include direct changes in many aspects of biodiversity and disturbance regimes (e.g., changes in the frequency and intensity of fires, pests, and diseases).

(b) *Adaptation* measures could reduce some of the impacts. Human and natural systems will to some degree adapt autonomously to climate change. Planned adaptation (see section 4.11) can supplement autonomous adaptation, though options and incentives are greater for adaptation of human systems than for adaptation for natural systems. Natural and human systems are considered to be vulnerable if they are exposed and/or sensitive to climate change and/or adaptation options are limited.

(a) *Vulnerability* is the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity.

(b) *Adaptive* capacity is the ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.

Chapter 2 has discussed the links between climatic factors and biodiversity. In this chapter, drawing on findings of the IPCC, the observed and the projected changes in the climate system

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[16] IPCC publications are based on extensive assessment of literature, both peer reviewed and some grey literature, from all over the world.

of relevance to biodiversity are summarised in sections 3.1 and 3.2. These include changes in the composition of the atmosphere (e.g., the atmospheric concentrations of CO_2), the Earth's climate (e.g., surface temperature, including day-night and seasonal, intensity and frequency of precipitation, snow cover, sea, river and lake ice, glaciers, sea level, and climate variability) as well as El Niño Southern Oscillation (ENSO) events. ENSO events consistently affect regional variations of precipitation and temperature over much of the tropics, subtropics, and some mid-latitude areas), and in some regions extreme climatic events (e.g., heat waves, heavy precipitation events).

As stated in chapter 2, ecosystems provide many goods and services crucial to human well being, including those for indigenous and local communities. These include food, fibre, fuel, energy, fodder, medicines, clean water, clean air, flood/storm control, pollination, seed dispersal, pest and disease control, soil formation and maintenance, cultural, spiritual, aesthetic and recreational values. Human activities create many pressures on ecosystems such as land use change, soil and water and air pollution. In many cases, climate change is an added stress. Climate and climate change can affect ecosystems and biodiversity in many ways: the impacts of observed and projected changes on terrestrial and inland wetlands (including freshwater systems), marine and coastal systems and the goods and services they provide is summarized in sections 3.3 to 3.5. Climate change is particularly likely to impact traditional and indigenous peoples and the projected impacts are summarised in section 3.6. Some ecosystems are sensitive to climatic factors and have limited adaptation options thus making them vulnerable to climate change; these are summarised in section 3.7. Some changes in terrestrial and marine biodiversity could affect the regional and global climate and these interactions are summarised in section 3.8. The chapter ends with summarising the information gaps and research needs that have to be considered to increase the understanding of the impacts of climate change on ecosystems and to reduce some uncertainties in projecting the impacts.

3.1 OBSERVED CHANGES IN THE CLIMATE

Changes in climate occur as a result of internal variability of the climate system and external factors (both natural and as a result of human activities). Emissions of greenhouse gases and aerosols due to human activities change the composition of the atmosphere. Increasing greenhouse gases tend to warm the Earth's climate, while increasing aerosols can either cool or warm the Earth's climate.

The IPCC findings of the observed changes over the 20th century in the composition of the atmosphere (e.g., the increasing atmospheric concentrations of greenhouse gases such as CO_2 and methane (CH_4), the Earth's climate (e.g., temperature, precipitation, sea level, sea ice, and in some regions extreme climatic events including heat waves, heavy precipitation events and droughts) are summarized in this section (IPCC 2001, [questions 2, 4, 5] and the IPCC Working Group 1, SPM).

a) **Concentrations of atmospheric greenhouse gases have generally increased.** During the period 1750 to 2000, the atmospheric concentration of CO2 increased by 31±4%, primarily due to the combustion of fossil fuels, land use, and land-use change (see also chapter 4 on carbon cycle explanation). The atmospheric concentration of CH_4 increased by 151±25% from the years 1750 to 2000, primarily due to emissions from fossil-fuel use, livestock, rice agriculture, and landfills. Stratospheric aerosols from large volcanic eruptions have led to important, but brief-lived, negative forcings, particularly the periods about 1880 to 1920 and 1963 to 1994.
b) **Over the 20th century there has been a con-**

sistent, large-scale warming of both the land and ocean surface. Most of the observed warming over the last 50 years has been due to the increase in greenhouse gas concentrations. The global mean surface temperature has increased by 0.6°C (range of 0.4–0.8°C) over the last 100 years. The warming has been greatest in the mid-high latitudes. Since the year 1950, the increase in sea surface temperature is about half that of the increase in mean land surface air temperature and night-time daily minimum temperatures over land have increased on average by about 0.2°C per decade, about twice the corresponding rate of increase in daytime maximum air temperatures.

c) **Precipitation has** *very likely*[17] **increased during the 20th century by 5 to 10% over most mid- and high latitudes of the Northern Hemisphere continents, but in contrast precipitation has** *likely* **decreased by 3% on average over much of the subtropical land areas.** There has *likely* been a 2 to 4% increase in the frequency of heavy precipitation (50 mm in 24 hours) events in the mid- and high latitudes of the Northern Hemisphere over the latter half of the 20th century. There were relatively small increases over the 20th century in land areas experiencing severe drought or severe wetness: in many regions these changes are dominated by inter-decadal and multi-decadal climate variability with no significant trends evident.

d) **Snow cover and ice extent have decreased.** It is *very likely* that the snow cover has decreased by about 10% on average in the Northern Hemisphere since the late 1960s (mainly through springtime changes over America and Eurasia) and the annual duration of lake- and river-ice cover in the mid- and high latitudes of the Northern Hemisphere has been reduced by about 2 weeks over the 20th century. There was also widespread retreat of mountain glaciers in non-polar regions during the 20th century. Northern Hemisphere spring and summer sea-ice extent decreased by about 10 to 15% from the 1950s to the year 2000.

e) **The average annual rise in sea level was between 1 and 2 mm during the 20th century.** This is based on the few, very long, tide gauge records from the northern hemisphere and after correcting for vertical land movements. It is *very likely* that the 20th century warming contributed significantly to the observed sea level rise through thermal expansion of seawater and widespread loss of land ice.

f) **Warm episodes of the ENSO phenomenon have been more frequent, persistent, and intense since the mid-1970s,** compared with the previous 100 years.

g) **There have been observed changes in some extreme weather and climate events.** It is *likely* that there have been higher maximum temperatures, more hot days and an increase in heat index, and *very likely* that there have been higher minimum temperatures and fewer cold days and frost days over nearly all land areas. In addition, it is *likely* that there has been an increase in summer continental drying and associated risk of drought in a few areas.

3.2 PROJECTED CHANGES IN THE CLIMATE

The Working Group I contribution to the IPCC Third Assessment Report (IPCC 2001) provided revised global and, to some extent, regional climate change projections based on a new series

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[17] Based on the IPCC Working Group I lexicon use, the following words have been used where appropriate to indicate judgemental estimates of confidence: *very likely* (90–99% chance) and *likely* (66–90% chance). When the words *likely* and *very likely* appear in italics, these definitions are applied; otherwise, they reflect normal usage.

of emission scenarios from the IPCC Special Report on Emissions Scenarios (SRES). The SRES scenarios consist of six scenario groups, based on narrative storylines. They are all plausible and internally consistent, and no probabilities of occurrence are assigned. They encompass four combinations of demographic, social, economic, and broad technological development assumptions. Each of these scenarios results in a set of atmospheric concentrations of greenhouse gases and aerosols from which the changes in the climate can be projected. CO_2 concentrations, globally averaged surface temperature, and sea level are projected to increase during the 21st century. Substantial differences are projected in regional changes in climate and sea level as compared to the global mean change. An increase in climate variability and some extreme events is also projected. The projected changes, extracted from section 4 of IPCC (2002), and that have relevance to biodiversity--supplemented with any recent literature--are summarized below.

(a) **The concentrations of greenhouse gases are projected to increase in the 21st century and sulphate aerosol are projected to decrease.** The projected concentrations of CO_2, in the year 2100 range from 540 to 970 parts per million (ppm), compared to about 280 ppm in the pre-industrial era and about 368 ppm in the year 2000. Sulfate aerosol concentrations are projected to fall below present levels by 2100 in all six illustrative SRES scenarios, whereas natural aerosols (e.g., sea salt, dust) and emissions leading to sulfate and carbon aerosols (e.g. dimethyl sulphide – DMS – emitted by some species of phytoplankton) are projected to increase as a result of changes in climate.

(b) **The projected global average increases in temperature are about two to ten times larger than the central value of observed warming over the 20th century** and the projected rate of warming of 1.4 to 5.8°C over the period 1990 to 2100 is *very likely* to be without precedent during at least the last 10,000 years. The most notable areas of warming are in the landmasses of northern regions (e.g., North America, and northern and central Asia), which exceed global mean warming in each climate model by more than 40%. In contrast, the warming is less than the global mean change in south and southeast Asia in summer and in southern South America in winter.

(c) **Globally averaged annual precipitation is projected to increase during the 21st century**, with both increases and decreases in precipitation of typically 5 to 20% projected at the regional scale. Precipitation is *likely* to increase over high-latitude regions in both summer and winter. Increases are also projected over northern mid-latitudes, tropical Africa and Antarctica in winter, and in southern and eastern Asia in summer. Australia, Central America, and southern Africa show consistent decreases in winter rainfall. Larger year-to-year variations in precipitation are *very likely* to occur over most areas where an increase in mean precipitation is projected.

(d) **Models project that increasing atmospheric concentrations of greenhouse gases will result in changes in daily, seasonal, interannual, and decadal variability in temperature.** There is projected to be a decrease in diurnal temperature range in many areas, with nighttime lows increasing more than daytime highs. The majority of models show a general decrease in daily variability of surface air temperature in winter and increased daily variability in summer in the Northern Hemisphere land areas. Although future changes in El Niño variability differ from model to model, current projections show little change or a small increase in amplitude for El Niño events over the next 100 years. Many models show a more El Niño-like mean response in the tropical Pacific, with the central and eastern equatorial Pacific sea surface temperatures projected to warm more than the western equatorial Pacific and with a corresponding mean eastward shift of precipitation. Even with little or no change in El Niño strength, global warming is likely to lead to greater extremes of drying and heavy rainfall and increase the risk of droughts and floods that occur with El Niño events in many different regions. There is no clear agreement between models concerning the changes in frequency or structure of other naturally occurring atmosphere-ocean circulation patterns such as the North Atlantic Oscillation (NAO).

(e) **The amplitude and frequency of extreme precipitation events are** *very likely* to increase over many areas and the return periods for extreme precipitation events are projected to decrease. This would lead to more frequent floods even in areas of decreasing overall precipitation (Christensen and Christensen 2003). A general drying of the mid-continental areas during summer is *likely* to lead to increases in summer droughts and could increase the risk of wild fires.

(f) **More hot days and heat waves and fewer cold and frost days are** *very likely* **over nearly all land areas.**

(g) **High-resolution modelling studies suggest that over some areas the peak wind intensity of tropical cyclones is** *likely* **to increase over the 21st century** by 5 to 10% and precipitation rates may increase by 20 to 30%, but none of the studies suggest that the locations of the tropical cyclones will change. There is little consistent modelling evidence for changes in the frequency of tropical cyclones

(h) **There is insufficient information on how very small-scale phenomena may change.** Very small-scale phenomena such as thunderstorms, tornadoes, hail, hailstorms, and lightning are not simulated in global climate models.

(i) **Glaciers and ice caps are projected to continue their widespread retreat during the 21st century.** The Antarctic ice sheet is *likely* to gain mass because of greater precipitation, while the Greenland ice sheet is *likely* to lose mass because the increase in runoff will exceed the precipitation increase.

(j) **Global mean sea level is projected to rise by 0.09 to 0.88 m between the years 1990 and 2100, with substantial regional variations.** Projected rise in sea-level is due primarily to thermal expansion and loss of mass from glaciers and ice caps. The projected range of regional variation in sea-level change is substantial compared to projected global average sea-level rise, because the level of the sea at the shoreline is determined by many additional factors (e.g., atmospheric pressure, wind stress and thermocline depth). Confidence in the regional distribution of sea-level change from complex models is low because there is little similarity between model results, although nearly all models project greater than average rise in the Arctic Ocean and less than average rise in the Southern Ocean.

(k) **Most models project a weakening of the ocean thermohaline circulation, which leads to a reduction of the heat transport into high latitudes of Europe.** The current projections do not exhibit a complete shutdown of the thermohaline circulation by 2100. Beyond 2100, there is some evidence to suggest that the thermohaline circulation could completely, and possibly irreversibly, shut down in either hemisphere if the change in radiative forcing is large enough and applied long enough. The impact of this on biodiversity is unknown.

3.3 OBSERVED CHANGES IN TERRESTRIAL AND MARINE ECOSYSTEMS ASSOCIATED WITH CLIMATE CHANGE

IPCC evaluated the effect of climate change on biological systems by assessing 2 500 published studies. Of these, 44 studies, which included about 500 taxa, met the following criteria: 20 or more years of data; measuring temperature as one of the variables; the authors of the study finding a statistically significant change in both a biological/physical parameter and the measured temperature; and a statistically significant correlation between the temperature and the change in the biological/physical parameter. Some of these studies investigated different taxa (e.g., bird and insect) in the same paper. Thus, a total of 59 plants, 47 invertebrates, 29 amphibians and reptiles, 388 birds, and 10 mammal species. Approximately 80% showed change in the biological parameter measured (e.g., start and end of breeding season, shifts in migration patterns, shifts in animal and plant distributions, and changes in body size) in the manner expected with global warming, while 20% showed change in the opposite direction. Most of these studies have been carried out (due to long-term research funding decisions) in the temperate and high-latitude areas and in some high-altitude areas. The main findings of the IPCC are that some ecosystems that are particularly sensitive to changes in regional climate (e.g., high-altitude and high-latitude ecosystems) have already been affected by changes in climate (IPCC 2002– section 5.1, Root et al. 2003, Parmesan and Yohe 2003). Specifically, there has been a discernible impact of regional climate change, particularly increases in temperature, on biological systems in the 20th century. Specific changes highlighted in the IPCC paper, supplemented by recent material, include changes in terrestrial (including freshwater) species distributions, population sizes, community composition and plant productivity: declines in frog and some bird species have been assessed in the IPCC Third assessment Report, but it is not clear that climate change is the causal factor, with pressures from other human activities being implicated. The main findings of the IPCC Third Assessment Report (IPCC 2002) are:

(a) **Changes in the timing of biological events (phenology) have been observed.** These include changes the timing of growth, flowering and reproduction. Such changes have been recorded in some insects, amphibians, reptiles, birds, and plant species.

(b) **Changes in species distribution linked to changes in climatic factors have been observed.** These include extension of range limit of some species polewards, especially in the northern hemisphere. Drought associated shifts in animal's ranges and densities have been observed in many parts of the world.

(c) **Many taxa (birds, insects, plants) have shown changes in morphology, physiology, and behavior** associated with changes in climatic variables.

(d) **Changes in climatic variables has led to increased frequency and intensity of outbreaks of pests and diseases** accompanied by range shifts poleward or to higher altitudes of the pests/disease organisms.

(e) **Changes in streamflow, floods, droughts, water temperature, and water quality have been observed** and they have affected biodiversity and the goods and services ecosystems provide.

(f) **In high-latitude ecosystems in the Northern Hemisphere, the warmer climate has lead to increased growing degree-days** for agriculture and forestry. However, the amount of sunlight and perhaps the proportion of direct and diffuse sunlight also influence plant productivity. There has been altered plant species composition, especially forbs and lichens in the tundra, due to thermokarst, some boreal forests in central Alaska have been transformed into extensive wetlands during the last few decades of the

20th century. The area of boreal forest burned annually in western North America has doubled in the last 20 years, in parallel with the warming trend in the region.

(g) **There has been observed decrease in survivorship of adult penguins.** Over the past 50 years, the population of emperor penguins in Terre Adelie has declined by 50% because of a decrease in adult survival during the late 1970s when there was a prolonged abnormally warm period with reduced sea-ice extent (Barbraud and Weimerschkirch 2001).

(h) **Extreme climatic events, and variability (e.g., floods, hail, freezing temperatures, tropical cyclones, droughts), and the consequences of some of these (e.g., landslides and wildfire) have affected ecosystems in many continents.** Climatic events such as the El Niño event of the years 1997–1998 had major impacts on many terrestrial ecosystems.

The coastal and marine ecosystems are sensitive to changes in water temperature and extreme climatic events. Specific findings of the IPCC (2002 – section 5.2, IPCC 2001, SYR, Question 2) include:

(a) **Tropical and subtropical coral reefs have been adversely affected** by rising sea surface temperatures, especially during El-Nino events during which the temperatures increase beyond the normal seasonal range. These bleaching events are often associated with other stresses such as, sediment loading and pollution. The repercussions of the 1998 mass bleaching and mortality events will be far-reaching (Reaser et al. 2000).

(b) **Diseases and toxicity have affected coastal ecosystems** related to increased seasonal or annual water temperatures.

(c) **Changes in marine systems, particularly fish populations, have been linked to large-scale climate oscillations.**

(d) **Large fluctuations in the abundance of marine birds and mammals across parts of the Pacific and western Arctic have been detected** and may be related to changing regimes of disturbances, climate variability, and extreme events.

3.4 PROJECTED IMPACTS OF CHANGES IN MEAN CLIMATE AND EXTREME CLIMATIC EVENTS ON TERRESTRIAL (INCLUDING RIVERS, LAKES AND WETLANDS) AND MARINE ECOSYSTEMS

Climate change and elevated atmospheric concentrations of CO_2 is projected to affect individuals, populations, species and ecosystem composition and function both directly (e.g., through increases in temperature and changes in precipitation, changes in extreme climatic events and in the case of aquatic systems changes in water temperature, sea level, etc.) and indirectly (e.g., through climate changing the intensity and frequency of disturbances such as wildfires). The impacts of climate change will depend on other significant anthropogenic pressures. The most significant pressures are increased land-use intensity and the associated destruction of natural or semi-natural habitats, loss and fragmentation (or habitat unification, especially in the case of freshwater bodies), the introduction of invasive species, and direct effects on reproduction, dominance, and survival through chemical and mechanical treatments. No realistic projection of the future state of the Earth's ecosystems can be made without taking into account human land- and water-use patterns—past, present, and future. Human use will endanger some terrestrial and aquatic ecosystems, enhance the survival of others, and greatly affect the ability of organisms to adapt to climate change via migration (chapter 2). Independent of climate change, biodiversity is forecast to decrease in the future due to the multiple pressures from human activities—climate change constitutes an additional pressure. Quantification of the impacts of climate change alone, given the multiple and interactive pressures acting on the

Earth's ecosystems, is difficult and likely to vary regionally. Losses of species can lead to changes in the structure and function of the affected ecosystems, and loss of revenue and aesthetics (IPCC 2002 – section 6 introduction and 6.1).

IPCC (2002 – section 6.1, 6.2) stated that projecting changes in biodiversity in response to climate change presents some significant challenges, especially at the fine scale. Modelling requires projections of climate change at high spatial and temporal resolution and often depends on the balance between variables that are poorly projected by climate models (e.g., local precipitation and evaporative demand). It also requires an understanding of how species interact with each other and how these interactions affect the communities and ecosystems of which they are a part. The data and models needed to project the extent and nature of future ecosystem changes and changes in the geographical distribution of species are incomplete, meaning that these effects can only be partially quantified. Models of changes in the global distribution of vegetation are often most sensitive to variables for which we have only poor projections (e.g., water balance) and inadequate initial data.

Biodiversity is recognized to be an important issue for many regions of the world. It also provides goods and services for human wellbeing (Box 2.1). Different regions have varied amounts of biodiversity with varying levels of endemic species. The projected impacts of climate change at the regional level are summarised in Boxes no. 5 to 15 of the IPCC (2002) and will not be summarised here. It is worth noting that there is a limitation of region- and country-specific studies on the impacts of climate change on biodiversity particularly at the genetic level.

3.4.1 Projected impacts on individuals, populations, species, and ecosystems

Based on IPCC Reports (2001; 2002), and additional material (as listed), some examples of how individuals, populations, and species, ecosystems and some ecological processes that may be affected by climate change (directly or indirectly) include:

(a) **While there is little evidence to suggest that climate change will slow species losses, there is evidence that it may increase species losses.**

(b) **Extinction of wildlife populations may be hastened by increasing temporal variability in precipitation.** Models of checkerspot butterfly (a common species found in North America) populations showed that changes in precipitation amplified population fluctuations, leading to rapid extinctions (McLaughlin et al. 2002). This process will be particularly pronounced when a population is isolated by habitat loss.

(c) **Changes in phenology, such as the date of bud break of plants, hatching, and migration of insects, birds and mammals, have already been observed and are expected to continue.** This can be beneficial or detrimental, e.g., the changes in phenology of plants can lead to higher productivity, but can make the plants more vulnerable to early or late onset of frost and pest/disease outbreak. There could be further interaction between the phenology and changes in extreme climatic events, e.g., the lack of frost in some regions can stop the onset of flowering and thus fruit formation (e.g., in southern Australia- Pittock et al. 2001).

(d) **Ecosystems dominated by long-lived species (e.g., long-lived trees) will often be slow to show evidence of change** and slow to recover from climate-related stresses as the changes in the climate may not be sufficient to cause increased mortality among mature individuals. Changes in climate often also affect vulnerable life stages such as seedling establishment and are expected to continue to do so.

(e) **Plant communities are expected to be disrupted**, as species that make up a community are unlikely to shift together. In lakes and river systems, changes in water quality due to climate change could cause eutrophication and thus change the species composition.

(f) **Most soil biota have relatively wide temperature optima, so are unlikely to be adversely affected directly by changes in temperatures, although there is lack of information on the effect of changes in soil moisture.** Some evidence exists to support changes in the balance between soil functional types (see section 2.3 for discussion on functional types).

(g) **For inland wetlands, changes in rainfall and flooding patterns across large areas of arid land will adversely affect bird species** that rely on a network of wetlands and lakes that are alternately or even episodically wet and fresh and drier and saline (Roshier et al. 2001), or even a small number of wetlands, such as those used by the banded stilt (Cladorhynchus leucocephalus) which breeds opportunistically in Australia's arid interior (Williams 1998). Responses to these climate induced changes may also be affected by fragmentation of habitats or disruption or loss of migration corridors, or even, changes to other biota, such as increased exposure to predators by wading birds (Butler and Vennesland 2000, van Dam et al. 2002).

(h) **The lack of thermal refugia and migratory routes in lakes, streams and rivers, may cause contraction of the distributions of many fish species.** For example, warmer lake water temperature will reduce dissolved oxygen concentration and lower the level of the thermocline, most likely resulting in a loss of habitat for coldwater fish species in areas such as Wisconsin and Minnesota (western Great Lakes). In addition, reduced summer flows and increased temperatures will cause a loss of suitable habitat for cool water fish species in riverine environments in the Rocky Mountain region (British Columbia, western Canada; Gitay et al. 2001)

(i) **Species and ecosystems are projected to be impacted by extreme climatic events,** e.g., higher maximum temperatures, more hot days, and heat waves are projected to increase heat stress in plants and animals and reduce plant productivity; higher minimum temperatures, fewer cold days, frost days and cold waves could result in extended range and activity of some pest and disease vectors, increased productivity in some plant species and ecosystems; more intense precipitation events are projected to result in increased soil erosion, increased flood runoff; increased summer drying over most mid-latitude continental interiors and associated risk of drought are projected to result in decreased plant productivity, increased risk of wild fires and diseases and pest outbreaks; increased Asian summer monsoon precipitation variability and increased intensity of mid-latitude storms could lead to increased frequency and intensity of floods and damage to coastal areas.

(j) **The general impact of climate change is that the habitats of many species will move poleward or upward** from their current locations with most rapid changes being where they are accelerated by changes in natural and anthropogenic disturbance patterns. Weedy (i.e., those that are highly mobile and can establish quickly) and invasive species will have advantage over others.

(k) **Drought and desertification processes will result in movements of habitats of many species towards areas of higher rainfall from their current locations.**

(l) **The climatic zones suitable for temperate and boreal plant species may be displaced by 200–1,200 km poleward** (compared to the 1990s distribution) by the year 2100. The species composition of forests is likely to change and new assemblages of species may replace existing forest types that may be of lower species diversity due to the inability of some species to migrate fast enough and or due to habitat fragmentation. Increased frequency and intensity of fires and changes caused by thawing of permafrost will also affect some of these ecosystems.

(m) **For lakes and streams, the effects of temperature-dependent changes would be least in the tropics, moderate at mid-latitudes, and pronounced in high latitudes** where the largest changes in temperature are projected. Increased temperatures will alter thermal cycles of lakes and solubility of oxygen and other materials, and thus affect ecosystem structure and function. Changes in rainfall frequency and intensity combined with land-use change in watershed areas has led to increased soil erosion and siltation in rivers. This along with increased use of manure, chemical fertilizers, pesticides, and herbicides as well as atmospheric nitrogen deposition affects river chemistry and has led to eutrophication, with major implications for water quality, species composition, and fisheries. The extent and the duration of the ice cover is projected to decrease in some high latitude lakes and thus the biodiversity may be affected by the shorter ice cover season (Christensen and Christensen 2003)

(n) **Climate change will have most pronounced effects on wetlands through altering the hydrological regime** as most inland wetland processes are intricately dependent on the hydrology of the catchments (river basin) or coastal waters. This is expected to affect biodiversity and the phenology of wetland species (van Dam et al. 2002)

(o) **Land degradation arises both from human activities and from adverse climate conditions as to the exact quantitative attribution is difficult and controversial.** Climate-related factors such as increased drought can lead to increased risk of land degradation and desertification (Bullock et al. 1996, Le Houerou 2002, Nicholson 2001).

(p) **Disturbance can both increase the rate of loss of species and create opportunities for the establishment of new (including invasive alien) species.** Changes in the frequency, intensity, extent and locations of disturbances such as fires, outbreaks of pests and diseases, will affect whether and how existing ecosystems reorganize and the rate at which they are replaced by new plant and animal assemblages (see section 2.2.1).

(q) **The effect of interactions between climate change and changes in disturbance regime and their effect on biotic interactions may lead to rapid changes in vegetation composition and structure.** However, the quantitative extent of these changes is hard to project due to the complexity of the interactions.

3.4.2. Projected changes in biodiversity and changes in productivity

IPCC 2002 (section 6.2.2) stated that changes in biodiversity and the changes in ecosystem functioning associated with them might affect biological productivity. These changes may affect critical goods and services (see Chapter 2) and the total sequestration of carbon in ocean and terrestrial ecosystems, which can affect the global carbon cycle and the concentration of greenhouse gases in the atmosphere. Productivity can be measured as net primary productivity (NPP), net ecosystem productivity (NEP) or net biome productivity (NEB – see Box 4 of IPCC 2002).

3.4.2.1.Effects of elevated atmospheric CO_2 concentrations on vegetation

Climate change may either augment or reduce the direct effects of CO_2 on productivity, depending on the type of vegetation, the region, and the scenario of climate change. In most vegetation systems, increasing CO_2 concentrations would increase net primary productivity (often referred to as CO_2 fertilization effect) and net ecosystem productivity, causing carbon to accumulate in vegetation and soils over time assuming that the temperature increase is about 2-3 °C and there is little or no moisture limitation (Gitay et al. 2001).

The IPCC assessment was that over the 19th and for much of the 20th century the global terrestrial biosphere was a net source of atmospheric CO_2, but before the end of the 20th century it became a net sink, because of a combination of factors, e.g., changes in land-use and land management practices (e.g., reforestation and re-growth on abandoned land), increasing anthropogenic deposition of nitrogen, increased atmospheric concentrations of CO_2, and possibly climate warming (IPCC 2001, SYR, Question 2, IPCC 2001, section 6.2.2 --see also chapter 4).

54. During recent decades, the peak-to-trough amplitude in the seasonal cycle of atmospheric CO_2 concentrations has increased, and the phase has advanced at Arctic and sub-Arctic CO_2 observation stations north of 55° N. This change in carbon dynamics in the atmosphere probably reflects some combination of increased uptake during the first half of the growing season which could explain the observed increase in biomass of some shrubs, increased winter efflux and increased seasonality of carbon exchange associated with disturbance. This "inverse" approach has generally concluded that mid-northern latitudes were a net carbon sink during the 1980s and early 1990s. At high northern latitudes, these models give a wider range of estimates, with some analyses pointing to a net and others to a sink.

Free-air CO_2 enrichment (FACE) experiments suggest that tree growth rates may increase, litterfall and fine root increment may increase, and total net primary production may increase in forested systems, but these effects are expected to saturate because forest stands tend towards maximum carrying capacity, and plants may become acclimated to increased CO_2 levels. Longer-term experiments on tree species grown under elevated CO_2 in open-top chambers under field conditions over several growing seasons show a continued and consistent stimulation of photosynthesis, little evidence of long-term loss of sensitivity to CO_2, the relative effect on aboveground dry mass highly variable and greater than indicated by seedling studies, and the annual increase in wood mass per unit of leaf area. These results contradict some of the FACE experiment results.

On a global scale, terrestrial models project that climate change would reduce the rate of uptake of carbon by terrestrial ecosystems, but that they would continue to be a net, but decreasing, sink for carbon through 2100 (IPCC, 2001, Question 3).

The interaction between atmospheric CO_2 concentrations, air temperature and moisture is particularly noticeable in the context of plant-plant interactions (including shifts in competitiveness of some groups of plants, e.g. C_3 and C_4 species and lianas). Photosynthesis in C_3 plants is expected to respond more strongly to CO_2 enrichment than in C_4 plants. If this is the case, it is likely to lead to an increase in geographic distribution of C_3 (many of which are woody plants) at the expense of the C_4 grasses. However, the impacts are not that simple. In pot experiments, elevated CO_2 is reported to improve water relations and enhance productivity in the C_4 shortgrass Bouteloua gracilis. In modelling and experimental studies, NPP of both C_3 and C_4 grasses increased under elevated CO_2 for a range of temperatures and precipitation but could result in relatively small changes in their geographical distributions. There are additional interactions with soil characteristics and climatic factors. The rate and duration of any change is likely to be affected by the human activity where a high grazing pressure may mean more establishment sites for the C_4 grasses (Gitay et al. 2001). Phillips et al. (2002) have found increased competitiveness and dominance of lianas in Brazilian Amazon under higher CO_2 situations. There could be a resultant degradation of forest structure with increased liana biomass pulling down trees.

3.4.2.2. Summary findings of projected changes in biodiversity and changes in productivity

The main findings of IPCC (2002 – section 6.2.2) are:

(a) **Where significant ecosystem disruption occurs (e.g., loss of dominant species or losses of a high proportion of species, thus much of the redundancy), there may be losses in NEP during the transition.**

(b) **The role of biodiversity in maintaining ecosystem structure, functioning, and productivity is still poorly understood** (see also section 2.3).

3.5. PROJECTED IMPACTS ON BIODIVERSITY OF COASTAL AND MARINE ECOSYSTEMS

Climate change will affect the physical, biological, and biogeochemical characteristics of the oceans and their coasts at different time and space scales, modifying their ecosystem structure and functioning. This in turn could exert feedbacks on the climate system (IPCC 2002 - section 6.3).

Human populations dependent on reef and coastal systems face losses of marine biodiversity, fisheries, and shoreline protection. Even those reefs with well-enforced legal protection as marine sanctuaries, or those managed for sustainable use, are threatened by global climate change and thus would have repercussions for the human populations that depend on them for various goods and services (Reaser et al. 2000).

61. Wetlands, including reefs, atolls, mangroves, and those in prairies, tropical and boreal forests and polar and alpine ecosystems, are considered to be amongst those natural systems especially vulnerable to climate change because of their limited adaptive capacity, and are likely to undergo significant and irreversible change (IPCC 2001 – WG2 SPM).

Other wetlands that could be impacted by climate change are those in regions that experience El Niño-like phenomena, which are projected to increase, and/or are located in the continental interiors, and thus are likely to experience changes in the catchment hydrology (van Dam et al. 2002).

3.5.1 Projected impacts on ecosystems in coastal regions

Some of the findings of IPCC (2002- section 6.3.1) and supplemented by recent material include:

(a) **Coral reefs will be impacted detrimentally if sea surface temperatures increase by more than 1°C above the seasonal maximum temperature.** In addition, an increase in atmospheric CO_2 concentration and hence oceanic CO_2 affects the ability of the reef plants and animals to make limestone skeletons (reef calcification); a doubling of atmospheric CO_2 concentrations could reduce reef calcification and reduce the ability of the coral to grow vertically and keep pace with rising sea level (see also section 3.7).

(b) **In the near-shore marine and coastal systems, many wetlands could be impacted indirectly as a result of climate change due to changes in storm surges.** As a result, there will be saltwater intrusion into the freshwater systems. This may result in large-scale translocation of populations in low lying coral reef countries when tropical storm surges pollute water supplies and agricultural land with saltwater (Wilkinson and Buddemeier 1994). Mangroves and coastal lagoons are expected to undergo rapid change and perhaps be lost as relocation may be impeded by physical factors, including infrastructure and physical geographical features (van Dam et al. 2002). Some examples are the United States of America coastal ecosystems where the increasing rates of sea-level rise and intensity and frequency of coastal storms and hurricanes over the next decades will increase threats to shorelines, wetlands, and coastal development (Scavia et al. 2002, Burkett and Kusler 2000).

(c) **Sea-level rise and changes in other climatic factors (e.g., more intense monsoonal rains, and larger tidal or storm surges) may affect a range of freshwater wetlands in low-lying regions.** For example, in tropical regions, low lying floodplains and associated swamps could be displaced by salt water habitats due to the combined actions of sea level rise, more intense monsoonal rains, and larger tidal/storm surges. Such changes are likely to result in dislocation if not displacement of many wetland species, both plants and animals. Plants, turtles, some frogs and snakes, a range of invertebrate species, bird and fish populations and species not tolerant to increased salinity or inundation, have and could continue to be eliminated or restricted in their distribution, whilst salt-tolerant mangrove species could expand from nearby coastal habitats.

(d) **The combined pressures of sea level rise and coastal development (resulting in coastal squeeze) could reduce the availability of intertidal areas**, resulting in loss of feeding habitat and leading to population declines in wintering shorebirds (Lindström and Agrell 1999). For a number of trans-African-Arctic migratory bird species, the wintering grounds in Africa and breeding grounds in the Arctic will be threatened by sea level rise, especially due to loss of mudflats (Bayliss et al. 1997, Lindström and Agrell 1999, van Dam et al. 2002). Migratory and resident animals, such as birds and fish, may lose important staging, feeding and breeding grounds (Bayliss et al. 1997, Eliot et al. 1999, Finlayson et al. 1993, Lal et al. 2001, Li et al. 1999, van Dam et al. 2002).

(e) **Currently eroding beaches and barriers are expected to erode further as the climate changes and sea level rises.**

(f) **Globally, about 20% of coastal wetlands could be lost** by the year 2080 due to sea-level rise, with significant regional variations.

(g) **The impact of sea-level rise on coastal ecosystems (e.g., mangroves, marshes, seagrasses) will vary regionally** and will depend on the interactions between erosion processes from the sea depositional processes from land and sea-level rise. The ability of fringing and barrier reefs to reduce impacts of storms and supply sediments can be adversely affected by sea-level rise.

3.5.2 Projected impacts on marine ecosystems

Marine ecosystems include various functionally different seas and oceans. Changes in the physical and chemical characteristics of the ocean and seas (e.g. currents or circulation patterns, nutrient availability, pH, salinity, and the temperature of the ocean waters) will affect marine ecosystems. Climate change impacts on the marine system include sea surface temperature-induced shifts in the geographic distribution of the biota and compositional changes in biodiversity, particularly in high latitudes. The literature in this area is not as extensive as in the terrestrial and coastal ecosystems. In addition, the present knowledge of the impacts of potential changes in entire ecosystems due to climate change is still poor.

Current scenarios of global climate change include projections of increased upwelling and consequent cooling in temperate and subtropical upwelling zones. Ecological evidence, despite being limited, suggests that such cooling could disrupt trophic relationships and favour retrograde community structures in those local areas (Aronson and Blake 2001, Barret 2003).

The response of marine productivity to climate change, using two different ocean biogeochemical schemes and two different atmosphere-ocean coupled general circulation models (GCM), suggest a reduction in marine export production (-6%) although regional changes can be both negative and positive (from -15% zonal average in the tropics to +10% in the Southern Ocean; Bopp et al. 2001).

The main findings of the IPCC (2002- section 6.3.2) supplemented by recent literature include:

(a) **The mean distribution of plankton and marine productivity in the oceans in many regions could change during the 21st century** with projected changes in the sea surface temperature, wind speed, nutrient supply, and sunlight.

(b) **Climate change will have both positive and negative impacts on the abundance and distribution of marine biota**. Recent findings show that warming will cause a northern shift of distribution limits for the cod (*Gadus morhua*) and common eelpout (*Zoarces viviparus*) with a rise in growth performance and fecundity larger than expected in the north and lower growth or even extinction of the species in the south. Such a shift may heavily affect fishing activities in the North Sea (Portner et al. 2001).

(c) **Productivity of commercially important fish species could be affected.** There are clear linkages with the intensity and position of the Aleutian Low Pressure system in the Pacific Ocean and the production trends of many of the commercially important fish species (see also Napp and Hunt 2001).

(d) **There is likely to be a poleward shift of marine production** due mainly to a longer growing season at high latitudes. At low latitudes the effect of reduced upwelling would prevail. Ocean warming is expected to cause poleward shifts in the ranges of many other organisms, including commercial species, and these shifts may have secondary effects on their predators and prey (Bopp et al. 2001).

(e) **Climate change could affect food chains, particularly** those that include marine mammals. Reductions in sea ice in Arctic and Antarctic could alter the seasonal distributions, geographic ranges, migration patterns, nutritional status, reproductive success, and ultimately the abundance of marine mammals.

3.6 PROJECTED IMPACTS ON TRADITIONAL AND INDIGENOUS PEOPLES

Traditional[18] and indigenous peoples depend directly on diverse resources from ecosystems and biodiversity for many goods and services (e.g., food and medicines from forests, coastal wetlands, and rangelands – see also chapter 2). These ecosystems are already under stress from many current human activities and projected to be adversely affected by climate change (IPCC 2002 – section 6.6). The main findings of IPCC (2002 –section 6.6, Box 5-12) supplemented with additional material include:

(a) **The effects of climate change on indigenous and local peoples are likely to be felt earlier than the general impacts.** The livelihood of indigenous peoples will be adversely affected if climate and land-use change lead to losses in biodiversity, especially mammals, birds medicinal plants and plants or animals with restricted distribution (but have importance in terms of food, fibre or other uses for these peoples) and losses of terrestrial, coastal and marine ecosystems that these peoples depend on. In some terrestrial ecosystems, adaptation options (such as efficient small-scale or garden

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[18] Following IPCC (2002) "Traditional peoples" here refers to local populations who practice traditional lifestyles that are often rural. Traditional people may, or may not, be indigenous to the location.

irrigation, more effective rain-fed farming, changing cropping patterns, intercropping and/or using crops with lower water demand, conservation tillage and coppicing of trees for fuelwood) could reduce some of the impacts and reduce land degradation (see section 4.10).

(b) **Climate change will affect traditional practices of indigenous peoples in the Arctic**, particularly fisheries, hunting, and reindeer husbandry. The on-going interest among indigenous groups relating to the collection of traditional knowledge and their observations of climate change and its impact on their communities could provide future adaptation options.

(c) **Cultural and spiritual sites and practices could be affected by sea level rise and climate change.** Shifts in the timing or the ranges of wildlife species due to climate change could impact the cultural and religious lives of some indigenous peoples. Sea-level rise and climate change, coupled with other environmental changes, will affect some, but not all, unique cultural and spiritual sites in coastal areas and thus the people that reside there.

(d) **The projected climate change impacts on the biodiversity, including disease vectors, at ecosystem and species level could impact human health.** Many indigenous and local peoples live in isolated rural living conditions and are more likely to be exposed to vector- and water-borne diseases and climatic extremes and would therefore be adversely affected by climate change. The loss of staple food and medicinal species could have an indirect impact and can also mean potential loss of future discoveries of pharmacological products and sources of food, fibre and medicinal plants for these peoples (Gitay et al. 2001, McMichael et al. 1996, 2001)

(e) **Loss of food sources and revenues from key sectors such as tourism and fisheries could occur** As summarised in Section 3.5.1, coral reefs will be negatively affected by bleaching; Fishing, although largely artisanal or small-scale commercial, is an important activity on most small islands, and makes a significant contribution to the protein intake of island inhabitants and thus could lead to loss of food source and revenue.

(f) **Change in food production and water flows in mountainous areas could affect the indigenous and local people of those areas.** For indigenous and local people living in mountainous regions, the impacts of climate change are projected to result in altering the already marginal food production, change the seasonality of water flows and thus the habitats of many species that these people depend on.

(g) **The potential expansion of tree monoculture used as "carbon sinks" can compete with traditional land use practices** by indigenous and local communities, e.g., in South Africa (see also chapter 4). However, community involvement and knowledge could help towards win-win situations.

3.7 POPULATIONS, SPECIES AND ECOSYSTEMS VULNERABLE TO CLIMATE CHANGE

Many of the Earth's species are already at risk of extinction due to pressures arising from natural processes and human activities. Climate change will add to these pressures for many threatened and vulnerable species. For a few, climate change may relieve some of the existing pressures (IPCC 2002- section 6.4). Regional variation in the impacts of climate change on biodiversity is expected because of multiple interactions between drivers of biodiversity loss. The main findings of IPCC (2002) are:

(a) **Species with limited climatic ranges and/or restricted habitat requirements are typically the most vulnerable to extinc-**

tion. These include species on mountainous areas (as they cannot move up in elevation), and species restricted to islands or peninsulas (e.g., the Cape Floral Kingdom including the fynbos region at the southern tip of South Africa). Additionally, biota with particular physiological or phenological traits (e.g., biota with temperature-dependent sex determination like sea turtles and crocodiles, amphibians with a permeable skin and eggs) could be especially vulnerable. For some threatened species, habitat availability will increase (e.g., warm-water fish are projected to benefit in shallow lakes in cool temperate regions), possibly reducing vulnerability.

(b) **The risk of extinction will increase for many species, especially those that are already at risk** due to factors such as low population numbers, restricted or patchy habitats, limited climatic ranges, or occurrence on low-lying islands or near the top of mountains.

(c) **Geographically restricted ecosystems, especially in regions where there is added pressure from other human activities, are potentially vulnerable to climate change.** Examples of geographically restricted, vulnerable ecosystems include coral reefs, mangrove forests and other coastal wetlands, high mountain ecosystems (upper 2000 to 3000 m), prairie wetlands, remnant native grasslands, ecosystems overlying permafrost, and ice-edge ecosystems.

(d) **Many important reserve systems may need to be extended in area or linked to other reserves, but for some such extensions are not possible as there is simply no place to extend them.**

3.8 IMPACTS OF CHANGES IN TERRESTRIAL AND MARINE BIODIVERSITY ON REGIONAL AND GLOBAL CLIMATE

70. Changes in genetic or species biodiversity can lead to changes in the structure and functioning of ecosystems and their interaction with the water, carbon, nitrogen, and other major biogeochemical cycles and so affect climate. Changes in diversity at ecosystem and landscape scales in response to climate change and other pressures could further affect regional and global climate. Changes in trace gas fluxes are most likely to exert their effect at the global scale due to rapid atmospheric mixing of greenhouse gases, whereas the climate feedbacks from changes in water and energy exchange occur locally and regionally (IPCC 2002 – section 6.5). The IPCC (2002 – section 6.5) findings were as follows:

Changes in community composition and ecosystem distribution due to climate change and human disturbances may lead to feedbacks that affect regional and global climate. For example, in high-latitude regions, changes in community composition and land cover associated with warming are likely to alter feedbacks to climate. If regional surface warming continues in the tundra, reductions in albedo are likely to enhance energy absorption during winter, acting as a positive feedback to regional warming due to earlier melting of snow and over the long term the poleward movement of treeline. Surface drying and a change in dominance from mosses to vascular plants would also enhance sensible heat flux and regional warming in tundra during the active growing season. Boreal forest fires, however, may promote cooling because post-fire herbaceous and deciduous forest ecosystems have higher albedo and lower sensible heat flux than does late successional pre-fire vegetation. Northern wetlands contribute 5 to 10% of global CH_4 emissions to the atmosphere. As temperature, hydrology, and community composition change and as permafrost melts, there is a potential for release of large quantities of greenhouse gases from northern wetlands, which may provide a further positive feedback to climate warming.

(a) **Human actions leading to the long-term**

clearing and loss of woody vegetation have and continue to contribute significantly to greenhouse gases in the atmosphere. In many cases the loss of species diversity associated with forest clearing leads to a long-term transition from a forest to a fire and/or grazing-maintained, relatively low diversity grassland with significantly lower carbon content than the original forest. Deforestation and land-clearing activities contributed about a fifth of the greenhouse gas emissions (1.7±0.8 Gt C yr-1) during the 1990s with most being from deforestation of tropical regions. A total of 136±55 Gt C have been released to the atmosphere due to land clearing since the year 1850.

(b) **Changes in land surface characteristics—such as those created by land-cover change—can modify energy, water, and gas fluxes and affect atmospheric composition creating changes in local, regional, and global climate.** Evapotranspiration and albedo affect the local hydrologic cycle, thus a reduction in vegetative cover may lead to reduced precipitation at local and regional scales and change the frequency and persistence of droughts. For example, in the Amazon basin, at least 50% of precipitation originates from evapotranspiration from within the basin. Deforestation reduces evapotranspiration, which could reduce precipitation by about 20%, producing a seasonal dry period and increasing local surface temperatures by 2°C. This could, in turn, result in a decline in the area of wet tropical rainforests and their permanent replacement by less diverse drought-deciduous or dry tropical forests or woodlands.

(c) **Marine ecosystems can be affected by climate-related factors, and these changes in turn could act as additional feedbacks on the climate system.** Some phytoplankton species cause emission of dimethylsulfide to the atmosphere that has been linked to the formation of cloud condensation nuclei. Changes in the abundance or distribution of such phytoplankton species may cause additional feedbacks on climate change.

3.9 RESEARCH NEEDS AND INFORMATION GAPS

Further research of present and projected climate change impacts on soils and on coastal and marine ecosystems is warranted. There are also some information gaps that affect the ability of making reliable projections of impacts. The main ones relate to development of data and models for:

(a) the geographical distribution of terrestrial, freshwater, coastal and marine species, especially those based on quantitative information and at high resolution Special attention should be given to invertebrates, lower plants and key species in ecosystems.

(b) the inclusion of human land and water use patterns, as they will greatly affect the ability of organisms to respond to climate change via migration, to provide a realistic projection of the future state of the Earth's ecosystems.

(c) enabling the elucidation of the impacts of climate change compared with pressures from other human activities.

(d) projections on changes in biodiversity in response to climate change especially at the regional and local level.

(e) assessing impacts and adaptations to climate change at genetic, population and ecosystem level.

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4. CLIMATE CHANGE MITIGATION AND ADAPTATION OPTIONS: LINKS TO, AND IMPACTS ON, BIODIVERSITY

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INTRODUCTION

The purpose of this chapter is to review the possible biodiversity implications of climate change mitigation and adaptation activities, and approaches to integrate biodiversity concerns into these activities, in order to generate mutually beneficial outcomes—or at least to minimize conflicting ones. The first section briefly describes the current status of the Earth's carbon cycle. Section 4.2 discusses articles and provisions of the United Nations Framework Convention on Climate Change and its Kyoto Protocol that are pertinent to the present assessment. Biodiversity concerns relevant for mitigation and adaptation actions are discussed in light of the underlying philosophy of the Ecosystem Approach of the Convention on Biological Diversity (section 4.3). Sections 4.4 to 4.8 generally follow the Kyoto Protocol activities (i.e., land-use, land-use change and forestry and low- or zero-greenhouse gas emission energy technologies). Considerable attention is given to mitigation options related to forests and land management, as biodiversity relationships are presently best understood in these situations. Section 4.9 discusses some mitigation options that may be relevant to national climate change and/or biodiversity policies, although not credited under the Kyoto Protocol (e.g., carbon sequestration in ocean systems, wetlands, and geologic formations). Mitigation options aimed at reducing emissions from energy generation are also considered because some of them may have impacts on biodiversity (section 4.10). The focus of the discussion in section 4.11 is on identifying the key issues for biodiversity conservation in adaptation activities aimed at assisting ecosystems to adjust to climate change (although it should be noted that certain activities can be considered as both mitigation and adaptation options).

4.1 THE CARBON CYCLE

When a forest is planted (or when is naturally young as during early secondary succession) it acts as a carbon "sink" by absorbing atmospheric carbon dioxide and storing it in living plant biomass and in materials that accumulate on the forest floor and in the soil. In old-growth, primary forests, carbon stocks remain approximately constant or increase over time and the forest is referred to as a carbon "sink" at least in temperate and tropical systems (Carey et al. 2001), although they can be subject to reversal, e.g. during El Niño type conditions in Amazonia (Tian et al. 1998). However, when a forest or wood products are burned, much of the stored carbon is rapidly converted to carbon dioxide and the forest then acts as a "source" of carbon dioxide to the atmosphere. Harvested wood that is stored in products that are not burned serve as a carbon reservoir for various periods of time depending on use and degree of preservation.

The atmospheric concentration of carbon dioxide has historically oscillated between about 180 ppm (parts per million) during glacial periods and 280 ppm during interglacial periods. However, since the industrial revolution began in the mid 1800's, human activities, primarily through the combustion of fossil fuels and land-use changes, have and are continuing to perturb the carbon cycle, increasing the atmospheric concentration of carbon dioxide to the current level of about 368 ppm.

While the terrestrial biosphere has historically (from the year 1800 until about 1930) been a net source of carbon to the atmosphere, in the last several decades or so it has become a net sink. Since 1930 there has been an ever-increasing uptake by terrestrial biosphere, with the gross terrestrial uptake exceeding emissions from land-use changes.

Table 4.1 and Figure 4.1 (both based on Watson and Noble 2002) show that during the 1990s the net global uptake of carbon by the terrestrial biosphere was about 1.4 Gigatons C per year. Assuming emissions from tropical deforestation in the 1990s were about 1.6 Gt C per year (the same as in the 1980s), then the gross global uptake of carbon by the terrestrial biosphere was about 3 Gt C per year. Inverse modeling suggests that about half of the global uptake is occurring in the tropics and the other half in the mid- and high-latitudes of the northern hemisphere, hence the net emissions from the tropics are close to zero, while the net emissions in mid- and high latitudes are about 1.5 Gt C per year. The primary cause of the current uptake of about 1.5 Gt C per year in North America, Europe and Asia is thought to be re-growth due to management practices on abandoned agricultural land, with carbon dioxide and nitrogen fertilization and climate change contributing, but possibly to a smaller extent.

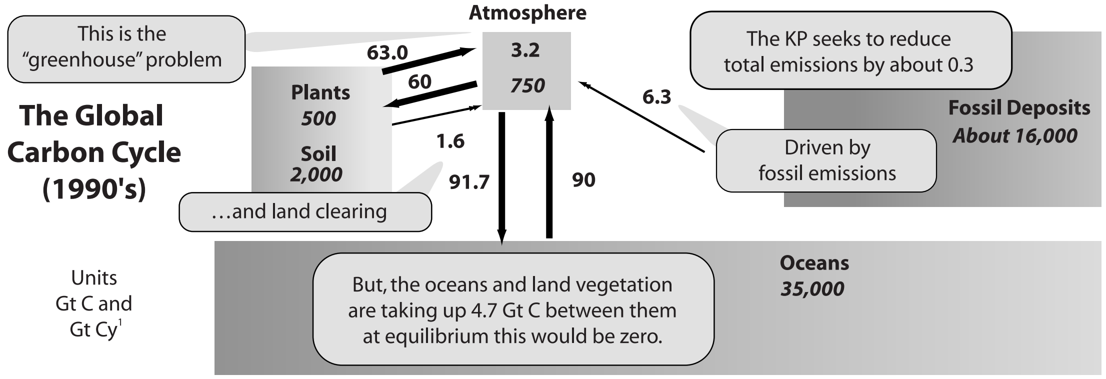
One important feature of the carbon cycle is the considerable year-to-year variability in the growth of atmospheric carbon dioxide, with the annual rate of increase varying by ±2 Gt C. This variability is largely caused by changes in the uptake and release of carbon dioxide in the terrestrial biosphere, with smaller changes in the uptake and release of carbon dioxide in the oceans. The most likely cause of the temporal variability is caused by the effect of climate on carbon pools with short lifetimes through variations in photosynthesis, respiration and fires. Evidence suggests that variations in respiration, rather than photosynthesis, are the primary cause. A key question is: how will compliance with the Kyoto Protocol be measured against this year-to-year background variability of about ±2 Gt C around the mean?

Based on plausible future demographic, economic, socio-political, technological and behavioral changes, and in the absence of coordinated international actions to protect the climate system by reducing greenhouse gas emissions, the Intergovernmental Panel on Climate Change projected that the atmospheric concentration of carbon dioxide would increase from the current level of about 368 ppm, to between 540 and 970 ppm by 2100, without taking into account possible climate-induced additional releases from the biosphere in a warmer world.

Table 4.1: Estimated carbon fluxes for two contrasting time periods (in Gigatons).

Flux type	**1980s**	**1990s**
Atmospheric increase	3.3 ± 0.1	3.2 ± 0.1
Fossil emissions	5.4 ± 0.3	6.3 ± 0.4
Ocean - Atmosphere flux	-1.9 ± 0.6	-1.7 ± 0.5
Net Land – Atmosphere flux	-0.2 ± 0.7	-1.4 ± 0.7
Land-use Change	1.7 ± ?	1.6 ± 0.8
Residual terrestrial sink	-1.9 ± ?	- 3.0 ±?

Figure 4.1: The carbon cycle during the 1990s



4.2 THE UNFCCC AND THE KYOTO PROTOCOL

Article 4.1(b) of the United Nations Framework Convention on Climate Change (UNFCCC) states that all Parties shall formulate and implement national programs containing measures to mitigate climate change by addressing anthropogenic emissions by sources and removals by sinks of all greenhouse gases and to facilitate adequate adaptation to climate change. Acknowledging that Parties have "common but differentiated responsibilities" the UNFCCC divides countries into two main groups: Annex I includes most countries from the Organization for Economic Cooperation and Development (OECD), and countries with economies in transition (EIT); all other countries are designated as non-Annex I. The ultimate objective of the UNFCCC is the stabilization of atmospheric greenhouse gas concentrations at levels that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a timeframe sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner (Article 2).

Article 3.1 of the UNFCCC recognizes that Annex I Parties should take the lead in combating climate change and the adverse effects thereof. To this end, these Parties have agreed, under Article 4.2(a), to adopt national policies and to take corresponding measures for climate change mitigation through two main avenues including: (a) actions aimed at reducing or limiting greenhouse gas emissions (for example, fuel switching, the use of renewable energies and others); and (b) the protection and enhancement of sinks and reservoirs (mainly forestry-related activities).

With the adoption of the Kyoto Protocol, Annex I Parties agreed to reduce their aggregate anthropogenic greenhouse gas emissions by at least 5% below the 1990 levels during 2008-2012. In order to meet this target, Annex I Parties can make use of two basic alternatives:

83. First, Article 2 of the Kyoto Protocol identifies policies and measures to be implemented domestically that may include, among others:

(a) Energy-related activities, including the enhancement of energy efficiency and the use of renewable sources.

(b) Land-use related activities including the protection and enhancement of sinks (also known as LULUCF[19]) and the promotion of sustainable forms of agriculture. Article 3.3 specifies that Parties can execute activities of afforestation, reforestation, and deforestation, and shall account for the emissions and removals from these activities that have occurred since 1990. Article 3.4 of the Kyoto Protocol allows Annex I Parties to implement additional land-use related activities. These additional activities were defined by the Marrakesh Accords[20] and include forest management, revegetation, grazing land management and/or cropland management. An Annex I Party can choose within this list which activities to implement.

Second, domestic actions may be supplemented with three flexibility mechanisms, which include:

(a) Joint Implementation (JI) - (Article 6 of the Kyoto Protocol), comprising projects designed between two or more Annex I Parties and which are implemented in one of them. These projects may include any of the activities cited above. Through JI, investors can benefit by earning units resulting from these projects.

(b) Clean Development Mechanism (CDM) - (Article 12 of the Kyoto Protocol), comprising projects that take place in a non-Annex I Party. The purpose of the CDM is both to assist Annex I Parties in meeting their commitments, and to assist non-Annex I Parties in achieving sustainable development. CDM projects may include activities that reduce emissions of greenhouse gases, but for land-use change related activities, eligibility has been restricted to afforestation and reforestation.

(c) Emissions Trading (ET) - (Article 17 of the Kyoto Protocol), comprising trading of carbon units among Annex I Parties. ET primarily takes place when an Annex I Party has reduced emissions below its target, thus resulting in a surplus that could be traded.

Article 3.3 of the Kyoto Protocol obligates all Annex I Parties to account for the changes in carbon stocks and non-carbon dioxide greenhouse gas emissions attributable to afforestation, reforestation, and deforestation (ARD). If the ensamble of ARD activities result in a net sink of greenhouse gases, the Party will be given credit towards meeting its emissions target. On the other hand, net emissions resulting from higher deforestation will represent a debit towards meeting commitments.

The Marrakesh Accords allow Annex I Parties to account for changes in carbon stocks and non-carbon dioxide greenhouse gas emissions resulting from forest management, revegetation, cropland and grazing land management (Article 3.4). A Party may choose to include any or all of these in meeting its commitments. Once taken, the decision cannot be changed. For forest management there is a quantified "cap" specified for each Party. Credits for revegetation, cropland, and grazing land management are calculated on a "net-net" basis[21]. If a sink becomes a source, the net emissions originating from this source will add to the compliance burden of the Party concerned.

The Marrakesh accords state that emissions and removals resulting from LULUCF activities shall be measured as verifiable changes in carbon stocks and non-carbon dioxide greenhouse gas emissions during the period from 1 January 2008 to 31 December 2012. The Accords also state that these changes must be measured for five different pools: aboveground biomass, below-ground biomass, litter, dead wood and soil organic carbon. However, a party may choose not to account for a given pool if this Party can demonstrate that the pool is not a source of greenhouse gas.

The Marrakesh Accords affirm the inclusion of Land Use, Land Use Change and

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[19] LULUCF stands for Land Use, Land-Use Change and Forestry.

[20] The term "Marrakesh Accords" is used in this document to refer to the group of decisions adopted in 2001 during the seventh session of the COP of the UNFCCC. These decisions define the operational rules for the implementation of the Kyoto Protocol.

[21] "Net-net" accounting for specific activities under Article 3.4 is performed by subtracting the net changes in carbon stocks resulting from these activities in 1990 multiplied by five from the net changes in carbon stocks resulting from these activities during the commitment period.

Forestry (LULUCF) project activities under the CDM, limiting eligibility to afforestation and reforestation. For the first commitment period (2008 - 2012), credits resulting from afforestation and reforestation under the CDM are limited to one percent of the Party's base year emissions times five.

The Marrakesh Accords require CDM projects and JI Track II[22] projects to submit documentation on the analysis of the environmental impacts of the project activities. If project participants or the host Party consider these impacts significant, an environmental impact assessment (EIA) must be undertaken in accordance with the requirements of the host Party. These assessments can assist project participants in modifying projects to protect, conserve and enhance biodiversity (see chapter 5).

Climate change mitigation activities that the Parties could implement may impact biodiversity in positive or negative ways (IPCC 2002). The major focus of domestic mitigation policies and measures, as well as JI and CDM activities, will be on the reduction of emissions from the production and use of fossil fuels through the use of alternative energy technologies (e.g., renewable energy), but there will also be activities in the fields of forestry, agriculture, and waste disposal. An activity may or may not have implications to biodiversity conservation, depending on its nature and the location of the activity. However, activities can often be optimized to help conserve or even enhance biodiversity, while at the same time sequestering carbon, resulting in 'win-win' solutions for society. Mitigation actions, such as forest conservation and forest management, are particularly relevant for biodiversity concerns, as they have the potential to contribute to the conservation of biological diversity.

Implementation of climate change adaptation activities will depend on the expected climate change impacts in the country concerned: for example, sea level rise, increased risk of flooding, and occurrence of extreme weather events. Article 4.8 of the UNFCCC lists categories of countries (e.g., small island countries; countries with arid and semi-arid areas, forested areas, and areas liable to forest decay; countries with fragile ecosystems, including mountainous regions) with environments that are particularly vulnerable to climate change and where adaptation actions may be necessary. The decisions related to developing country funding in the Marrakesh Accords state that adaptation activities are to be implemented, inter alia, in the areas of water resource management, land management, fragile ecosystems, and integrated coastal management (FCCC/2001/13/Add.1 Decision 5/CP7). From this list, it can be inferred that conservation of biodiversity may be a key objective of many adaptation activities.

4.3 THE ECOSYSTEM APPROACH OF THE CONVENTION ON BIOLOGICAL DIVERSITY

The ecosystem approach, which acknowledges the three objectives of the Convention on Biological Diversity (CBD), is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way (decision V/6 of the Conference of the Parties to the CBD). An ecosystem is defined as a dynamic complex of plant, animal, and micro-organism communities and their non-living environment interacting as a functional unit (CBD, Article 2). The ecosystem approach encompasses the essential processes, functions, and interactions among organisms and their environment, and recognizes that humans are an integral component of most ecosystems.

The ecosystem approach does not preclude

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[22] JI track II projects follow stringent validation and verification procedures. This track has to be followed when the Party where the project will be implemented does not meet all the criteria specified in the Annex to UNFCCC COP draft decision -/CMP.1 (Article 6), paragraph 21.

other management and conservation approaches, such as protected areas or single species conservation programs, but rather can be used to integrate all these approaches in order to achieve better management of complex situations. The strength of the ecosystem approach lies in the participation of stakeholders; the consideration of all knowledge, including traditional knowledge; and in the balance it strikes among ecological, economical, and social interests. Adaptive management is an integral part of the ecosystem approach, allowing for adjustments to changing situations and new knowledge. The ecosystem approach is based on twelve inter-related guiding principles, which facilitate decision-making concerning the conservation and sustainable use of biological diversity (Box 4.1)[23].

Two requirements specified by the Marrakesh accords make the ecosystem approach relevant for the design and implementation of mitigation and adaptation activities. The first one refers to the fact that LULUCF activities shall contribute to the conservation of biodiversity and sustainable use of natural resources. The second is the objective of the CDM to assist non-Annex I parties in achieving sustainable development. As stated above, the ecosystem approach is an integrated strategy that promotes conservation and sustainable use of natural resources and does not preclude other management and conservation approaches (for example, carbon management). Thus, the broader perspective of the ecosystem approach synergistically addresses sustainable development, biodiversity conservation and carbon sequestration objectives, potentially resulting in win-win situations.

Box 4.1. The 12 Principles of the Ecosystem Approach of the Convention on Biological Diversity

1. The objectives of management of land, water and living resources are a matter of societal choice.
2. Management should be decentralized to the lowest appropriate level.
3. Ecosystem managers should consider the effects (actual and potential) of their activities on adjacent and other ecosystems.
4. Recognizing potential gains from management, there is usually a need to understand and manage the ecosystem in an economic context. Any such ecosystem-management programs should:
    - Reduce those market distortions that adversely affect biological diversity (i.e., eliminate perverse subsidies, etc.);
    - Align incentives to promote biodiversity conservation and sustainable use;
    - Internalize costs and benefits in the given ecosystem to the extent feasible (including full accounting for ecosystem goods and services).
5. Conservation of ecosystem structure and functioning, in order to maintain ecosystem services, should be a priority target of the ecosystem approach.
6. Ecosystems must be managed within the limits of their functioning.
7. The ecosystem approach should be undertaken at the appropriate spatial and temporal scales.
8. Recognizing the varying temporal scales and lag-effects that characterize ecosystem processes, objectives for ecosystem management should be set for the long term.
9. Management must recognize that change is inevitable.
10. The ecosystem approach should seek the appropriate balance between, and integration of, conservation and use of biological diversity.
11. The ecosystem approach should consider all forms of relevant information, including scientific and indigenous and local knowledge, innovations and practices.
12. The ecosystem approach should involve all relevant sectors of society and scientific disciplines.

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[23] Further elaboration on the ecosystem approach and proposed guidelines for its implementation are contained in UNEP/CBD/SBSTTA/9/8, and discussed at the ninth meeting of the Subisdiary Body on Scientific, Technical and Technological Advice (SBSTTA) to the CBD during November 2003.

4.4 MITIGATION OPTIONS

4.4.1 General concepts related to mitigation

Mitigation is defined as an anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases (IPCC 2001a). Activities that reduce net greenhouse gas emissions diminish the projected magnitude and rate of climate change and thereby lessen the pressure on natural and human systems from climate change. Thus, mitigation activities are expected to delay and reduce environmental damage caused by climate change, providing environmental and socio-economic benefits, including biodiversity conservation. Mitigation activities may have positive or negative impacts on biodiversity, independent of their effect on the climate system. Nevertheless, it is important to note that minimal gains can be achieved by land use change, relative to the major gains that can be achieved through reductions in the use of fossil fuels (House et al. 2002).

Mitigation activities include emission avoidance activities and carbon sequestration activities. According to the IPCC (2000) about 80 percent of the carbon dioxide emitted into the atmosphere between 1989 and 1998 resulted from fossil fuel burning and cement production with about 20 percent from land use changes, predominantly from deforestation. Emission avoidance activities include, among others, increased energy efficiency or generation efficiency, increased use of low-carbon or carbon-free energy systems (including biomass energy), and solar-, wind-, and hydropower.

4.4.2 Carbon sequestration potential of mitigation activities

In terrestrial systems, mitigation activities accumulate carbon both above- and below-ground. The estimated global potential of biological mitigation options in forested systems from afforestation, reforestation and avoided deforestation, is on the order of 60-87 Gt C (cumulative) by the year 2050, with 70 percent in tropical forests, 25 percent in temperate and 5 percent in boreal forests (IPCC 2002). In addition, improved forests, agricultural lands, grasslands, and other terrestrial ecosystems offer significant carbon mitigation potential (IPCC 2000). House et al. (2002) indicate that the likely maximum reduction of atmospheric carbon achievable through afforestation and reforestation is between 17 and 31 ppm after accounting for ocean response.

Ecosystem management strategies may depend on whether the goal is to enhance short-term carbon accumulation or to maintain carbon reservoirs over time. Carbon reservoirs in most ecosystems eventually approach maximum levels in the various compartments (e.g., Carey et al. 2001), with the rate of carbon sequestering diminishing over time (Paul et al. 2003). Nevertheless, in old-growth forests carbon continues to accumulate in the soil and vegetation, and especially where decomposition is slow, carbon stores can be maintained for long periods (Kimmins 1997, Carey et al. 2001, Schultze et al. 2000, Paul et al. 2003). Thornley and Cannell (2000) reported that more carbon was stored in undisturbed forests than in any managed forest regime where wood was harvested. Although both the sequestration rate and the amount of sequestered carbon may be concurrently high at some stages, they cannot be maximized simultaneously (Turner and Lambert 2000, Carey et al. 2001, Paul et al. 2003, Law et al. 2001, Klopatek 2002). The ecologically achievable balance between the two goals is constrained by degree of site degradation, site productivity, time frame considered, type of management intervention, stand origin, amount of woody debris, and species attributes (e.g. Amiro 2001, Knohl et al. 2002, Vesterdal et al. 2002). Different species grow at different rates and hence sequester carbon at different rates. There are often interactions among tree species in mixed species forests that influence growth and soil carbon condition (e.g., Kimmins 1997, Paul et al. 2002, Vesterdal et al. 2002). Further, there is no universally applicable biological growth response to increasing temperature and CO_2, as these factors interact in complex ways with a number of other limiting factors such as wildfire and moisture regimes (Kirschbaum 1999—and see section 3.4.2.1). There is a need for stand level modeling (as opposed to tree-based models) to understand the true potential of forests to sequester carbon over time. Such models need to be built to allow scenario-testing of exogenous factors such as harvesting and fire on carbon accumulation over time. This is especially true in light of recent research that suggests an interaction between increased temperature and elevated CO_2 that has depressed tree growth in a tropical forest (Clark et al. 2003).

4.4.3 Key concerns

In addition to the effectiveness of carbon mitigation options, environmental, social, and economic considerations should be taken into account. Land is a finite resource and the relationship of climate mitigation activities with other land use activities may be competitive, neutral, or complementary. Measures adopted within different sectors (e.g., forestry, agriculture, or other land uses) to provide carbon sequestration should strive to achieve social, economic, and environmental goals (IPCC 2000; 2001a,b,c) and could be assisted by consideration of the ecosystem approach (Box 4.1). Social acceptance can influence how effectively mitigation options are implemented (see section 6.3.1).

For land-use changes, such as afforestation or reforestation, there are concerns regarding the permanence of biological sinks. The primary concern is that the carbon stored will be labile, unlike carbon stored in fossil material that remains in underground. The stored carbon could be released back into the atmosphere by natural (e.g. fires) or anthropogenic occurrences (Brown et al. 2002). Fire is of particular concern because of its capacity to emit carbon fixed over a period of 50 to 300 years in a matter of hours (Körner 2003) and because of the recent increases in the number and severity of fires in moist tropical forests, where fires are historically rare (Cochrane 2003). There is concern that climate change itself will reduce a forest's capacity to act as a sink by increased soil respiration (Royal Society 2001). Hence, biological sinks can, realistically, only be regarded as a temporary mitigation option. Critical concepts for carbon storage and biodiversity conservation in connection with climate change mitigation activities are listed and discussed in Box 4.2 and paragraphs below.

Carbon activities that offer multiple benefits, including socio-economic benefits, are more likely to be retained by society. For example, greater permanence may be associated with afforestation and reforestation activities that are designed to restore key watershed functions, establish biological corridors, and afford recreational and amenity values. Similarly, the revegetation of grasslands or wetland systems can also be viewed by society as having long-term conservation benefits.

Leakage problems can be minimized when carbon mitigation activities are incorporated into existing land uses. For example, agroforestry projects integrate planted trees and shrubs into ongoing farm activities to achieve conservation and economic goals rather than convert agricultural lands to forest. Thus, the pressure to convert other forested lands to agriculture can be reduced.

Mitigation activities that use the ecosystem approach to incorporate biodiversity considerations can potentially have lower risk of failure. For example, planting a variety of native tree species, or mixtures of single-species stands rather than a monoculture of trees, can reduce the probabilities of insect and disease attack and help to achieve levels of ecosystem structure and function that are greater than those of single

Box 4.2. Concepts and definitions on carbon storage in connection to mitigation activities

Permanence. The Intergovernmental Panel on Climate Change (IPCC 2000) defines permanence as the longevity of a carbon pool and the stability of its stocks, given the management and disturbance environment in which it occurs. The concept of permanence is frequently used in connection with carbon uptake activities because of the exposure of terrestrial carbon reservoirs to natural and anthropogenic factors, e.g., harvesting, fires, and pests. The principles that govern the concept of permanence in the Kyoto Protocol stipulate that the reversal of any removal resulting from these activities should be accounted for at the appropriate point in time (FCCC/CP/2003/13/Add.1). In addition, the ongoing process to develop definitions and modalities for afforestation and reforestation for CDM projects will take into account the issue of non-permanence.

Leakage. Leakage refers to the situation where a carbon sequestration activity (e.g., tree planting) in one location, either directly or indirectly, triggers another activity in a different location, which in whole or part, leads to carbon emissions (IPCC 2001a,b,c). Leakage caused by activities within Annex I Parties is accounted through a comprehensive emission reporting system. In the Marrakesh Accords, the concept of leakage is considered only in connection with CDM projects and is defined as the net change in anthropogenic emissions by sources of greenhouse gases that occur outside the project boundary and that are measurable and attributable to the project activity (FCCC/CP/2001/13/Add.2).

Risk and Uncertainty. The IPCC defines "uncertainties" as an expression of the degree to which a value is unknown. Uncertainty can result from lack of information or from disagreement about what is known or knowable. The UNFCC states that Parties should take precautionary measures to anticipate, prevent or minimize the causes of climate change and mitigate its adverse effects. Where there are threats of irreversible damage, lack of full scientific certainty should not be used as a reason for postponing such measures (Article 3). Regarding the elaboration of greenhouse gas inventories, uncertainties relating to the estimation and measurement of greenhouse gases emissions and removals are addressed through the application of the so-called "Good Practice Guidance", which complements the revised 1996 IPCC guidelines for national greenhouse inventories. Uncertainties are to be addressed also in the context of definitions and modalities for afforestation and reforestation CDM activities.

Additionality. The Marrakesh Accords stipulate that JI and CDM projects must result in anthropogenic greenhouse gas emissions reductions or removals that are additional to any that would have occurred in their absence, prior to 1990.

Baseline. In the Marrakesh Accords, a baseline for an activity must reflect the expected changes in carbon storage and greenhouse gas emissions that would have occurred in the absence of the proposed project.

tree species systems (Carnus et al. 2003, Thompson et al. 2003).

4.4.4 Monitoring of mitigation activities

All UNFCCC Parties are required to report greenhouse gas emissions and activities to address climate change. Annex I Parties have strict obligations: they have to submit greenhouse gas inventories annually and submit national communications, which provide extensive detail on current and planned activities to address climate change, every three to four years. Both reports are subject to international expert reviews. Non-Annex I Parties also prepare national communications, but the requirements are less strict. Annex I Parties must meet monitoring and reporting requirements to be eligible for participation in the market-based Kyoto Mechanisms (JI, CDM, ET). The rules for monitoring CDM projects include a requirement to collect and archive information relevant to environmental impacts (FCCC/2001/13/Add.2).

4.5 AFFORESTATION, REFORESTATION AND DEFORESTATION

4.5.1 Afforestation, reforestation and deforestation in the Kyoto Protocol

As part of the commitments under the UNFCCC, Parties shall protect and enhance sinks and reservoirs (Article 4.1(d)). Under the Kyoto Protocol Article 3.3, all Annex I Parties have to account for greenhouse gas sequestration and emissions attributable to afforestation, reforestation, and deforestation. The Protocol specifies that accounting under Article 3.3 be restricted to direct human-induced land-use changes that have taken place since 1990[24] .

In the context of Article 3.3 of the Kyoto Protocol, both afforestation and reforestation refer to the conversion of land under other uses to forest. Afforestation is defined as the direct human-induced conversion of land that has not been forested for a period of at least 50 years to forested land through planting, seeding, and/or the human-induced promotion of natural seed sources. Reforestation is defined as the direct human-induced conversion of non-forested land to forested land through planting, seeding, and/or the human-induced promotion of natural seed sources on land that was forested but that has been converted to non-forested land (note that these definitions are different than those generally used by foresters). For the Kyoto Protocol's first commitment period (2008–2012), reforestation activities will be limited to reforestation occurring on those lands that, had been forested once, but that did not contain forest on 31 December 1989 (Marrakesh Accords FCCC/CP/2001/13/Add.1; page 58). The time limit included in the definitions is important; since only reforestation activities in areas that were non-forested prior to 1990 can be accounted for, it is thought that activities under the Kyoto Protocol do not generally create a perverse incentive for conversion of natural forests into plantation forests. However, this incentive has not been totally removed as lands that did not contain forest as of 1990 but may have since been reforested, e.g. through natural forest succession, will be eligible for reforestation activities.

These two activities are the only carbon uptake activities that are also eligible under the CDM (Marrakesh Accords FCCC/CP/2001/13/Add.1 and Add.2). However, at this time, it is unclear whether the same definitions of reforestation and afforestation under the CDM will apply.

4.5.2 Biodiversity and afforestation and reforestation activities

In planted forests, species selection often results in a trade-off between fast carbon assimilation and subsequent release vs. slower carbon assimilation and longer retention time. How these tradeoffs are made will affect biodiversity. This implies that fast rate of carbon uptake from the atmosphere and long retention time of the sequestered carbon cannot be maximized at the same time (e.g., Carey et al. 2001). In many types of tree plantations, soil carbon continues to be lost during the first 10-20 years due to continued leaching (e.g., Turner and Lambert 2000), and net accumulation only becomes positive with increased time the length of which is likely ecosystem-dependent. The

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[24] The Marrakesh Accords include the following definition for a forest:
"Forest" is a minimum area of land of 0.05-1.0 hectares with tree crown cover (or equivalent stocking level) of more than 10-30 per cent with trees with the potential to reach a minimum height of 2-5 m at maturity in situ. A forest may consist either of closed forest formations where trees of various storeys and undergrowth cover a high proportion of the ground or open forest. Young natural stands and all plantations which have yet to reach a crown density of 10-30% or tree height of 2-5 m are included under forest, as are areas normally forming part of the forest area which are temporarily unstocked as a result of human intervention such as harvesting, or natural causes, but which are expected to revert to forest. (Source: Marrakesh Accord – FCCC/CP/2001/13/Add.1, page 58). Reforested and afforested sites are considered as forest (FAO Forestry Paper no. 140: Global Forest Resources Assessment 2000).

total carbon pool of a carbon-sequestering activity, the rate of positive change of the pool, and the time that carbon will remain sequestered in the system, strongly depend not only on climate, soil nutrients, and rotation length, but also on the dominant tree species (Paul et al. 2002, Vestedal et al. 2002). For example in temperate forests, poplars (*Populus*) are fast-growing, may become very large, but are short-lived, while oaks (*Quercus*) and beeches (*Fagus*) are slow-growing, also become very large, but are very long-lived. Forests of the latter species are less ephemeral than poplar forests where in turn, dead wood is more rapidly decomposed. From a biodiversity perspective, the choice of tree species can greatly affect the types of animals and associated understory plant species that can be supported. The use of either short- or long-lived species depends on the goals. Long-lived forest ecosystems, support more complex (plant-animal; plant-plant) relationships than do simple and hence shorter-lived forests; therefore, the former support greater levels of biodiversity (e.g., Thompson et al. 2002). A decision on how to balance the alternative goals for carbon and biodiversity (rapid accumulation vs. long-term sequestration) will have to be made in any forest carbon-uptake activity (Aerts 1995, Caspersen and Pacala 2001).

4.5.3. Impact of afforestation and reforestation on biodiversity

Afforestation and reforestation projects can have positive, neutral or negative impacts on biodiversity. The impact depends on the level and nature of biodiversity of the ecosystem being replaced, the spatial scale being considered (e.g., stand vs. landscape), and other spatial design and implementation issues (e.g., non-native versus native species, native single versus native mixed-species, and location). Afforestation and reforestation activities may help to promote the return, survival, and expansion of native plant and animal populations. Degraded lands may offer the best opportunities for such activities, as these lands have already lost much of their original biodiversity. Plantations may allow the colonization and establishment of diverse understory communities by providing shade and ameliorating harsh microclimates. Specific sites may be better candidates for implementing such activities than others, based on past and present uses, the local or regional importance of their associated biological diversity and proximity to nearby, natural forests. In particular, the reduction of forest fragmentation, e.g. by careful design of native plantation establishment and/or forest regeneration strategies sites to give the most functionally connected forest landscape possible would have positive impacts on biodiversity, improving ecosystem resilience and allowing species migration in response to climate change (see also section 4.11.4.3). Plantations of exotic species may only be capable of supporting low levels of local biodiversity at the stand level (e.g., Healey and Gara 2002), but they could contribute to biodiversity conservation if appropriately situated within the broader landscape context; e.g. connecting areas of natural forest enabling for species migration and gene exchange (CIFOR 2003).

Activities that maintain a high ecosystem-service value contribute to both carbon-uptake and forest biodiversity conservation. An important aspect is the extent to which activities take into account concerns of the local and indigenous communities in meeting the carbon credit priorities of investors (Prance 2002, Pretty et al. 2002). Incorporation of what is 'valuable biodiversity' from the local community perspective helps to strike a balance between biodiversity and carbon uptake, and promote long-term protection of plantings (Díaz and Cáceres 2000, Prance 2002). The stipulation in the Marrakesh Accords that CDM projects must contribute to the sustainable development of the host country and may best be achieved by the CBD ecosystem approach may encourage project planners to design activities that conserve and enhance biodiversity.

Afforestation and reforestation plantations can have beneficial environmental impacts, especially if modifications are incorporated. Although plantations typically have lower biodiversity than natural forests (see references in Hunter 1999, Thompson et al. 2003), in some cases they can reduce pressures on natural forests by serving as sources of forest products, thereby leaving greater areas of natural forests for biodiversity conservation and provision of environmental services. Afforestation and reforestation activities may also re-establish critical ecological functions, such as erosion control within degraded watersheds, and corridors within a fragmented landscape. Further, in some countries success at supporting at least some native (non-tree) species in plantation forests has been achieved, by paying attention to (stand and landscape) structure, stem density, and species mixing (Thompson et al. 2002, Carnus et al. 2003 and references therein). In some instances, plantation forests have been shown to maintain considerable numbers of local species (Carnus et al. 2003). Even modest changes in project design have the potential to significantly benefit biodiversity in plantation forests. For example, mixing different species along the stand edge, creating small clearings within the stand, creating small water catchments in or near the stand, and allowing under-story growth may greatly improve habitat for some animals and create favorable microsite conditions for some plants. Significant biodiversity benefits can be achieved by allowing a portion of the stand on a landscape to age past maturity, by reducing chemical and insect control, and avoiding locales where rare or vulnerable ecosystems and species are present at the time of site selection (Hunter 1999, Thompson et al. 2003). Finally, mixed-species plantations have more overall ecosystem-service value and therefore are more likely to be retained by local communities for a longer time than single-species plantations (Daily 1997, Prance 2002). However, it must be noted that under climate change, there is considerable uncertainty associated with the permanence of benefits (Royal Society 2001).

Afforestation and reforestation activities that replace native non-forest ecosystems (e.g., species-rich native grasslands, wetland, heathland or shrubland habitats) with non-native species, or with a single or few species of any origin, can negatively affect biodiversity. For example, in South Africa, expansion of commercial plantations (Eucalyptus and Pinus) has led to significant declines in several endemic and threatened species of native grassland birds and suppression of indigenous ground flora (Matthews et al. 1999). Similarly, drainage of wetlands for afforestation and reforestation activities may not be a viable carbon mitigation option, as drainage will lead to immediate loss of carbon stocks and potential loss of biodiversity.

Afforestation with non-indigenous species may result in higher rates of water uptake than by existing vegetation and this could cause significant reductions in streamflow especially in ecosystems where water is limiting. These changes could have adverse effects on in-stream, riparian, wetland, and floodplain biodiversity (Le Maitre et al. 2002, Scott and Lesch 1997). For example, the water yield from catchments in South Africa was significantly reduced when the catchments were planted with pines and eucalypts (UNEP 2002).

Tree improvement through silvicultural techniques can increase the productivity associated with plantations, and maintain genetic diversity of local species. Individual tree species are adapted to specific ranges of moisture and temperature. Careful selection of seeds and tree stocks under climate change scenarios, based on modeling, will enable more rapid growth and increase survivorship of planted tree species and individuals than would be expected by relying on available stocks (e.g., Rehfeldt et al. 1999). This can be accomplished by matching expected temperature and moisture regimes to planted species and individuals within species and paying attention to maintaining species genetic diversity to enhance success of plantation forests (Carnus et al. 2003). Conversely, single-species plantations of commercially valuable tree species have been widely planted in many regions of the world. While still within their geographic range, these plantations have often been planted off-site into areas where factors like soil, elevation, moisture, slope, and aspect differ significantly from where they are normally found in the landscape. Many of these plantations will become susceptible to reduce growth or dieback under drier or warmer climate scenarios (e.g., Lexer et al. 2002, Rehfeldt et al. 1999).

Measuring the success of afforestation and reforestation activities can be accomplished with a series of indicators for carbon uptake, as well as for biodiversity, at the site and landscape scale (see chapter 5). In developing such activities, the following considerations for biodiversity may be useful (Noss 2001, Thompson et al. 2002, 2003; Carnus et al. 2003):

(a) landscape structure and planted trees species composition can affect understory plant species and animal species diversity;
(b) a regional suite of animal species requires the full variety of local forest types and ages of stands, with the structures normally associated with those forests;
(c) planted forests that are structurally diverse maintain more species than those that have simple structure (i.e., monocultures);
(d) planted forests of native species conserve local and regional animal species better than do plantations of exotic tree species, or monocultures of native species;
(e) large areas of forest maintain more species than do small areas, and fragmented forests maintain fewer species than do continuous forests;
(f) core areas and protected areas connected by reforested corridors or habitats enhance population levels of species by reducing fragmentation effects and improving dispersal capability, and through supporting more individuals;
(g) some exotic tree species have the potential to become invasive, with potentially negative consequences for ecosystem functioning and biodiversity conservation;
(h) planted forests that have high genetic diversity are likely to be more successful over time and under climate changes than those with reduced genetic diversity.
(i) the spatial context where activities take place is important to optimize for biodiversity of desired species.

Uncertainty pertaining to the benefits of mitigation and adaptation measures suggests that adaptive management should be designed into any project. Afforestation and reforestation projects should be viewed as experiments with respect to their possible benefits to biodiversity. Monitoring programs should be put in place to enable the long-term assessment of benefits compared to expectations, and possible adjustments made as required to design and future efforts.

4.5.4 Afforestation and reforestation of mires and peatlands as a special case

Pristine mires play an important role with respect to global warming as carbon stores. Their impact on climate change due to the emission of methane (CH_4) and nitrous oxide (N_2O) is typically insignificant (Joosten and Clarke 2002). However, methane production can be high when water tables are within 20 cm of the surface. Mires and peatlands[25] are characterized by their unique ability to accumulate and store dead plant material originating from mosses, sedges, reeds, shrubs, and trees (i.e., peat), under waterlogged conditions. About 50% of the dry organic matter of peat consists of carbon. Peatlands are the most prevalent wetland in the world, representing 50 to 70 percent of all

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[25] A peatland is an area of landscape with a naturally accumulated peat layer on its surface. A mire is a peatland on which peat is currently forming and accumulating. All mires are peatlands but peatlands that are no longer accumulating peat would not be considered mires anymore.

wetlands and covering more than four million km^2 – or three percent – of the land and freshwater surface of the planet (Lappalainen 1996). Between 270-370 Gt of carbon is currently stored in the peats of boreal and sub-boreal peatlands alone (Turunen et al. 2000). This means that, globally, peat represents about one-third of the total soil carbon pool (about 1395 Gt) (Post et al. 1982). Peat contains the equivalent of approximately 2/3 of all carbon in the atmosphere and carbon equivalent to all terrestrial biomass on the earth (Houghton et al. 1990). Peatlands exist on all continents, from tropical to polar zones, and from sea level to high altitude. Humans affect peatlands both directly, through drainage, land conversion, excavation, and inundation, and indirectly, as a result of air pollution, water contamination, water removal, and infrastructure development.

Anthropogenic drainage has changed mires and peatlands from a global carbon sink to a global carbon (and other greenhouse gas) source, and afforestation and reforestation activities in recently drained peatlands may be inconsequential as carbon sequestration activities (Joosten and Clarke 2002). Human activities continue to be the most important factors affecting peatlands, both globally and locally, leading to a current annual decrease of the mire resource. When peatlands are drained to create more agricultural land N_2O emissions are increased and these lands become more prone to fires. In some years greenhouse gas emissions from the burning of these drained peatlands (e.g., in South East Asia) may constitute a substantial portion of the global emissions (Page et al. 2002).

4.5.5 Agroforestry as a special case of afforestation and reforestation

Agroforestry systems incorporate trees or shrubs in agricultural landscapes. Agroforestry practices could be considered eligible under the CDM if they meet the adopted CDM definition of afforestation or reforestation. Agroforestry systems include a wide variety of practices: agrosilvicultural systems; silvopastoral systems; and tree-based systems such as fodder plantations, shelterbelts, and riparian forest buffers. These systems are typically managed, but can also be natural, such as silvopastoral systems in Sudan. Agroforestry systems may lead to more diversified and sustainable production systems than farming systems without trees, and may provide increased social, economic and environmental benefits (IPCC 2000, Leakey 1996). The IPCC recognizes two classes of agroforestry activities for increasing carbon stocks: (a) land conversion; and (b) improved land use. Land conversion includes transformation of degraded cropland and grassland, into new agroforests (IPCC 2000). Improved land use requires the implementation of practices such as high-density plantings and nutrient management that result in increased carbon stock.

Globally, significant amounts of carbon could be sequestered in agroforestry systems, due to the large agricultural land base in many countries. In temperate systems, agroforestry practices have been shown to store large amounts of carbon in trees and shrubs (Kort and Turlock 1999, Schroeder 1994, IPCC 2000, Dixon et al. 1994, van Kooten et al. 1999). Positive net differences in carbon stocks, including those in the soil, have been documented in the tropics between agroforestry systems and common agricultural practices (IPCC 2000, Palm et al. 2002, Woomer et al. 1999, Fay et al. 1998, Sanchez et al. 1997).

In addition to carbon uptake, agroforestry activities can have beneficial effects on biodiversity, especially in landscapes that are dominated by production agriculture. Agroforestry can add plant and animal diversity to landscapes that might otherwise contain only monocultures of crops. Freemark et al. (2002) demonstrated the important role of farmland habitat for the conservation of native plant species in Eastern Canada. In the Great Plains region of the United

States, where cropland occupies most of the landscape, linear riparian zones and field shelterbelts play essential roles in maintaining natural habitats for biodiversity (Guo 2000). In the same region, Brandle et al. (1992) highlighted the potential of agroforestry practices to provide wildlife habitat. Traditional agroforestry systems, e.g. shaded coffee plantations, are common throughout Central and South America. These systems may contain well over 100 annual and perennial plant species per field and provide beneficial habitat for birds (including migratory species) and other vertebrates (Altieri 1991, Thrupp 1997).

Agroforestry can enhance biodiversity on degraded and deforested sites (IPCC 2002). Agroforestry systems tend to be more biologically diverse than conventional croplands, degraded grasslands or pastures, and the early stages of secondary forest fallows. However, where agroforestry replaces native forests biodiversity is usually lost (IPCC 2002). The use of native species in agroforestry systems will provide greatest benefits to biodiversity. In view of human migrations to the forest margins, the optimal tradeoffs between carbon sequestration and economic and social benefits are an important policy determination. Examples of such tradeoffs are described in Gockowski et al. (1999), Vosti et al. (1999), and Tomich et al. (1998, 1999).

Agroforestry can be used to functionally link forest fragments and other critical habitat as part of a broad landscape management strategy. Agroforestry can augment the supply of forest habitat and enhance its connectivity. This can facilitate the migration of species in response to climate change. Even when there are forest reserves in an area, they may be too small in size to contain the habitat requirements of all animal species, and whose populations may extend in range beyond reserve boundaries (Kramer et al. 1997).

4.6 DEFORESTATION

The Marrakesh Accords define deforestation as the direct human-induced conversion of forested land to non-forested land (FCCC/CP/2001/13/Add.1 page 58). Deforestation, especially of primary forests, causes an immediate reduction in above- and below-ground biomass carbon stocks, followed by several years of decreases in other carbon stocks, including soils and a consequent decline in associated biodiversity. Increased soil temperature following deforestation leads to an increase in the rate of decay of surface dead wood and litter, as well as the decay of soil organic matter, thus increasing the loss of carbon from the system (e.g., Fearnside 2000, Duan et al. 2001). Deforestation may result in forest fragmentation, which adversely affects the ability of the forest to uptake carbon, and can interact synergistically with other changes, such as edge effects and fire, potentially leading to serious degradation of the ecosystem (Gascon et al. 2000, Laurance and Williamson 2001, Laurance et al. 1997). Large-scale deforestation may also cause a decrease in precipitation, by reducing plant evapotranspiration and altering local microclimates and reducing moisture in the fragmented stand and leading to increased fire potential (Laurance and Williamson 2001).

In the tropics, expansion of agriculture is the principal cause of deforestation. Tropical forests currently experience the highest rates of deforestation of all forest ecosystems. Achard et al. (2002) estimate that between 1990 and 1997, about 5.8 Mha of tropical forests were lost each year (a much lower estimate than that of FAO [2001] of 15 Mha per year). Globally, emissions of carbon from land use changes have been estimated to be 1.7 + 0.8 Gt/yr (Houghton 1999, Houghton et al. 2000, IPCC 2000). The future carbon mitigation potential of slowing current rates of tropical deforestation has been estimated at about 11-21 Gt of carbon by 2050 (IPCC 2002). Worldwide, forests currently represent a carbon sink of about 3 Gt of carbon per year – about half is taken up by northern hemisphere ecosystems with the major contribution fluctuating between Eurasia and North America. The other half is in tropical ecosystems, which means that the tropical zone is currently neither a significant net source or sink (Watson and Noble 2002), but also suggests that slowing the rate of deforestation would make tropical forests a net carbon sink.

In addition to climate change mitigation benefits, slowing deforestation and/or forest degradation could provide substantial biodiversity benefits. Primary tropical forests contain an estimated 50–70 percent of all terrestrial species, and tropical deforestation and degradation of forests are major causes of global biodiversity loss. Deforestation reduces the availability of suitable habitats for species coexistence, may cause local extinctions, and can decrease both population and genetic diversity. Thus reducing the rate of deforestation is key to halting the loss of biodiversity in forests (Stork 1997, Iremonger et al. 1997, Thompson et al. 2002). Although any project that slows deforestation or forest degradation will help to conserve biodiversity, projects in threatened/vulnerable forests that are unusually species-rich, globally rare, or unique to that region can provide the greatest biodiversity benefits. Projects that protect forests from land conversion or degradation in key watersheds have potential to substantially slow soil erosion, protect water resources, and conserve biodiversity.

Forest protection through avoided deforestation may have either positive or negative social impacts. The possible conflicts between the protection of forested ecosystems and ancillary negative effects, restrictions on the activities of local populations, reduced income, and/or reduced products from these forests, can be minimized by appropriate stand and landscape management, as well as using environmental and social assessments (IPCC 2002).

Pilot projects designed to avoid emissions by reducing deforestation and forest degradation have produced marked ancillary environmental and socio-economic benefits. These include biodiversity conservation, protection of watersheds, improved forest management, and local capacity-building. Although avoided deforestation is not an eligible CDM activity, it is an important mechanism to maintain biodiversity. It is important that reduced deforestation in one location does not simply result in intended or unintended deforestation at another location; i.e., leakage (see Box 4.2).

4.7. REVEGETATION

Revegetation is an eligible activity under Article 3.4 of the Kyoto Protocol. "Revegetation" is defined as a direct human-induced activity to increase on-site carbon stocks through the establishment of vegetation that covers a minimum area of 0.05 hectares and does not meet the definitions of afforestation and reforestation (FCCC/CP/2001/13/Add. 1, page 58).

Revegetation includes various activities designed to increase plant cover on eroded, severely degraded or otherwise disturbed land. Short-term goals of revegetation are often erosion control, improved soil stability, recovery of soil microbial populations, increased productivity of degraded rangelands and improved appearance of sites damaged by such activities as mining or construction. It is often the initial step in the long-term restoration of ecosystem structure and function, natural habitats, and ecosystem services.

Soils of eroded or degraded sites generally have low carbon levels but have high potential for carbon sequestration through revegetation. Lal (2001) estimated the sequestration potential of eroded land restoration as 0.2-0.3 Gt of carbon yr-1. Research in Iceland has demonstrated sequestration of carbon in soils, above- and below-ground biomass, and litter, but sequestration rates depend on various factors, including the revegetation method, soil characteristics, and climate (Aradottir et al. 2000, Arnalds et al. 2000).

The effects of revegetation on biodiversity will vary depending on the site conditions and methods used. Effects on biodiversity can be positive if revegetation efforts create conditions that are conducive to an increase of native plant species over time (e.g., Choi and Wali 1995, Aradottir and Arnalds 2001, Gretarsdottir 2002), or if it prevents further degradation and protects neighboring ecosystems. Conversely, biodiversity can be negatively affected by revegetation if it results in conditions that impede the colonization of native species (Densmore 1992, Forbes and McKendrick 2002). In certain instances where endemic species may now be impossible to grow on some severely degraded sites, the use of exotic species and fertilizers may provide the best opportunity as a catalyst for regeneration of natural vegetation. However, in such instances, it is desirable that the use of exotic species is temporary (D'Antonio and Mayerson 2002, Ewel et al. 1999). Furthermore, exotic species used for revegetation can invade native habitats and alter plant communities and ecosystem processes far beyond the areas where they were originally used (e.g., Pickard et al. 1998, Whisenant 1999, Magnusson et al. 2001, Williamson and Harrison 2002).

Revegetation actions that do not depend on direct seeding or planting enhance local populations and have positive effects on biodiversity. Such actions involve manipulation of: seed dispersal processes (Robinson and Handel 2001), seedbed properties (Urbanska 1997, Whisenant 1999) and resource base for establishment and growth of plants (e.g. Tongway and Ludwig 1996, Whisenant 1999). This should enhance local populations and have positive effects on biodiversity, unless exotic species are common at the given site.

4.8 LAND MANAGEMENT

Land management actions to offset greenhouse gas emissions can affect overall environmental quality, including soil quality and soil erosion, water quality, air quality, and wildlife habitat and in turn, affect terrestrial and aquatic biodiversity (IPCC 2002). The subsections below deal with management of forests, croplands and grazing lands.

4.8.1 Forest management

Most of the world forests are managed (FAO 2001)**, so improved management can enhance carbon uptake, or at least minimize carbon losses, and maintain biodiversity.** For the purposes of the Kyoto Protocol, forest management is defined as a system of practices for stewardship and use of forest lands, aimed at fulfilling relevant ecological (including biodiversity), economic, and social functions of the forest in a sustainable manner (FCCC/CP/2001/13/Add.1 page 58). Forest management is one of the carbon uptake activities for which Annex 1 countries can receive credit when fulfilling their commitments under the Kyoto Protocol. Forest management refers to activities such as harvesting, thinning and regeneration. These management activities provide opportunities to promote conditions that are conducive to increased biodiversity. Zhang and Justice (2001) estimated that improved forest management in central Africa could provide the uptake of an additional 18.3 Gt of carbon over the next 50 years. By reducing the amount of logging debris through "good" forestry practices such as low-impact harvesting in tropical forests, significant amounts of carbon in the standing vegetation can be retained and that otherwise would have been released to the atmosphere by decomposition (e.g., Pinard and Putz 1996). Low impact harvesting also minimizes the probability of forest fires, as there is little woody debris that otherwise would serve as combustion fuel (Holdsworth and Uhl 1997).

Forest ecosystems are extremely varied and the positive or negative impacts on biodiversity of any forest management operation will differ according to soil, climate, and site history. Therefore, it would not be helpful to recommend that any specific system or measure is inherently good or bad for biodiversity under all circumstances. Prescriptions must be adapted to specific local forest conditions and the type of forest ecosystem under management.

Because forests are enormous repositories of terrestrial biodiversity at all levels of organization (genetic, species, population, and ecosystem), good management practices can have positive effects on biodiversity. Forestry practices that enhance biodiversity in managed stands and have a positive influence on carbon retention within forests include: increasing rotation age, low intensity harvesting, leaving woody debris, post-harvest silviculture to restore native plant communities that are similar to natural species composition, and harvesting that emulates natural disturbance regimes (Hunter 1999). The application of appropriate silvicultural practices can reduce local impacts while ensuring the long-term protection of soils and animal and plant species (see section 6.3.5). The use of appropriate harvesting methods can lessen the negative impacts on biodiversity, while still providing socio-economic benefits to local owners and communities that are largely dependent on the forest for their livelihoods.

Measuring progress towards sustainability, and managing adaptively, is an important aspect of forest management. Many national and international agencies, have adopted a series of indicators to measure progress in conserving biological diversity in sustainable forest management, for which there is a large body of available literature (see chapter 5).

Forest regeneration includes practices such as planting at specific stocking levels, enrichment planting, reduced grazing of forested savannas, and changes in tree provenances/genetics or tree species.

Box 4.3. Forest Management Practices with Potential Impacts on Biodiversity

Improved regeneration, or the act of renewing tree cover by establishing young trees naturally or artificially—generally, before, during or promptly after the previous stand or forest has been removed.

Fertilization, or the addition of nutrients to increase growth rates or correct a soil nutrient deficiency.

Forest fire management, which is used to reduce the loss of forest biomass from fires, and reduce emissions of greenhouse gases.

Pest management, or the application of strategies to maintain pest populations within acceptable levels.

Harvest level and timing, including thinnings, selection, and clear-cut harvesting.

Regeneration techniques can influence species composition, stocking, and density and can affect biodiversity. Natural regeneration of forests can provide benefits for biodiversity by expanding the range of natural or semi-natural forests. Areas adjacent to natural forests demonstrate the most potential for such activities. Plantations, even of indigenous species, adjacent to natural or semi-natural forests may not provide maximum benefits to biodiversity unless designed as part of an integrated scheme for the eventual restoration of natural forests (Niesten et al. 2002). Efforts to understand and integrate land use at the landscape scale can increase the likelihood that biodiversity will be accommodated.

Forest fertilization may have negative or positive environmental effects. Fertilization may adversely affect biodiversity, soil and water quality by improving the environment for unwanted species (i.e., weeds), by altering species composition and by increasing nutrients in water run-off that adversely affect watercourses (e.g., increased emissions of nitrous oxide [N_2O] to air, ground, and water). Although careful attention to the rate, timing, and method of fertilization can minimize environmental impacts, in general, positive environmental benefits are not likely to result from forest fertilization, except on highly degraded sites. There, fertilization may be necessary where soils and nutrients have been depleted. Fertility can affect the establishment of trees, shrubs, and understory plant communities (Oren et al. 2001). When organic and inorganic amendments were applied to an eroded site in South Iceland, plant cover and the diversity of native vascular plant and moss species increased (Elmarsdottir 2001). Another study on the same site showed increased carbon stocks in soil, vegetation and litter in similar but successively older treatments (Aradottir et al. 2000). Approaches that use not only inorganic fertilizers, but also organic amendments and nitrogen fixing plant species as well should be considered.

Fire management has environmental impacts that are difficult to generalize because in some forest ecosystems fires are essential for regenerative processes to occur. Restoring near-historical fire regimes may be an important component of sustainable forestry but may also require practices, such as road construction, that may create indirect deleterious environmental effects. The suppression of natural fire cycles leads to the excessive accumulation of combustible material, potentially leading to larger, more intense fires and is unlikely to provide viable long-term carbon sequestration (Noss 2001). In some forest ecosystems periodic fires are necessary to regenerate understory plant communities and their associated biodiversity. However, in forests not subjected to recurrent natural fires, e.g., tropical rainforests, increased fire frequencies lead to overall negative effects on biodiversity, and loss of soil nutrients through leaching and runoff.

The use of biocides to control pests may result in increased or reduced biodiversity. Many introduced plant and animal species have had unintended negative impacts on biodiversity. Carefully targeted pest management efforts have been used to reduce the impact of introduced species on native populations, for example predation of birds and their eggs. Biocides can, at times, prevent large-scale forest die-off, and can increase benefits associated with landscape, recreation, and watersheds. Conversely, the potential adverse effects of herbicides and pesticides on biodiversity include disruption of root-mycorrhizae symbiosis (Noss 2001) and a reduction in plant species populations and diversity. Pesticide use may also have undesired secondary effects on predators (Noss and Cooperrider 1994). If not carefully used, pesticides can be leached into surface waters and groundwater and cause negative impacts to aquatic biodiversity and human health.

Harvesting practices affect the quality and quantity of timber produced, which has implications for carbon storage and biodiversity. Harvesting can have positive or negative impacts on biodiversity, recreation, and landscape management. Small-scale harvesting (i.e., patch or selection) is often appropriate in forest ecosystems on soils that are subject to erosion.

4.8.2 Management of cropland

The Marrakesh Accords define cropland management as "the system of practices on land on which agricultural crops are grown, and on land that is set aside or temporarily not being used for crop production" (FCCC/CP/2001/13/Add.1 page 58).

Most carbon stocks in cropland are housed in the soil; they currently constitute about 8-10 percent of total global carbon stocks. Some studies suggest that most of the world's agricultural soils have about half of their pre-cropped soil carbon and that change in soil management, especially reducing tillage, can greatly increase their carbon stocks (IPCC 1996, IPCC 2000).

Generally, conversion of natural systems to cropland results in losses of soil organic carbon ranging from 20-50 percent of the pre-cultivation carbon stocks (IPCC 2000). For example, following conversion from forest to row-crop agriculture, soil carbon losses associated with CO_2 emissions is about 20-30 percent of the original carbon stocks. On a global basis, the cumulative historic loss of carbon from agricultural soils due to practices such as crop residue removal, inadequate erosion control and excessive soil disturbance has been estimated at 55 Gt, or nearly one third of the total carbon loss (i.e., 150 Gt of carbon) from soils and vegetation (IPCC 1996, Houghton 1999).

Activities in the agricultural sector that reduce greenhouse gas emissions and increase carbon sequestration may enhance or decrease given levels of biodiversity. There are many agricultural management activities that can be used to sequester carbon in soils (e.g., intensification, irrigation, conservation tillage, and erosion control). Practices may have positive or negative effects on biodiversity, depending on the specific practice and the context in which it is applied. Activities include adopting farmer participatory approaches; consideration of local knowledge and technologies; the use of organic materials; and the use of locally adapted crop varieties and crop diversification. Agricultural practices that enhance and preserve soil organic carbon can affect CH_4 and N_2O emissions.

Agricultural intensification practices that may enhance production and increase plant residue in soil include crop rotations, reduced bare fallow, cover crops, improved varieties, integrated pest management, optimization of inorganic and/or organic fertilization, irrigation, water table management, and site-specific management. These have numerous ancillary benefits including increased food production, erosion control, water conservation, improved water quality, and reduced siltation of reservoirs and waterways benefiting fisheries and biodiversity. However, soil and water quality is adversely affected by indiscriminate use of chemical inputs and irrigation, and increased use of nitrogen fertilizers will increase fossil energy use and may increase N_2O emissions. Agricultural intensification influences soil carbon through the amount and quality of carbon returned to the soil, and through water and nutrient influences on decomposition.

Irrigation can increase crop production, but may also degrade ecosystems. Irrigation also increases the risk of salinization and may divert water from rivers and flood flows with significant impacts on the biodiversity of rivers and flood plains. Return flows from irrigation can cause downstream impacts on water quality and aquatic ecosystems. Additional impacts can include the spread of water-borne diseases.

Conservation tillage denotes a wide range of tillage practices, including chisel-plow, ridge-till, strip-till, mulch-till, and no-till to conserve soil organic carbon. Adoption of conservation tillage has numerous ancillary benefits, including control of water and wind erosion, water conservation, increased water-holding capacity, reduced compaction, improved soil, water, and air quality, enhanced soil biodiversity, reduced energy use, reduced siltation of reservoirs and waterways with associated benefits for fisheries and biodiversity. In some areas (e.g., Australia), increased leaching from greater water retention with conservation tillage could cause downslope salinization.

Reduction or elimination of intensive soil tillage practices can preserve and increase soil organic carbon stocks. In these practices 30% or more of crop residues are left on the soil surface after planting. Conservation tillage has the potential to sequester significant amounts of carbon in the soil. Soil carbon sequestration can be further increased when cover crops are used in combination with conservation tillage (IPCC 2000). Carbon levels can be increased in the soil profile for 25 to 50 years, or until saturation is reached, but the rate may be highest in the initial 5 – 20 years. However, long-term soil carbon sequestration through conservation tillage will largely depend on its continued use, as reversion back to conventional practices can cause the rapid loss of sequestered carbon.

Erosion control practices—which include water conservation structures, vegetative strips used as filters for riparian zone management, and agroforestry shelterbelts for wind erosion control—can reduce the global quantity of soil

organic carbon displaced by soil erosion. There are numerous ancillary benefits and associated impacts, including increased productivity; improved water quality; reduced use of fertilizers, especially nitrates; decreased siltation of waterways; reduced CH_4 emissions; associated reductions in risks of flooding; and increased biodiversity in aquatic systems, shelter belts, and riparian zones.

Rice management strategies—which include irrigation, fertilization, and crop residue management—affect CH_4 emissions and carbon stocks. But there is limited information on the impacts of greenhouse gas mitigation rice management activities on biodiversity.

4.8.3 Grazing lands and grasslands

The response of grazing land systems will vary under potential climate change scenarios depending on its type and location. Grazing land (which include grasslands, pasture, rangeland, shrubland, savanna, and arid grasslands) contain 10-30 percent of the world's soil carbon (IPCC 2000). The mixture of grass, herb, trees and shrub species usually determines the productivity of a given rangeland. Grazing land with a higher percentage of grass in relation to other plant components is likely to have higher productivity. A greater percentage of annual or ephemeral species would suggest lower annual productivity, whereas a predominance of perennial species is more likely to result in high productivity. The Marrakesh Accords define grazing land management as "the system of practices on land use for livestock production aimed at manipulating the amount and type of vegetation and livestock produced" (FCCC/CP/2001/13/Add.1, page 58). Operationally, a distinction is sometimes made between grazing land management and grassland management; grazing lands are managed for livestock, whereas grasslands may be managed for different purposes, including conservation, but not specifically for livestock. One of the goals of grazing land management is to prevent overgrazing, which is the single greatest cause of grassland degradation and the overriding human-influenced factor in grassland soil carbon loss (Ojima et al. 1993).

In grazing lands, carbon accumulates above- and below-ground, and transforming cropped or degraded lands to perennial grasslands can increase above- and below-ground biomass, soil carbon, and biodiversity. Protection of previously intensively grazed lands and reversion of cultivated lands to perennial grasslands is likely to be more prevalent in countries with agricultural surpluses, but opportunities for environmental protection set-asides are possible in all countries. Globally, estimates of the potential area of cropland that could be placed into set-asides are approximately 100 M ha (IPCC 1996).

Grasslands management activities that can be used to sequester carbon in soils include grazing management, protected grasslands and set-asides, grassland productivity improvements, and fire management. The productivity of many pastoral lands, and thus the potential for carbon sequestration, particularly in the tropics and arid zones, is restricted by nitrogen and other nutrient limitations and the unsuitability of some native species to high-intensity grazing. Introduction of nitrogen-fixing legumes and high-productivity grasses or additions of fertilizer can increase biomass production and soil carbon pools, but some of these introduced species have significant potential to become weeds (IPCC 2000).

Most grassland management activities are beneficial to biodiversity and carbon uptake; some such as fertilization may decrease on-site biodiversity (LULUCF 2000-Table 4.1). Carbon accumulation can be enhanced through improved practices when grazing lands are intensively managed or strictly protected. Properly managed native species can enhance the biodiversity associated with grazing lands. Native species are also often more tolerant of climatic variations than exotic species, and can provide essential habitat for animals. Buckland et al. (2001) suggest that native perennial species of grass have the potential to establish and effectively compete with annuals, improving system stability. Grazing lands can also be made more productive, e.g., through fertilization, although it may lead to a reduction in the biodiversity of native grasslands.

4.9 CARBON SEQUESTRATION IN OCEAN SYSTEMS, WETLANDS AND GEOLOGIC FORMATIONS

Oceans and wetlands are enormous reservoirs of carbon; currently, there is approximately 50 times as much carbon in the oceans as in the atmosphere. Oceans have provided a sink for up to 30 percent of the anthropogenic carbon dioxide emissions (Raven and Falkowski 1999). However, these activities cannot generate credits to meet commitments under the Kyoto Protocol.

Marine ecosystems may offer mitigation opportunities for removing CO_2 from the atmosphere, but the implications for biodiversity and ecosystem functioning are not well understood. Mitigation of climate change impacts by means of the direct introduction of fossil fuel-derived carbon dioxide into marine waters was first proposed in 1977. Subsequently, proposals have been developed to inject CO_2 gas into intermediate depth waters (800 m), either from fixed shore-based pipelines (Drange et al. 2001) or from pipelines towed behind ships. Other proposals envisage delivery of CO_2 into deep water to form a lake covered with CO_2-clathrate hydrate (Brewer 2000).

All proposed oceanic CO2 storage schemes have the potential to cause ecosystem disturbance (Raven and Falkowski 1999). Carbon dioxide introduced at depth will alter seawater pH, with potentially adverse consequences for marine organisms (Ametistova et al. 2002). A decline in pH associated with a CO_2 plume could disrupt marine nitrification and lead to unpredictable phenomena at both the ecosystem and community level (Huesemann et al. 2002). Organisms unable to avoid regions of low pH because of limited mobility will be most affected; layers of low pH water could prevent vertical migration of species and alter particle composition, affecting nutrient availability (Ametistova et al. 2002). Deep-sea organisms are highly sensitive to changes in pH and CO_2 concentration (Seibel and Walsh 2001). Thus, even small changes in pH or CO_2 could have adverse consequences for deep-sea ecology and hence for global biogeochemical cycles that depend on these ecosystems (Seibel and Walsh 2001). The introduction of CO_2 into seamount ecosystems, which are essentially the tops of mountains or chains of mountains beneath the sea, raises further concerns. While data is limited, it appears that seamounts have high levels of endemic biodiversity; i.e., containing species unique found nowhere else in the world (Koslow et al. 2000, Forges et al. 2000). The overall ecological and biodiversity implications of ocean CO_2 disposal are highly uncertain, especially to benthic systems, due to a lack of knowledge about the faunal assemblages likely to be affected, and the extent of the areas affected. It is important to note that these activities are likely to take place on the high seas outside of national jurisdiction.

Ocean fertilization is another type of carbon sequestration. The concept of mitigating climate change through increased biological sequestration of carbon dioxide in oceanic environments (IPCC 2001a) has mainly focused on fertilization of the limiting micronutrient, iron, to marine waters that have high nitrate and low chlorophyll levels (Boyd et al. 2000). The aim is to promote the growth of phytoplankton that, in turn, will fix significant amounts of carbon. The introduction of nitrogen into the upper ocean as a fertilizer has also been suggested (Shoji and Jones 2001). However, the effectiveness of ocean fertilization as a means of mitigating climate change may be limited (Trull et al. 2001, Buesseler and Boyd 2003).

The consequences of larger and longer-term introductions of iron remain uncertain. There are several feedback mechanisms between ocean systems and climate, and there is a danger to disrupt the current functioning of the Earth's largest ecosystem through mitigation activities. There are concerns that the introduction of iron could alter food webs and biogeochemical cycles in the oceans (Chisholm et al. 2001) causing adverse effects on biodiversity. There are also possibilities of nuisance or toxic phytoplankton blooms and the risk of deep ocean anoxia from sustained fertilization (Hall and Safi 2001). A series of experimental introductions of iron into the Southern Ocean promoted a bloom of phytoplankton (Boyd et al. 2000) but also produced significant changes in community composition and the microbial food web (Hall and Safi 2001).

Wetlands have positive impacts on water quality, provide protection against local flooding, help control soil and coastal erosion, and are important reservoirs of unique biodiversity. They also serve as corridors for many long-range, migrant species and provide important breeding grounds for fish. Long-term revegetation (i.e., ecological restoration) of former wetlands can increase carbon sequestration but may lead to increases in other gas emissions. Wetlands are important reservoirs of biodiversity. Thus restoration of wetlands that have been formerly drained for agriculture or forestry will provide important benefits: improvement of water quality, control of soil and coastal erosion, as well as providing protection against local flooding (IPCC 2000). Restoration of wetlands will increase carbon storage as organic matter, but may also increase methane (CH_4) emissions.

Effects of carbon sequestration in geological formations on biodiversity are not well understood. As with marine carbon sequestration, this option is not explicitly incorporated in the Kyoto Protocol, but the technical potential is very large, and considerable governmental and private sector investments in research are underway to further develop this alternative. The biodiversity implications of the different technologies applied (storage in oil fields, coal beds or aquifers) are not well understood; possible negative effects could be due to release of carbon dioxide from underground storage or by changing the chemical properties of ground water (Reichle et al. 1999).

4.10 ENERGY ACTIVITIES

About 60 % of anthropogenic global greenhouse gas emissions originate from the generation and use of energy. The majority of mitigation efforts are therefore focused on energy production, transport and space heating.

A substantial proportion of anthropogenic greenhouse gas emissions originate from non-energy sources. Measures are being taken to cut emissions from sources such as waste disposal, forestry and agriculture, as well as enhance removals. By definition, these actions provide environmental benefits in terms of climate change; they may have beneficial or adverse effects on biodiversity. Potential impacts on biodiversity of some emission reduction actions are discussed below.

Mitigation options in the energy sector that may affect biodiversity include increasing the use of renewable energy sources such as bioenergy, and wind-, solar-, and hydropower. Some activities that increase efficiency in the generation or use of fossil fuels are not discussed in this report but may also have beneficial effects on biodiversity. Increased efficiency in these types of activities will reduce fossil-fuel use, thereby reducing the impacts on biodiversity caused by mining, extraction, transport, and combustion of fossil fuels.

4.10.1 Use of biomass / Bioenergy

The use of biomass (plant material) as a fuel can mitigate the impacts of climate change by decreasing fossil fuel use. Bioenergy carriers store solar energy in the form of organic material, which can be used at any time. The variety of forms in which bioenergy carriers occur is a further advantage: they can be used in solid, liquid or gaseous state to produce either electricity or heat or both. During plant growth, plants assimilate carbon dioxide from the atmosphere. The CO_2 is released during combustion. Therefore, the use of bioenergy is more or less CO_2-neutral. Any difference will depend on the amount of fossil fuels used to produce, harvest and convert bioenergy carriers. Generally, the use of agricultural or forest residues requires a smaller incremental use of fossil energy than the cultivation of specialized energy crops. However, emissions from biomass fuels still include components such as sulphur and black carbon particles, or gases (such as N_2O or CH_4) that have negative effects on the environment.

Today, eleven percent of the global primary energy consumption (419 EJ) is produced from bioenergy (Goldemberg 2000). In some developing countries the share of bioenergy can be as high as 90 percent of total energy consumption, although the average for developing countries is 33 percent (Hall 1997). According to IPCC calculations, energy crops could supply much of modern bioenergy, which could be cultivated on about 10 percent of the world's land area (Table 4.2). Achieving the technical potential indicated by IPCC's calculation would require setting aside large areas in Latin America and Africa for bioenergy crops.

Despite many advantages, such as overall availability and diversity of uses, bioenergy also bears risks for the global biosphere and for food security. To exploit bioenergy to the potential presented in the IPCC third assessment report (IPCC 2001a,b,c), it may require the conversion of natural vegetation, especially forests, to bioenergy plantations, and causing a significant loss of biodiversity in the affected regions. Several studies have shown that bioenergy tree plantations host less breeding bird and mammal species and individuals than the surrounding forests and shrublands (Hanowski et al. 1997, Christian et al. 1998). Moreover, these plantations are not colonized by forest animals but by species typical of open landscapes (Christian et al. 1997;1998). The introduction of wood energy crops into open landscapes changes wildlife community dynamics and might lead to a fragmentation of grasslands, precipitating the loss of species who depend on large open areas (Paine et al. 1996).

Nevertheless, bioenergy crops can result in neutral or positive impacts on biodiversity if

Table 4.2: **Comparison of several studies calculating global bioenergy potentials.**

Study	**IPCC (2001a,b,c)**	**Kaltschmitt et al. (2002)**	**Fischer and Schrattenholzer (2001)**
Potential (EJ)	396 (+45)	104	370-450
Area for energy crops	~10% of world's land area	~2.5% of world's land area	Whole grassland area
	16% of Africa		
	32% of Latin America		
Yields for energy crops	High	Moderate	Moderate
[t ha^{-1}]	15	6-7	4.7
Residue use (average) [t ha^{-1}]	No data	Forest: 0.5	Forest: 1.4
		Agriculture: 0.7	Agriculture: 1.2

several points are considered.

(a) Bioenergy plantations, which do not replace natural vegetation but cropland or non-native grazing land (e.g., managed pastures or plantations) in areas affected by degradation or erosion, may result in improved soil fertility and structure. Precise land use models, such as those developed for north-eastern Brazil (Schneider et al. 2001), can identify suitable land and avoid competition with food production areas.

(b) Bioenergy plantations containing a high level of structural heterogeneity are better for biodiversity than large homogenous monocultures (Christian et al. 1994). Examples of these plantations are stands that are established with patches of different species or clones.

(c) Use of native species that resemble as closely as possible the natural vegetation of a certain region. For example, switchgrass (Panicum virgatum) plantations in the North American prairie region provides suitable habitat for native wildlife species (Paine et al. 1996).

(d) Perennial energy crops require less agrochemicals than annual crops and are often more productive (Graham et al. 1996, Paine et al. 1996, Zan et al. 2001).

4.10.2 Fuel wood as a special case of bioenergy

More than half of the world's total round wood production is used as fuel wood, and fuelwood and charcoal consumption in tropical countries is estimated to increase from 1.3 billion m^3 in 1991 to 3.4 billion m^3 by 2050 (Schulte-Bisping et al. 1999). In the rural areas of most developing countries fuel wood collected in forested common lands is the main source of domestic energy (Heltberg et al. 2000). In several Asian and African countries, e.g., China, India, and Kenya, wood consumption exceeds plant growth rates. Several authors have described the cycle induced by fuel wood scarcity: increased efforts to find fuel wood lead to increased environmental degradation, which in turn intensifies fuel wood scarcity (Heltberg et al. 2000, Köhlin and Parks 2001). Integration of sustainable production of fuel wood into forest management, afforestation/reforestation, agroforestry, revegetation and grassland management projects will help to reduce the pressure on forests and their biodiversity.

The extent of environmental degradation and the effects for biodiversity depend on the type of wood collected. Normally, fuel wood collectors first gather dry wood lying on the forest floor, before breaking dead twigs and branches off living trees (Du Plessis 1995). The removal of these substrata may affect a variety of species, which use dead wood for food, shelter, or nesting. The disruption of nutrient flows that are supplied to the soil from decomposing wood may disturb or even eliminate biotic decomposers that include insects, fungi, and microbes. (Shankar et al. 1998). Similar effects are caused by the excessive removal of uprooted shrubs and over-topped trees on village common lands in India (Ravindranath and Hall 1995). Liu et al. (1999) noted that giant panda habitat declined in the Wolong Nature Reserve in China as the population, and hence the demand for fuel wood increased.

Fuelwood conservation measures, such as efficient cookstoves, solar cooking and biogas, have the potential to reduce pressure on forests and thus conserve both carbon reservoirs and biodiversity. Biogas derived from anaerobic decomposition of crop waste and cattle dung can potentially substitute for fuelwood at the household or community levels. The same holds true when solar energy is used. Thus, mitigation activities aimed at reducing fuelwood use for cooking and heating through improvements in efficiency (improved stoves and biogas) and changes in behavior of local people can significantly reduce pressure on forests and thereby contribute to biodiversity conservation. In some circumstances however, like in Mediterranean countries, the termination of brushwood gathering led to an increase in fire risk and thus put a potential threat to biodiversity.

4.10.3 Hydropower and dams

Hydropower has been promoted as a technology with significant potential to mitigate climate change by reducing the greenhouse gas intensity of energy production (e.g., International Hydropower Association 2000). Greenhouse gas emissions from most hydropower projects are relatively low, with the exception of large shallow lakes in heavily vegetated tropical areas where emissions of methane (CH_4) from decaying vegetation can be substantial. Currently, about 19 percent of the world's electricity is produced from hydropower. While a large proportion of hydropower potential in Europe and North America is already tapped, a smaller proportion of the larger potential in developing countries has been exploited. Of the first 25 projects moving through the Clean Development Mechanism validation process as of August 2002, seven were hydro projects (Pearson, in press).

Emissions of carbon dioxide and methane caused by dams and reservoirs may be a limiting factor on the use of hydropower to mitigate climate change. Preliminary research suggests that emissions from dams and reservoirs worldwide may be equivalent to about one-fifth of estimated total anthropogenic methane (CH_4) emissions and four percent of anthropogenic carbon dioxide emissions. The science of quantifying reservoir emissions is, however, still developing and subject to many uncertainties. One major issue requiring further study is how dams and reservoirs affect watershed carbon cycling. Measurements of gross reservoir emissions may significantly under- or over-estimate net emissions depending on how pre-dam carbon fluxes have been affected (World Commission on Dams 2000a).

Large-scale hydropower development can also have other high environmental and social costs. The large-scale promotion of hydropower for climate mitigation could have serious impacts on biodiversity, especially in aquatic and riparian ecosystems. The World Bank/IUCN-sponsored World Commission on Dams (World Commission on Dams 2000b) concluded that "large dams have many, mostly negative impacts on ecosystems. These impacts are complex, varied and often profound in nature. In many cases, dams have led to the irreversible loss of species populations and ecosystems". Dam reservoirs result in loss of land, which may lead to loss of local terrestrial biodiversity. Dams may also prevent fish migration, an essential part of the life cycle of some species and thus damage fishing resources with its associated social impacts on local populations. Altering the timing, flow, flood pulse, oxygen and sediment content of water may reduce aquatic and terrestrial biodiversity. Systematic changes of the aquatic habitats by hydropower projects may cause a cumulative negative effect on specialized aquatic and semi-aquatic species. Disturbing aquatic ecosystems in tropical areas can also induce indirect environmental effects; for example, increased pathogens and their intermediate hosts may lead to an increase in human diseases such as malaria, schistosomiasis, filariasis, and yellow fever. The environmental impacts of hydropower plants are summarized in Table 4.3.

The ecosystem impacts of specific hydropower projects vary widely and may be minimized depending on factors including type and condition of pre-dam ecosystems, type and operation of dam, and the height of dam and area of reservoir. Well-designed installations, for example using modern technologies that cascade the water through a number of smaller dams and power plants, may reduce the adverse environmental impacts of the system. Small and micro-scale hydroelectric schemes normally have low environmental impacts, but the cumulative effects of many projects within

Table 4.3: Typology of main environmental impacts from hydropower (from McCully 1996).

Impacts Due to Dam and Reservoir Presence	Impacts Due to Pattern of Dam Operation
Upstream change from river valley to reservoir (includes flooding of terrestrial habitats and conversion of aquatic habitats from wetland and riverine to lacustrine).	Changes in downstream hydrology; changes in total flows; change in seasonal timing of flows; short-term fluctuation in flows; change in extreme high and low flows.
Changes in downstream morphology of riverbed and banks, delta, estuary and coastline due to altered sediment load.	Changes in downstream morphology caused by altered flow patterns.
Changes in downstream water quality: effects on river temperature, nutrient load, turbidity, dissolved bases, concentration of heavy metals and minerals.	Changes in downstream water quality caused by altered flow patterns.
Reduction of biodiversity due to the blocking of movement of organisms and because of the above changes.	Reduction in riverine/riparian/floodplain habitat diversity, especially due to elimination of floods.

a watercourse may have considerable impact on the biodiversity within a larger area. In general, run-of-river projects will have fewer impacts than storage dams with large reservoirs[26] but they may also have serious effects on biodiversity. These impacts are mainly due to the blocking of fish migration, either because of the physical barrier of the dam wall or through the dewatering of a stretch of river below the dam. Cumulative impacts of small dams on biodiversity need to be considered even when individual installations may have only a small impact (World Commission on Dams 2000b).

Proper design and operation of reservoirs and dams could decrease their impact on biodiversity. Another important determinant of dam impacts is their location within the river system. Dams near the headwaters of tributaries will tend to have fewer impacts than mainstream dams that may cause perturbations throughout the whole watershed (see e.g. Pringle 1997). The protection of dams from siltation may be a mayor incentive for biodiversity conservation in the form of reforestation or afforestation measures within the watershed. The World Commission on Dams has published a comprehensive list of guidelines for water and energy planning which might be helpful in that respect (World Commission on Dams 2000b).

4.10.4 Wind energy

Wind energy plays an important role in the development of renewable energy; the use of wind energy is increasing rapidly and it is one strategy to mitigate climate change. The additionally installed capacity in the record year 2001 was 6824 MW worldwide (Krogsgaard and Madsen 2002). Today wind energy next to hydropower is the most important renewable energy source of electricity. Europe accounts for more than 70 percent of the total installed capacity in the world, and the United States of America has 18 percent. In Germany 37 percent

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[26] The term run-of-river is ill-defined but refers to projects with very small storage capacity relevant to streamflow.

of the world's capacity is connected to the grid (Brown 2002, Bundesverband Windenergie 2002). In addition to the installation onshore, development of offshore wind farms will accelerate in the future.

Onshore, as well as offshore, the construction and the operation of wind energy plants may cause negative impacts on the natural environment. Detailed and long-term research programs are needed to provide data on the effects of onshore and offshore wind farms on the natural environment and biological diversity. Onshore, there is proof of impacts on fauna, mainly avifauna. Wind energy farms may also lead to direct and/or indirect loss of habitat (Ketzenberg et al. 2002), which may be critical for rare species. Most of the studies have demonstrated low rates of collision mortality, but these rates could nevertheless be significant for some species (BfN 2000, and references therein). Studies conducted so far indicate species and site-specific sensitivity of birds, but further research is needed (Anderson et al. 1999, Kruckenberg and Laene 1999, Leddy et al. 1999, Morrison et al. 1998, Winkelmann 1992).

At present, knowledge of the effects of offshore wind farms on the avifauna (migration paths) is less extensive than the information available on onshore farms (Garthe 2000). Little is known about the impacts on sea mammals, fish, and the biotic-communities of the seabed (Merck and Nordheim 1999), but in sea mammals, there is a high potential risk of disorientation or displacement due to the noise during the construction and operation of wind farms. Benthic communities and fish may be affected by direct loss of habitats (during construction), or through rearrangement of the sediment. The input of solid substrates (concrete or steel foundation) may also have negative impacts on biodiversity. However, current knowledge about these impacts is still limited. Land use planning can help identify biologically sensitive areas and prevent them from being negatively impacted (Huggett 2001). For example, Germany is currently performing respective action with reference to their offshore wind energy strategy (BMU 2002) identifying ecologically sensitive areas and simultaneously defining wind energy qualification areas. Parallel to this strategy an extensive research plan related to possible environmental effects of wind farms is executed.

4.11 OPTIONS FOR ADAPTATION TO CLIMATE CHANGE

The Intergovernmental Panel on Climate Change has defined "adaptation" as adjustment in natural or human systems to a new or changing environment. In the context of climate change, adaptation refers to adjustment in practices, processes, or structures in response to actual or expected climatic stimuli or their effects, with an effort to reduce a system's vulnerability and to ease its adverse impacts. While ecosystems can, to a certain extent, adapt naturally to changing conditions, in human systems adaptation requires: an awareness of potential impacts of climate change, the need for taking action, an understanding of available strategies, measures and means to assess adaptive responses, and the capacity to implement effective options. In the following discussion, the term "adaptation" does not include the autonomous response of natural systems to climate change (e.g., to changed CO_2 levels).

Adaptation activities could include policies and programs to:

(a) Increase robustness of infrastructure and investments to climate change impacts (e.g., expanding buffer zones against sea level rise);
(b) Discourage investments that would increase vulnerability in systems sensitive to climate change;
(c) Increase flexibility of managed systems to accommodate and adapt to climate change;
(d) Learn from, and enhance resilience and adaptability of, natural systems; and
(e) Reverse maladaptive trends in development

and resource management and use (e.g., reducing subsidies associated with inefficient use of energy and water; GEF 2003).

Inertia[27] in the climate, ecological, and socio-economic systems makes adaptation inevitable and already necessary in some cases. Mitigation of climate change itself is a long-term endeavor. Even if all anthropogenic additions of greenhouse gases to the atmosphere were to be stopped immediately, global warming and associated impacts such as sea level rise, would be expected to continue for many decades (IPCC 2001d). Thus mitigation options alone (see section 4.4) may not be adequate to reduce the impacts of climate change on biodiversity and ecosystems; adaptation activities need to be considered along with mitigation options.

Adaptation activities to climate change will be required in all countries and in most sectors. For example, adaptation activities may be necessary for water management, agriculture, and forestry, and infrastructure development. It is generally considered that adaptation options are best carried out as part of an overall approach to sustainable development, integrated, for example, with national biodiversity strategies and action plans. As mentioned in Section 4.3, the ecosystem approach provides a unifying framework for adaptation activities to climate change in the context of sustainable development. Implementing appropriate monitoring systems will help detect potential trends in changes in biodiversity and help plan adaptive management strategies.

4.11.1 Adaptation options to reduce the negative impacts of climate change on biodiversity

Adaptation is necessary not only for the projected changes in climate but also because climate change is already affecting many ecosystems. Adaptation options include activities aimed at conserving and restoring native ecosystems, managing habitats for rare, threatened, and endangered species, and protecting and enhancing ecosystem services.

Reduction of other pressures on biodiversity arising from habitat conversion, over-harvesting, pollution, and alien species invasions, constitute important climate change adaptation measures. Since mitigation of climate change itself is a long-term endeavour, reduction of other pressures may be among the most practical options. For example, increasing the health of coral reefs may allow them to be more resilient to increased water temperature and reduce bleaching (see section 4.11.4).

A major adaptation measure is to counter habitat fragmentation, through the establishment of biological corridors between protected areas, particularly in forests. More generally, the establishment of a mosaic of interconnected terrestrial, freshwater and marine multiple-use reserve protected areas designed to take into account projected changes in climate, can be beneficial to biodiversity.

While some protected areas are large, usually the entire suite of local species including their full genetic variation are absent as most reserves are too small to contain the habitat requirements of all species (Kramer et al. 1997). Biodiversity affects, and is affected by, ecological processes that typically span spatial scales greater than the area encompassed within a protected area (Schulze and Mooney 1993; chapters 2 and 3). Moreover, because biodiversity responds intimately to climate change, with among other effects, shifts in species distributions, efforts may have to be directed to actions that increase the resiliency of existing protected areas to future climate change while recognizing that some

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[27] According to the Intergovernmental Panel on Climate Change, inertia means delay, slowness, or resistance in the response of the climate, biological, or human systems to factors that alter their rate of change, including continuation of change in the system after the cause of that change has been removed.

change is inevitable as a consequence of the response of species to climate change. For example, many species have populations that extend beyond current reserve boundaries; in Alaska and Canada, it is not possible to protect the full range of migratory caribou (Rangifer tarandus) herds, as these cover tens of thousands of km2.

Networks of reserves with connecting corridors provide dispersal and migration routes for plants and animals. The placement and management of reserves (including marine and coastal reserves) and protected areas will need to take into account potential climate change if the reserve system is to continue to achieve its full potential. Options include corridors, or habitat matrices that link currently fragmented reserves and landscapes to provide the potential for migration. In many instances, corridors can be used to connect fragmented habitats. For example, agroforestry shelterbelts across agricultural lands can be designed to connect forest fragments. A ‘corridor’ may simply be habitat areas sufficiently close to each other (i.e., functionally linked) to enable dispersal. The appropriate width and species composition, how the edges of the corridors should be managed, and the optimal pattern of patches within the matrix of surrounding land needs to be understood. Many corridors may be useful for animals but their utility for plants or entire vegetation types to move with climate change is less certain. Transitional zones between ecosystem types within and among reserves (ecotones) serve as repository regions for genetic diversity that may be drawn upon to restore degraded, adjacent regions. Hence, additional adaptation measures may be needed in ecotones. As an insurance measure, such approaches can be completed by *ex situ* conservation.

Conservation of biodiversity and maintenance of ecosystem structure and function are important climate change adaptation strategies because genetically-diverse populations and species-rich ecosystems have a greater potential to adapt to climate change. Conserving biodiversity at the species and genetic levels (including food crops, trees, and livestock races) means that options are kept open to adapt human societies better to climate change. While some natural pest-control, pollination, soil-stabilization, flood-control, water-purification and seed-dispersal services can be replaced when damaged or destroyed by climate change, technical alternatives may be costly and therefore not feasible to apply in many situations.

Captive breeding for animals, *ex-situ* conservation for plants, and translocation programs can be used to augment or reestablish some threatened or sensitive species. Captive breeding and translocation, when combined with habitat restoration and *in situ* conservation, may be successful in preventing the extinction of small numbers of key taxa under small to moderate climate change. Captive breeding for reintroduction and translocation is likely to be less successful if climate change is more dramatic as such change could result in large-scale modifications of environmental conditions, including the loss or significant alteration of existing habitat over some or all of a species’ range. However, it is technically difficult, often expensive, and unlikely to be successful in the absence of complete knowledge about the species’ biology (Keller et al. 2002).

Moving populations of threatened species to adapt to the changing climate zones is fraught with scientific uncertainties and considerable costs. Special attention may be given to poor dispersers, specialists, species with small populations, endemic species with a restricted range, those that are genetically isolated, or those that have an important role in ecosystem function. These species may be assisted by the provision of migration corridors (e.g., by erecting reserves with north–south orientation), but many may eventually require assisted migration to keep up with the speed with which their suitable habitats move with climate change. Superimposing a new biota on a regional biota that is experiencing an increase in problems from warmer climates will likely be a controversial adaptation.

4.11.2 Consequences of adaptation activities on ecosystems and biodiversity

Adaptation activities may be necessary to reduce the impacts of climate change on human wellbeing. Some such adaptation measures may threaten biodiversity, although the negative effects can often be mitigated by careful design. Depending on the location, some climate change adaptation activities may have either beneficial or adverse impacts on biodiversity.

Physical barriers may be necessary to protect against extreme weather events as adaptation measures (e.g., storm surges, floods), and may have positive or negative impacts on biodiversity. In terms of negative impacts, a loss of biodiversity due to adaptation measures may impair ecosystem functions, resulting in increased vulnerability to future climate change. For example, in some cases, certain ecosystems in small islands may be largely destroyed by efforts to obtain construction material for coastal protection. On the other hand, certain adaptation options may benefit biodiversity; for example, the preservation of ecosystems that serve as natural protection against potential impacts of climate change, such as mangrove forests and coral reefs, and the strategic placement of artificial wetlands. Traditional responses to climate change (e.g., building on stilts and the use of expandable, readily available indigenous building materials) have proven to be effective responses in many regions.

The use of pesticides and herbicides may be increased to control new pest and diseases, and invasive alien species that might result from climate change. This may lead to damage to existing plant and animal communities, water quality, and human health. Human responses to climate change may also contribute synergistically to existing pressures; for example, if new pest outbreaks are countered with increased pesticide use, non-target species might have to endure both climate and contaminant-linked stressors. In addition, non-target species could include natural predators of other pests thus creating more problems due to even more frequent pest outbreaks. In some cases, use of integrated pest management may offer a more sustainable solution, especially in agriculture.

Changes in agriculture and increased use of aquaculture--including mariculture--employed to compensate for climate-induced losses in food production, may have negative effects on natural ecosystems and associated biodiversity. However, there may also be opportunities for sustainable agriculture and aquaculture.

4.11.3 The contribution of biodiversity to adaptation options

The protection, restoration or establishment of biologically diverse ecosystems that provide important goods and services may constitute important adaptation measures to supplement existing goods and services, in anticipation of increased pressures or demand, or to compensate for likely losses. Although climate change has been observed to affect ecosystems and their biodiversity, biodiversity itself can play a potentially important role in enhancing ecosystem capacity to recover (resilience) and adapt to the impacts of climate change (see Chapter 2). In addition, recent work on the valuation of the services provided by ecosystems suggests that in many cases, the value of ecosystems in their natural state is greater than that of their converted state. For example, the net present value of intact mangrove in Thailand is greater than the value obtained from shrimp farming once converted (Balmford et al. 2002). Reducing general environmental pollution and other external stresses, as noted above, can increase ecosystem resilience against climate change. For example:

(a) The protection or restoration of mangroves can offer increased protection of coastal areas to sea level rise and extreme weather events (see section below on marine and coastal ecosystems);

(b) The rehabilitation of upland forests, coastal forests, and wetlands can help regulate flow in watersheds, thereby moderating floods from heavy rain and ameliorating water quality; and

(c) Conservation of natural habitats such as primary forests, with high ecosystem resilience, may decrease losses of biodiversity from climate change and compensate for losses in other, less resilient, areas.

4.11.4 Adaptation options in various ecosystems

4.11.4.1 Marine and coastal ecosystems

An integrated approach to fisheries management, which takes into consideration ecological as well as socio-economic issues and reduces pressures on fisheries and associated ecosystems constitute an adaptation strategy. Recent (2002) FAO fisheries statistics indicate that 47% of global fisheries are fully fished, while 18% are overfished and 9% depleted. In addition, 90% of large predatory fish biomass worldwide has been lost since pre-industrial times (Myers and Worm 2003). The relationship between climatic factors and fish carrying capacity is complicated, and the effects of climate change will likely have different consequences for various species. Overfishing causes a simplification of marine food webs, and will thus affect the ability of predators to switch between prey items (Stephens and Krebs 1986, Pauly et al. 2002). Healthy fisheries are better able to withstand environmental fluctuations, including climate change, than those under stress from overexploitation (see e.g., Jackson et al. 2001, Pauly et al. 2002).

Considering the depleted state of the world's fish stocks, a reduction of the pressures on fully- and overexploited coastal and oceanic fisheries can be an important component of adaptation measures to reduce impacts on biodiversity, and facilitate sustainable harvesting. The World Summit on Sustainable Development agreed on a goal to restore fish stocks to levels that can produce maximum sustainable yields by the year 2015 (WSSD Plan of Implementation, paragraph 30(a)). Means to reach this goal include, for example, reduction of the size of fishing fleets, ending subsidies for industrial fishing and establishing a global network of marine reserves, which would allow fish stocks to regenerate (Pauly and MacLean 2003).

Adaptation strategies relating to coral reefs will need to focus on the reduction and removal of other external stresses. Climate change may represent the single greatest threat to coral reefs worldwide (West and Salm 2003). The geographic extent, increasing frequency, and regional severity of mass bleaching events are an apparent result of steadily rising marine temperatures, combined with regionally specific El Niño and La Niña events (Reaser et al. 2000), and the frequency and severity of such bleaching events is likely to increase (Hoegh-Guldberg 1999). Although it may be possible that coral reefs will expand their range with the warming of water temperatures, the potential for establishing new reefs polewards will ultimately be limited by the light levels at higher (or lower) latitudes, and will be insufficient to compensate for the loss of reefs elsewhere. Given the inertia in the climate change system, adaptation measures will need to focus on reducing the anthropogenic stresses on coral reefs.

Although all reefs, even those granted well-enforced legal protection as marine protected areas or managed for sustainable use, are threatened by climate change, several recent studies suggest that unstressed and protected reefs are better able to recover from bleaching events (e.g., Reaser et al. 2000). The 2002 Status of Coral Reefs of the World report (Wilkinson 2002), concluded that reefs that are highly protected and are not stressed were better able to recover from bleaching events. Similarly, the Coral Reef Degradation in the Indian Ocean (CORDIO) 2002 Status Report (Linden et al. 2002) noted that while in most areas recovery following bleaching has been slow, patchy or non-existent, significant recovery had occurred in areas that were either far away from human influence or inside well protected marine reserves. These two studies support the use of effective integrated marine and coastal area management, including, as its central component, highly protected marine reserves as an adaptation strategy. Such highly protected areas also serve to spread risk, whereby areas that escape damage can act as sources of larvae to aid recovery of nearby affected areas (Hughes et al. 2003). Practical advice on the management of bleached and severely damaged coral reefs is available (Westmacott et al. 2000).

Aquaculture, including mariculture, can negatively impact biodiversity at the genetic, species and ecosystem level, although such effects can be mitigated through sustainable practices. Development of mariculture and aquaculture has been proposed as a possible adaptation option to potential climate-change induced decline of wild fisheries. However, the claim that aqua- and mariculture would reduce the impact on the remaining coastal systems is disputed (Naylor et al. 1998; 2000). The farming of carnivorous species such as salmon, trout, and sea bream may have a detrimental effect on wild fisheries because the harvest of small fish for conversion to fish meal leaves less in the food web for other commercially valuable predatory fish, such as cod, and for other marine predators, such as seabirds and seals (Pauly et al. 1998). Some improvement to this situation may be provided in the future by development of new feeds where fishmeal can be replaced by other ingredients (Foster 1999). Importantly, in the context of climate change adaptation strategies, large- scale developments of aqua-and mariculture in, e.g. mangrove ecosystems, leading to clear cutting of large areas in coastal zones, may affect the ecosystems' capacity to mitigate floods and storms. Habitat conversion from mangrove swamp to shrimp farms in Malaysia has been estimated to produce a significant loss of wild fish from habitat conversion alone. Other negative biodiversity effects of unsustainable aquaculture include modification, degradation or destruction of habitat, disruption of trophic systems, depletion of natural seedstock, and transmission of diseases and reduction of genetic variability (Naylor et al. 2000). For example, fish-farming for salmon and char has been shown to increase the incidence of salmon lice on wild salmonid populations, which negatively affects the production, survivorship, and behaviour of the wild fish (Bjorn et al. 2001). Further, there are considerable localised eutrophication effects from aquaculture generally on the diversity and community structure of benthic communities (e.g., Pohle et al. 2001, Holmer et al. 2002, Yokoyama 2002). For aquaculture or mariculture to be considered as a viable climate change adaptation option, it needs to be undertaken in a sustainable manner, and in the context of integrated marine and coastal area management.

Coastal, marine and freshwater ecosystems offer adaptation services within the context of predicted sea level and climate changes. The protection and restoration of coastal ecosystems, such as mangrove and salt marsh vegetation, can protect coastlines from the impacts of climate induced sea-level rise, and also have biodiversity benefits (Suman 1994). Maintenance of healthy mangrove cover and restoration of mangroves in areas where they have been logged can be a positive adaptation strategy (Macintosh et al. 2002). There is also a possibility for the range of mangroves to be expanded landwards as a function of changes in sea level and other coastal climate change impacts (Richmond et al. 1998). Coastline adaptation strategies for ecosystems, such as the use of mangrove and salt marsh vegetation can be relatively easy to implement, unless dykes and tidal barriers are already installed. Adaptation measures should provide a holistic approach to the integrated management of entire watersheds, including inland water, coastal and marine areas.

4.11.4.2 Inland water ecosystems

As with terrestrial ecosystems, adaptation strategies to climate change in inland water ecosystems include conservation and spatial linkages. Climate change is expected to impact inland water ecosystems in two major ways. First, through changes in the water cycle. Second, through associated changes in the terrestrial ecosystem within a given catchment. Adaptation options to these changes should consider all components of the watershed (e.g., Sparks 1995). River biota, within reasonable limits, is naturally well adapted to rapid and unpredictable changes in environmental conditions (Puckridge et al. 1998). For rivers, it may be essential to conserve or restore ecosystem connectivity, both longitudinally along the river course and laterally between the river and its wetlands, in order to sustain ecosystem function (Ward et al. 2001). However, many of the natural aquatic corridors are already blocked through dams and embankments. This increases the vulnerability of freshwater biodiversity to climate change and constrains implementing adaptive strategies. In their lower reaches, coastal rivers enter the estuarine and coastal zone where they have a major influence. These areas should be considered a contiguous part of inland water ecosystems and managed together under the ecosystem approach. The identification of the degree of vulnerability of the various components of complex inland water ecosystems, and the subsequent development of appropriate ecosystem management plans based upon this information, is a critical requirement for adaptation to climate change for inland waters.

Any management that favors near natural hydrological function in inland water ecosystems is likely to have major benefits for the conservation of biodiversity. In particular, modern approaches to the management of rivers recognise that for many systems change is inevitable. This has stimulated much interest in the concept of sustaining "environmental flows" as a management target for rivers (Tharme in press). Such approaches need to take on board climate change if they are to be adaptive. The increase in extreme weather events that climate change may bring (for freshwaters - particularly the frequency and extent of droughts and floods) is likely to be more of a concern with isolated lakes and wetlands. The issue of extreme hydrological events is, however, of major significance to integrated water resources planning and management. For example, maintaining river floodplains and wetlands helps restore water balance and hence mitigate catastrophic flooding. Climate change, therefore, can be regarded as providing additional incentives to manage inland waters better and both the financial and conservation benefits of doing so are considerable. Maintaining natural river form and related ecosystem processes is likely to provide significant benefits for coastal regions.

4.11.4.3 Forest ecosystems

Due to their high resilience, adaptation strategies to climate change in forest ecosystems that mitigate the underlying causes of forest destruction and its degradation, are likely to be the most effective. It should be noted, however, that some of these strategies may overlap with those aimed at mitigating climate change through forest management (see section 4.5). For example, a forest plantation designed as an altitudinal wildlife migration corridor (to adapt to climate change) may also sequester carbon and hence be a mitigation activity. Nevertheless, there are some specific considerations relevant to forest ecosystem management as adaptation options that may help to conserve biodiversity in a changing climate (Noss 2001):

(a) **Maintaining representative forest ecosys-**

tem types across environmental gradients in protected areas. Because it is difficult to ascertain which forest types are to be the most sensitive to climate change, maintenance of a full spectrum of types serves as a "bet-hedging" strategy;

(b) **Protecting climatic refugia at all spatial scales,** therefore allowing persisting populations of plants and animals to recolonize the surrounding landscape when conditions favorable for their survival and reproduction return;

(c) **Protecting primary forests.** As the intensity and rate of biotic change is likely to be buffered in forest interiors, maintaining large patches of primary forests may help to maintain biodiversity during climate change. Primary forests also provide storehouses of genetic diversity that may be diminished in second-growth forests, and hence limiting the ability for various species to be able to adapt to climate change (e.g., Rajora et al. 2002);

(d) **Avoiding fragmentation and providing ecological connectivity, especially parallel to climatic gradients.** By increasing habitat isolation, fragmentation is likely to hamper the ability of a species to migrate due to climate change. Ecological connectivity can be achieved through a mixed strategy of corridors and unconnected but nevertheless "stepping-stone" habitats;

(e) **Providing buffer zones for adjustment of reserve boundaries.** With changing climate, buffer zones have the potential to provide for shifting populations as conditions inside reserves become unsuitable;

(f) **Practicing low-intensity forestry and preventing conversion of natural forests to plantations.** Mixed-species plantations, where appropriate, are likely to spread the risk of biotic change at the stand level because different species have distinct levels of response to climate change. They may also facilitate migrating species to be incorporated into the mix. This also applies to forest restoration practices that incorporate mixed species plantings of native trees in degraded areas;

(g) **Maintaining natural fire regimes where possible.** The threat to biodiversity from lack of fire in many forest ecosystem types may outweigh the potential advantages of suppressing fire even though in the short term, fire suppression enhances carbon storage;

(h) **Proactively maintaining diverse gene pools as genetic diversity is the basis for genetic adaptation to climate change.** This is particularly important in the case of mixed-species plantations and reforestation with monocultures when necessary; and

(i) **Identifying and protecting "functional" groups of similar species, and/or ecologically important species.** That is, large herbivores and carnivores, and frugivorous birds, as their presence may be essential for ecosystem adaptability to climate change.

4.11.4.4. Agricultural ecosystems and grasslands

Agricultural systems are vulnerable to climate change, but as a human managed ecosystem, adaptation is possible, given sufficient socio-economic resources and a supportive policy environment.

Conservation of crop and livestock genetic resources, ***in situ*** **and** ***ex situ*****, and their incorporation in long term strategic breeding programmes is important in maintaining future options for unknown needs of agriculture,** including those arising from the impacts of climate change (FAO 1998, Cooper et al. 2001). This includes conventional collection and storage in gene banks as well as dynamic management of populations allowing continued adaptation through evolution to changing conditions. Promotion of on-farm conservation of crop diversity may serve a similar function.

Conservation of other components of agricultural biodiversity, i.e., "the associated biodiversity" that provides natural pest control, pollination, and seed dispersal services and ensures soil health, can be promoted through measures such as integrated pest management and reduced tillage, while minimizing the use of pesticides and herbicides. On the other hand the services provided by such components of agricultural biodiversity can sometimes be replaced, but the alternatives may be costly, and may impact negatively on biodiversity.

211. Native grasslands species have adaptive characteristics that enable them to respond to climatic changes. For a grassland ecosystem to maintain resilience to adverse changes in climate, maintenance of a balanced native species composition may be essential. Prescribed grazing management regimes would be beneficial in order to enhance adaptability of the system to climatic changes. Rehabilitation of degraded pasturelands using native grass species would be important in enhancing species as well as genetic variability and increasing resilience and adaptability of the system.

4.11.4.5. Mountain Ecosystems and Arctic ecosystems

Mountain and arctic ecosystems and associated biodiversity could be under particular stress and threat of degradation due to their high sensitivity and vulnerable characteristics to climate change. But few adaptation options are available.

Arctic ecosystems are likely to be severely affected by climate warming and changes in precipitation regimes through increased UV-B radiation, deterioration of permafrost, melting of glaciers and icecaps, and reduced freshwater flows into Arctic oceans. The precise effects of climate change on arctic ecosystems while highly uncertain, will be negative to present biodiversity, and so the only adaptation strategies available are to carefully monitor changes to try to predict future conditions, make use of traditional knowledge to formulate hypotheses for testing, and to identify knowledge gaps that research can address.

Adaptation activities that best address how mountain ecosystem management leads to adaptation benefits may be those that link upland-lowland management strategies. These include mountain watershed management, and establishment of corridors that allow for species migration as well as adaptation to climatic stress. When adaptation measures are considered, programs and projects using integrated management of mountain ecosystems should identify ecosystems and human societies at risk from adverse change, and those likely to be vulnerable to climate change in the future.

4.12. RESEARCH NEEDS AND INFORMATION GAPS

The main message of this chapter is that, depending on the management options applied, the temporal and spatial scales considered, and the type of ecosystem, activities aimed at mitigating or adapting to climate change can have positive, neutral, or negative impacts on biodiversity; and that the conservation and use of biodiversity, and the maintenance of ecosystem structure and function, are in turn, related to the many options aimed at coping with global climate change through mitigation and adaptation strategies. Still, several research needs and information gaps exist:

(a) There is a need for stand level modeling (as opposed to tree-based models) to understand the true potential of forests (i.e., at broad scales) to sequester carbon over time.

(b) The relationships between elevated levels of CO_2 and plant growth, and forest functioning are presently not entirely clear; more knowledge is needed to calibrate models to predict changes both in forest structure and biodiversity.

(c) Climate change may affect rates of plant herbivory in future forest stands and this will have consequences for stand growth and survival; however, little predictive modeling has been done on this topic.

(d) Gathering of data for modelling relationships between climate change, ecosystem function, and biodiversity is needed; also, for modelling relative response of individual species to climate change and predicting community structures under climate change scenarios.

(e) The ability of migrating species to use tree plantations as corridors, and the relative 'hostility' of planted forests of various types to migrating animals, needs further assessment.

(f) The effects of energy activities (wind, water, solar, biomass energy) on biodiversity need to be better understood.

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5. APPROACHES FOR SUPPORTING PLANNING, DECISION MAKING AND PUBLIC DISCUSSIONS

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INTRODUCTION

Different types of mitigation activities (from national level policy changes to individual projects) undertaken by Parties to the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol with the goal of reducing net carbon emissions could have highly variable beneficial or adverse social and/or environmental-ecological consequences (see chapter 4). Similarly, adaptation activities undertaken by Parties to the UNFCCC and the Kyoto Protocol to adjust to climate change may have highly variable consequences as could activities to conserve and sustainably manage ecosystems undertaken by Parties to the Convention on Biological Diversity (CBD) and the United Nations Convention to Combat Desertification (UNCCD) and other biodiversity related conventions and agreements (e.g., Convention on Migratory Species, Convention on Wetlands, and World Heritage Convention). Activities may support or violate principles of equity, cultural needs or ecological sustainability, depending upon the political, social, institutional, technological and environmental settings within which the activity takes place. Therefore, tools that can be used to assess the environmental and social implications of different policy options and projects, and to choose among them, are discussed in the chapter.

There is a clear opportunity to implement mutually beneficial activities (policies and projects) that take advantage of the synergies between the UNFCCC and its Kyoto Protocol, the CBD and broader national development objectives. A critical requirement of sustainable development is the capacity to design policy measures that exploit potential synergies between national and sub-national economic development objectives and environmentally focused projects and policies. Therefore, the capacity of countries to implement climate change adaptation and mitigation activities will be enhanced when there is coherence between economic, social and environmental policies. The linkages among climate change, biodiversity and land degradation, and their implication for meeting human needs, offer opportunities to capture synergies in developing policy options, although trade-offs may exist. In order to do so the successful implementation of climate change mitigation and adaptation options would need to overcome technical, economic, political, cultural, social, behavioural and/or institutional barriers.

Decisions are value laden and combine political and technocratic elements. Ideally, they should combine problem identification and analysis, policy option identification, policy choice, policy implementation, and monitoring and evaluation in an iterative fashion. Transparency and participation by all relevant stakeholders are highly desirable properties of decision-making processes. Experience shows that transparent and participatory decision-making processes involving all relevant stakeholders, integrated into project or policy design right from the beginning, can enhance the probability of long-term success. The success and value of international environmental agreements depend critically on their successful implementation at the national and sub-national level, which depends on related institutional arrangements (section 5.1).

A range of tools and processes are available to assess the economic, environmental and social implications of different climate change mitigation and adaptation activities (projects and policies) within the broader context of sustainable development. These include, but are not limited to, environmental impact assessments (EIAs), strategic environmental assessments (SEAs), decision analytical frameworks, valuation techniques, and criteria and indicators. Decision analytical frameworks, valuation techniques, and criteria and indicators are tools that can be applied within the environmental impact and strategic environmental assessment processes.

Environmental impact assessments and strategic environmental assessments as processes that can be used to gauge the environmental and socioeconomic implications of different activities are discussed in section 5.2. Environmental impact assessments (EIAs) provide a process for assessing the possible environmental and social impacts at the project level, whereas strategic environmental assessments (SEAs) can be used as policy planning tools at a range of spatial scales up to the national scale and provide an analytical framework to assess the impacts of multiple projects and broad cross-cutting policies. Section 5.3 briefly addresses the implications of the lack of a set of minimum common international environmental and social standards for climate change mitigation and adaptation projects. A range of decision-analytical frameworks presented in section 5.4 are available to assist in selecting amongst the climate change mitigation and adaptation projects or policies as well as those for the conservation and sustainable use of biodiversity, from cost-benefit and cost-effectiveness analysis to cultural prescriptive rules.

Current decision-making processes often ignore or underestimate the value of ecological services. Therefore changes in current valuation practice may be required to better account for the intrinsic and utilitarian values of ecological services as discussed in section 5.5. Use and non-use, and market and non-market values are important to evaluate and take into account in the decision-making process. Decisions about the use of ecosystems often restrict or preclude alternative uses of these systems, therefore there are tradeoffs among different activities within an ecosystem that are important to be valued in terms of net social benefits.

National, regional and possibly international systems of criteria and indicators are needed for monitoring and qualitatively and quantitatively evaluating the impact of climate change, as well as to assess the impact climate change mitigation and adaptation activities, on biodiversity and other aspects of sustainable development (section 5.6). Indicators are needed at each stage in the decision-making process, recognizing that different spatial and temporal scales may require different indicators. Systems need to be developed to track project and policy performance. Section 5.6 concludes with a table that describes the possible elements of positive and negative effects from Land Use, Land Use Change and Forestry (LULUCF) projects on biodiversity. Finally, section 5.7 summarizes the key research needs and information gaps.

5.1 INSTITUTIONAL ARRANGEMENTS

The formation of institutional arrangements is constrained by several factors including socio-economic and environmental components. Institutions can be defined to be sets of rules, decision-making procedures, and programmes that define social practices, assign roles to the participants in these practices, and guide interactions among the occupants of individual roles.

The performance of institutions, which is crucial for achieving the targets they were set up to obtain, depends on several issues and the factors affecting the performance vary from case to case. The purpose of environmental institutions is usually to secure sustainable development in its different dimensions, but also other criteria can be formulated for assessing the performance of the institutions. Such criteria will often include the aspects of efficiency and equity.

Institutions play more or less significant roles with regard to most environmental changes involving human action. Yet institutions seldom account for all of the variance in these situations. In a typical case they are one among a number of driving forces, whose operation, both individually and in combination, generates relevant environmental changes. A prominent feature of research on the institutional dimensions of environmental change, therefore, is the effort to separate the signals associated with institutional drivers from those associated with other drivers and to understand how different driving forces interact with one another to account for observed outcomes.

International environmental agreements such as the CBD and the Kyoto Protocol form particular types of institutions. At the national level these institutions interact with other regimes including rules that govern international trade or investments and other social practices operating at the level of a social system. The interactions at the national level shape these institutions and affect their performance and efficiency.

The performance and efficiency of biodiversity and climate policy related institutions depend to a great extent on the design of the institutions as well as the capacities and resources available. Capacity building, especially in developing countries, forms, and is to be regarded as, an integral part of the CBD and the Kyoto Protocol. Consequently, to be effective, capacity building should be based on firm information on the performance and efficiency of differently relevant institutional designs, global, national as well as local.

The formation of national level institutions as a function of several factors will be of great importance. These factors consist of interaction of (1) international environmental regimes, (2) international economic regimes (such as trade and investment) and the globalisation of economies, (3) socio-cultural systems and (4) the governance structures, practices and histories of the countries. 229. An institutional arrangement that performs well dealing with one problem in a certain context may be a failure in solving other problems. The problem of fit in heterogeneous environmental, socio-economic and cultural systems calls for specific context related solutions requiring multilocal approaches. Causes for the problem of fit, that is, a mismatch between the problems and the institutional attributes, can be distinguished in three groups: state of knowledge, institutional constraints and rent-seeking behavior (Young 2002).

Most institutions interact with other similar arrangements both horizontally and vertically. Horizontal interactions occur at the same level of social organisations; vertical interplay is a result of cross-scale interactions or links involving institutions located at different levels of social organisation. Interplay between or among institutions may take the form of functional interdependencies or arise as a consequence of politics of institutional design and management (Young 2002).

5.2 IMPACT ASSESSMENTS

Environmental impact assessments (EIAs) and strategic environmental assessments (SEAs) can be used to assess the environmental and socio-economic implications of different energy and Land Use, Land use Change and Forestry (LULUCF) projects and policies. EIAs are applied at the project level, whereas SEAs are generally applied at the strategic policy level. The concept of EIAs has evolved from originally only encompassing abiotic environmental effects (e.g., local air pollution) to now encompassing biodiversity concerns and social aspects (e.g., impact on people's livelihoods), all of which are fundamental for a complete assessment process. However EIAs in practice often fail to adequately include the biodiversity and social aspects. The basic EIA and SEA methodologies can be modified to address specific issues identified under the UNFCCC regarding LULUCF projects, such as leakage and permanence[28].

5.2.1 Environmental Impact Assessments (EIA)

EIA is a planning process or a tool for assessing the environmental and socio-economic impacts of projects, including the possible impacts of climate change mitigation and adaptation activities on biodiversity. This section is not intended to be an exhaustive analysis of any specific assessment EIA method (see Box 5.1), but aims to present an overview of the EIA, and how EIAs could be used to integrate biodiversity and social considerations into project planning, risk minimization and benefit enhancement for climate change-related projects. There are numerous impact assessment

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[28] For a description of these terms see Box no. 4.2

methodologies and tools to be drawn from, all of which have a number of common steps.

Environmental impact assessments and strategic environmental assessments can be integrated into the design of climate change mitigation and adaptation projects and policies to assist planners, decision-makers and all stakeholders to identify and mitigate potentially harmful environmental and social impacts and enhance the likelihood of positive benefits such as carbon storage, biodiversity conservation and improved livelihoods. While the CBD explicitly encourages the use of EIA (Article 14), there is no respective reference to them in the UNFCCC or its Kyoto Protocol. The operational rules for the Kyoto Protocol included in the Marrakesh Accords only stipulate that the clean

Box 5.1. What is an EIA and what are the common steps

What is an EIA? An EIA is defined as a technique and a participatory process through which information about the environmental and social effects of a project can be collected, assessed and taken into account by the developer, governments, NGOs, community groups, etc., when designing a project. Public involvement is an important part of the EIA process. An EIA is thus a systematic and iterative process that examines the consequences of activities in advance of implementation, and takes steps to avoid potential negative outcomes, and promote more beneficial outcomes through such responses as impact minimisation or design modification. The EIA process has the potential to serve as the basis for negotiating trade-offs between the developer, public interest groups and decision makers. EIAs are often seen as an unnecessary, costly and time-consuming process to slow program or project finalization, however if structured correctly, they can be an invaluable tool to mitigate potential unforeseen costs and impacts. The main steps in an EIA are outlined below and presented in Figure 5.1.

1. Developing the project concept. The first step in defining the project and its objectives, as well as identifying alternatives

2. Screening. Identifying potentially significant impacts of project location and design on biodiversity and communities. Questions include: Is biodiversity likely to be significantly affected by the proposed project? Will local livelihoods be impacted adversely or will they benefit? What, in broad terms, will the impacts be? Does the project have the potential to enhance biodiversity and/or local livelihoods? This step separates those projects not likely to have significant environmental or social impacts from those that might.

3. Scoping. This step focuses on those project impacts, both positive and negative, that are likely to be significant. This step determines whether or not a project calls for an assessment, and the level of assessment and detail that may be necessary. Questions include: What are the main issues? What is required to set the baseline and how should the relevant information be collected? What socio-economic and environmental elements are of interest, and to which stakeholder(s)?

4. Information gathering. Establishes the baseline for environmental and social aspects under consideration at present and in the future under project and non-project scenarios. This step also includes the presentation and consideration of alternatives.

5. Prediction of impacts. This step attempts to identify and quantify the magnitude of potential impacts – e.g., positive and negative, long and short-term, on each stakeholder group; and put these into perspective as to their relative significance.

6. Mitigation measures and management plan. Provides options for eliminating, reducing to acceptable levels or mitigating adverse impacts on biodiversity and local communities, to enable project redesign, compensation, relocation and other alternatives.

7. Monitoring. Monitoring and supervision of the project is critical to ensure that the project is carried out according to the management plan.

development mechanism (CDM) and in some cases joint implementation (JI) project participants (see section 4.2 for definition) have to carry out an EIA in accordance with the requirements of the host Party if after a preliminary analysis they or host countries consider the environmental impacts of the project activities significant. Article 14 of the CBD requests EIAs for projects in order to avoid or minimize adverse effects on biological diversity and to allow public participation in such procedures. Decision VI/7 of the Conference of the Parties (COP) to the CBD includes an annex on "Guidelines for incorporating biodiversity-related issues into environmental impact assessment legislation and/or process and in strategic environmental assessment". These guidelines have also been adopted by the Convention on Wetlands. Some governments believe that use of the CBD EIA or SEA process to assess climate change mitigation and adaptation projects and policies would add further layers of assessment and compliance costs to UNFCCC and Kyoto Protocol projects, resulting in that many beneficial projects may not occur. The UNFCCC is in the process of developing definitions and modalities for CDM LULUCF projects to take into account socio-economic and environmental impacts, including impacts on biodiversity and natural ecosystems[29].

Most international and multilateral development agencies use EIAs to ensure their projects are environmentally and socially sustainable. International development agencies such as the UK Department for International Development (DFID) and the US Agency for International Development (USAID), multilateral development agencies such as the World Bank, Organization for Economic Cooperation and Development (OECD), Global

Box 5.2. The World Bank's "Safeguard Policies"

The World Bank uses environmental assessments, in conjunction with ten environmental, social, and legal Safeguard Policies, to identify, avoid, and mitigate the potential negative environmental and social impacts associated with lending operations. This improves decision making, ensuring that project options under consideration are sound and sustainable, and that potentially affected people have been properly consulted.

The World Bank’s environmental assessment policy and recommended processing are described in Operational Policy (OP)/Bank Procedure (BP) 4.01: Environmental Assessment. This policy is considered to be the umbrella policy for the Bank's environmental "safeguard policies" which among others include: Natural Habitats (OD 4.04), Forestry (OP 4.36), Pest Management (OP 4.09), Cultural Property (OPN 11.03), and Safety of Dams (OP 4.37). The ten safeguard policies are:

1. Assess potential environmental impacts of projects early in the project cycle;
2. Prohibit financing projects involving the degradation of natural habitats-unless there is no feasible alternative;
3. Financing of forest projects only if the assessment shows that sustainability requirements are fulfilled;
4. Support environmentally sound pest management;
5. Restore and improve income-earning capacity of involuntarily resettled people.
6. Avoid and mitigate adverse impacts on indigenous people;
7. Preserve cultural property and avoid their elimination;
8. Apply environmental assessments and detailed plans for safe construction and operation of dams;Require notifications and agreement between states/parties in international waterways; and
10. Identify problems in disputed areasing to the management plan.

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[29] FCCC/SBSTA/2003/5

Environment Facility (GEF), and United Nations Environment Program (UNEP) have environmental and social assessment or impact processes, as do many national governments. Most countries that are Parties to the CBD and UNFCCC have agreed to certain EIA protocols through membership in The World Bank Group and in receiving funding from bilateral donors. Both donor and recipient nations agree to The World Bank's policies, including environmental safeguards for project design and implementation, including the use of EIAs. The adoption of these EIA processes provides tools that could be applied to each country interested in hosting a climate-related project or program, thus assuring equity and consistency for projects worldwide.

5.2.1.1. Experience with EIAs and their application to climate change mitigation and adaptation projects

Years of development and experience show that transparent and participatory assessment approaches, integrated into project or program design right from the beginning, can enhance the probability of long-term environment and development success. EIAs should not be considered policy prescriptive in the context of designing adaptation or energy and carbon sequestration projects under the UNFCCC. EIAs remain the basic planning, information sharing and community empowering tools for sustainable development projects, but where there is a lack of a sound legal framework to broadly define the issues to be addressed within an EIA and procedures to conduct them, their effectiveness is greatly reduced (Mercier and Bekhechi 2002). Given that EIAs operate at the project level, they are inadequate to consider the cumulative effects of multiple projects. This limitation could be addressed through use of additional tools such as SEAs and by adopting the ecosystem approach (see section 4.3). Another critical lesson from past experience is that the social impacts need to be given full and equal review with environmental considerations (see case studies in chapter 6).

To maximize the value of an EIA process, it is critical that EIAs are applied systematically in the context of climate change mitigation and adaptation projects, to ensure that they go beyond the narrow scope of carbon dioxide emissions reductions or carbon sequestration. To date EIAs have not been systematically applied under the Kyoto Protocol framework for various reasons. These include: mitigation and adaptation project planning is relatively new and evolving (except for GEF projects); decisions were made only in November 2002 clarifying the types of LULUCF projects to be allowed for mitigation under the UNFCCC for its' first commitment period (2008-2012); some mitigation projects are seen only in terms of carbon dioxide emissions reductions or carbon sequestration, and not in broad terms of the overall environmental and social goods and services that such projects could provide, and EIAs are not currently required in some countries.

There is a wide array of environmental and social impact assessment methodologies, which can be modified for energy and LULUCF climate change mitigation and adaptation projects. An EIA adds critical qualitative, as well as additional quantitative (e.g., baseline assessments) information to the overall design and implementation process of projects, helping to identify and mitigate risks, and increasing the likelihood that the carbon asset, as well as biodiversity and social co-benefits, are maintained and/or enhanced. An EIA can be "modified" to take account of issues that are considered to potentially cause non-permanence and leakage in LULUCF projects and to adequately address biodiversity concerns. For example, issues related to permanence could include fires, pest outbreaks and diseases, and a management action plan could include risk minimization actions specifically addressing site and species choice, fire management, and promoting species diversification. Leakage can be more comprehensively addressed by doing an SEA and large-scale land-use planning that adopts an ecosystem approach to ensure that the potential causes of leakage are understood, and a management action plan developed where, inter-alia, alternative livelihood programs are offered and benefit sharing from the carbon incomes are considered. Given that EIAs often inadequately address biodiversity concerns, they could be modified, by applying the guidelines in the Annex to COP Decision VI/7 to the CBD, so the concept of biological diversity, as defined by the CBD, is incorporated into the term "environment" outlined in national legislation and procedures. The experience with, and development of EIA and SEA systems, could be useful if embodied into the development of afforestation and reforestation projects under the CDM.

5.2.2 Strategic Environmental Assessments (SEAs)

Strategic environmental assessments (SEAs) can be used to inform broad cross-cutting policy at the national level, as well as to assess the potential impacts of climate change mitigation and adaptation policies, or multiple projects in a region or sector, on the conservation and sustainable use of biodiversity. There are several types of SEA stemming from the many ideas over its role and purpose. The definition of a SEA used here is a systematic, decision aiding procedure for evaluating the likely significant environmental and social effects throughout the policy planning process or when considering multiple projects (Brown and Therivel 2000, Sadler and Verheem 1996). They therefore enable the integration of environmental considerations into national strategic decision-making (DEAT 2000, ICON et al. 2001, Partidario 1996;1999). They also seek to inform the decision-maker of the degree of uncertainty over impacts, as well as the level of consistency in objectives and the sensitivity of the baseline (i.e., state of the environment). It is important that SEAs be initiated at the earliest stages of policy planning and, as with EIAs, with the involvement of the public throughout the process. Indeed, SEAs provide a forum in which a wider group of people can be involved in decision-making (Sadler 1995).

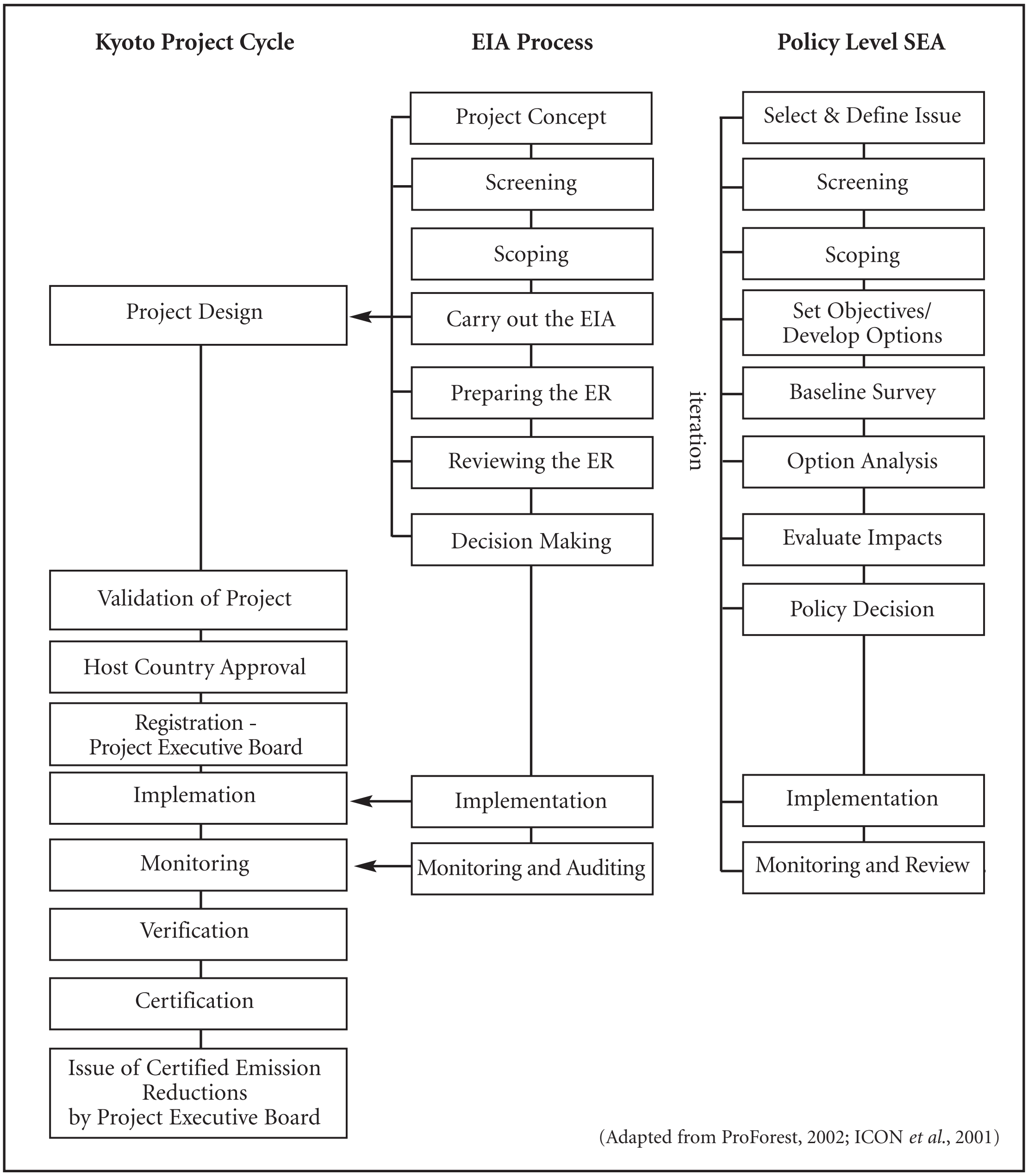
5.2.2.1 Key elements of a SEA process

The key elements of a SEA process in comparison with an EIA process and the Kyoto CDM "project cycle" are shown in Figure 5.1. It illustrates how different elements can be linked together to form a more systematic SEA process. One of the major success factors of SEA is its ability to enable decision makers to consider the subject of integration (be it environment, climate change or biodiversity related issues) at key stages in the policy making cycle (ICON et al. 2001). Furthermore, it will also facilitate SEA best practice elements such as public participation, through the involvement of, for example, a sustainable development round table, as well as quality control, through an audit committee.

5.3 ENVIRONMENTAL AND SOCIAL STANDARDS

Without a set of minimum common international environmental and social standards, climate change mitigation projects could flow to countries with minimal or non-existent standards, adversely affecting biodiversity and human societies. The current broad range of guidelines and procedures on design and implementation of projects among governments, international agencies, the private sector, non-governmental sector and project implementers could result in the potential for local environmental and social standards being met, but not those of international and multi-national development agencies or those consistent with the goals of multilateral environmental agreements, e.g., the CBD. The World Bank's environmental safeguards or other similar existing standards could be used as a starting point for exploring a minimum set of international standards for climate change mitigation and adaptation projects. If agreed internationally, such standards could be incorporated into national planning efforts. However, the Marrakesh Accords affirm that it is the host Party's prerogative to confirm whether a CDM project activity assists it in achieving sustainable development.

Figure 5.1: Flow diagram illustrating the Kyoto CDM "project cycle", EIA and SEA processes



(Adapted from ProForest, 2002; ICON *et al.*, 2001)

5.4 DECISION PROCESSES AND DECISION ANALYTICAL FRAMEWORKS AND TOOLS

Decision-making processes and institutions operate at a range of spatial scales from the local to the global level. A number of mechanisms can improve the process of making decisions about climate change mitigation and adaptation, and biodiversity conservation projects, and their environmental and social implications (Toth 2000). It is desirable that decision making processes at the local, national or global scales incorporate the following characteristics (Hemmati 2001, Petkova et al. 2002, and Dietz 2003): (i) use the best available information; (ii) be transparent involving all those with an interest in a decision (Fiorino 1990, Dietz 1994, Renn et al. 1995, Slocum et al. 1995, Stern et al. 2001, Chess et al. 1998, Chess and Purcell 1999, Webler 1999, US NRC 1999, USEPA SAB 2000, Beierle and Cayford 2002), recognizing the strengths and limitations of different stakeholder groups to process and use information (Kahneman et al. 1982, Cosmides and Tooby 1996, and Wilson 2002); and (iii) pay special attention to equity (Agrawal 2002, McCay 2002) and to the most vulnerable populations. Experience also suggests that policies and projects should be developed to incorporate lessons learnt from past experience (Gunderson et al. 1995, Yohe and Toth 2000), hedge against risk, consider uncertainties, maximize efficiency, consider all relevant spatial and temporal scales, and allow for adaptive management and thus allow mid-course corrections. In addition, effective decision-making can develop only if the people making decisions are accountable for them (Perrow 1984).

Decision-analytic frameworks are tools that can be used to evaluate the economic, social and environmental impacts of climate change mitigation and adaptation activities and those of biodiversity conservation activities. These include, but are not limited to, decision analysis, cost-benefit analysis, cost-effectiveness analysis, the policy exercise approach, to cultural prescriptive rules. Different decision making principles (objectives) can be used individually or in combinations as decision-analytic frameworks (DAFs) can be adopted to address specific problems. Each DAF can accommodate some decision objectives, e.g., optimizing cost-effectiveness or equity, better than others, but complete incompatibility is rare (Millenium Ecosystem Assessment 2003). For example, decision analysis, cost-benefit analysis and cost-effectiveness analysis are all well suited for economic optimization efficiency, noting however, that the issue of discounting and risk attitudes is important when taking a long-term perspective. They can be applied at all spatial scales from the farm or firm level, to local community, to national, and to global. However, issues associated with the precautionary principle and equity is not central within their frameworks. On the other hand, ethical and cultural prescriptive rules are weak with respect to economic optimization efficiency, but explicitly incorporate ethical considerations and are also applicable over a wide range of spatial scales.

Use of decision-analytic frameworks prior to implementing a project or a policy, can help address a series of questions that should be part of the project or policy design. E.g., (i) is this a cost-effective mitigation strategy (i.e., cost per ton of carbon), or is this a cost-effective adaptation or conservation strategy?; (ii) to what extent does the activity enhance or impair the ability of ecosystems to provide goods and services in the future (i.e., is it sustainable)? and; (iii) does the activity benefit or adversely affect one group or individual disproportionately (i.e., is it equitable)?

Decision-analytic frameworks can be divided into four broad categories, i.e.

(a) Those that deal directly with valuation and commensuration - **normative** (e.g., decision analysis, which is the product of utility theory, probability and mathematical optimization; cost-benefit analysis, which involves valuing all costs and benefits of a proposed project or policy over time; cost-effectiveness, which takes a predetermined objective and seeks approaches to minimize the cost of meeting that objective; and portfolio theory, which is concerned with creating an optimal composition of assets under a budget constraint);

(b) Those that are **descriptive** (e.g., game theory, which investigates interactions between stakeholders and predicts outcomes by simultaneously accounting for their objectives, utilities, costs and benefits; behavioral decision theory which combines economics and psychology to describe human decision making);

(c) Those that deal with the discovery of information from people - **deliberative** (e.g., policy exercise approach, which involves a flexibly structured process designed as an interface between experts/analysts and policymakers); and

(d) Those in traditional and transitional societies typified as **ethically and culturally based** (e.g., cultural theory is concerned with forms of social organizations that are largely ignored by economists and political scientists and emphasizes the importance in DAFs of social organizations that are usually excluded by conventional and social science dichotomies).

The diverse characteristics of the possible climate change mitigation and adaptation activities and biodiversity conservation activities imply the need for a diverse set of decision analytical frameworks so that the ones most relevant to the choices at hand can be selected and applied. Different DAFs overlap in practice, and one method of analysis usually requires input from the others. None of the frameworks can incorporate the full complexity of decision-making, hence their results comprise only part of the information shaping the outcome, i.e., each DAF has its own merits and shortcoming due to its ability to address some of the critical issues better, while other facets less adequately. There are certain features (e.g., sequential decision-making and hedging), specific methodologies (e.g., multi-criteria analysis), distinctive applications (e.g., risk assessment) or basic components (multi-attribute utility theory) of decision analysis that are all rooted in the same theoretical framework. Decision analysis, which may prove particularly attractive for sectoral and regional adaptation assessments, can be performed with single or multiple criteria, with multi-attribute utility theory providing the conceptual underpinnings for the latter. Decision analysis, adapted to managing technological, social or environmental hazards constitutes part of risk assessment.

Decision analysis uses quantitative techniques to identify the "best" choice or combination of choices from among a range of alternatives. Model-based decision analysis tools are often used as part of interactive techniques in which stakeholders structure problems and encode subjective preferences explicitly into the models, thus making the major trade-offs explicit. Although decision analysis can generate an explicit value as a basis for choice, they are based on a range of relevant monetary and non-monetary criteria. They are used to explore the decision and to generate improved options that are well balanced in the major objectives and are robust with respect to different futures. A review of the limitations of quantitative decision models when they have been applied to actual problems and the consistency of their theoretical assumptions with decision-making, highlighted the following points:

(a) There is no single decision maker in either climate change mitigation/adaptation activities, or in the conservation and sustainable use of biodiversity. As a result of differences in values and objectives between the different stakeholders (or decision makers), it means that the stakeholders that participate in a collective decision-making process do not apply the same criteria to the choice of alternatives. Consequently, decision analysis cannot yield a universally preferred solution.

(b) Decision analysis requires a consistent utility valuation of decision outcomes. In climate change mitigation activities and adaptation projects and the conservation and sustainable use of biodiversity, many decision outcomes are difficult to value.

(c) Decision analysis may help keep the information content of the climate change mitigation activities and adaptation projects and the conservation and sustainable use of biodiversity problems within the cognitive limits of decision makers. Without the structure of decision analysis, climate change and biodiversity information becomes cognitively unmanageable, which limits the ability of decision makers to analyse the outcomes of alternative actions rationally. Quantitative comparisons among decision options (and their attributes) are implied by choices between options (the concept of "revealed preference" in economics). Better decisions are made when these quantitative comparisons are explicit rather than implicit.

(d) The treatment of uncertainty in decision analysis is quite powerful, but the probabilities of uncertain decision outcomes must be quantifiable. In climate change mitigation activities and adaptation projects and the conservation and sustainable use of biodiversity, objective probabilities have not been established for many of the outcomes. In real-world applications subjective probabilities are used.

Uncertainties, coupled with different stakeholder preferences, may mean there may be no "globally" optimal climate mitigation/adaptation--biodiversity strategy; nevertheless, the factors that affect the optimal strategies for single decision makers still have relevance to individual stakeholders.

5.5 VALUE AND VALUATION TECHNIQUES

Ecological systems have both intrinsic and utilitarian value[30]. Ecosystems have utilitarian value by providing services of direct value to humans, e.g., the provisioning of food, regulating climate and maintaining soils. In addition, ecosystems have intrinsic (non-utilitarian) value arising from a variety of ethical, cultural, religious and philosophical perspectives, which cannot be measured in monetary terms. The valuation of ecological goods and services provides information to help guide social choice and policy formulation for informed management decisions that take account of economic, environmental and social considerations. Numerous studies have assessed the contribution of ecosystems to social and economic well being (Hartwick 1994, Asheim 1997, Costanza et al. 1997, Pimentel and Wilson 1997, Hamilton and Clemens 1998, World Bank 1997). While the contribution of ecological goods and services to human well being are well understood, many of these services are not normally traded in the market (e.g., pollination, climate control and water purification), i.e., they are public goods. Hence their value is not adequately captured in market prices nor reflected in national accounting. The depletion or appreciation of natural capital is typically ignored in assessing total national wealth, even though it is a significant share in many countries, especially in developing countries. Policy formulation and choice of projects undertaken by Parties to the UNFCCC (mitigation and adaptation), CBD, and UNCCD are likely to be less than optimal unless the current and future economic, environmental and social impacts of changes in ecological services are taken into account. Valuation is a tool that can be used to enhance the ability of the decision-maker to evaluate trade-offs between alternate projects and policies. When a decision-maker assesses the utilitarian value of making a decision regarding the possible conversion of an ecosystem, it is important that they also recognize the intrinsic value of the ecosystem.

The concept of total economic value is a useful framework for assessing the utilitarian value of both the use and non-use values of ecosystem services now and in the future. The use values arise from direct use, indirect use or option values, where-as the non-use values include existence values (Pearce and Warford 1993) – see Figure 5.2. Direct use values arise from the provisioning of goods produced or provided by ecosystems that are consumed. For example food, fibre, fresh water, and genetic resources; and from cultural services, which are non-material benefits obtained from ecosystems, such as recreational, aesthetic, spiritual and education, and that are non-consumptive. Indirect use values arise from supporting services whereby the benefits are

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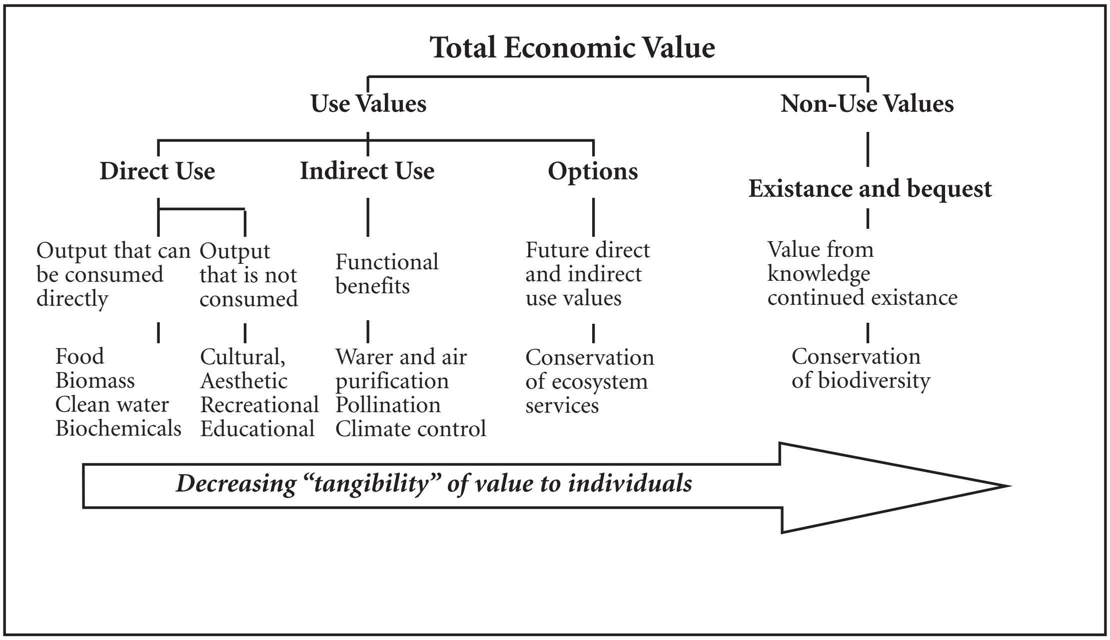
[30] The concepts of utilitarian and intrinsic values used in this paper are consistent with those recently published in the Conceptual Framework paper of the Millennium Ecosystem Assessment (MA). However, some experts would use different formulations for intrinsic value arguing that intrinsic value is a philosophical concept based on naturalism and is non-anthropocentric, where-as the ethical, cultural and religious perspectives incorporated within the MA intrinsic value framework are part of an anthropocentric framework (utilitarian non-use), and the value of these can be captured in an economic sense using techniques such as "willingness to pay".

Figure 5.2: Categories of economic values attributed to environmental assets



obtained from regulation of ecosystem processes, such as water purification, waste assimilation, storm protection, climate control and pollination. Option value is related to the value of preserving the option to use ecosystem services in the future by either this or future generations. Non-use values are also known as existence values (or sometimes conservation values). Humans ascribe value to knowing that a resource exists, even if they never use that resource directly – this is an area of partial overlap with the non-utilitarian (or intrinsic) sources of value.

Many methods are available for measuring the utilitarian values of ecosystem services, which are founded on the theoretical axioms and principles of welfare economics. Under the utilitarian approach, numerous methodologies have been developed to attempt to quantify the benefits of different ecosystem services (Hufschmidt et al. 1983, Braden and Kolstad 1991, Hanemann 1992, Freeman 1993, Dixon et al. 1994). Welfare change can be reflected in people's willingness to pay (WTP) or willingness to accept compensation (WTA) for changes in their use of ecosystem services (Hanemann 1991, Shogren and Hayes 1997). Measures of economic value can be either based on observed behaviour and decision-making of individuals, or hypothetical behaviour and decision-making of economic value. For example, direct observed behaviour methods are typically based on market prices, e.g., of food and fibre, which reflect the observed decision-making behaviour of producers and consumers in functioning markets. Indirect observed behaviour methods are used where a market does not exist for a particular ecosystem service, but observations of the actual market behaviour in an appropriate surrogate market. Methods to elicit economic value, that are based on hypothetical behaviour, use responses to questionnaires which describe hypothetical markets or situations to assess WTP or WTA. Such methods include contingent valuation, contingent ranking or choice experiment tests, where consumer behaviour is investigated under controlled market simulation contexts. Importantly, only such methods can capture non-use values like existence or bequest values. Other methods include the Avoidance Cost Method, where the ecosystem value is calculated as the cost of restoring the environment to a predefined level; the Opportunity Cost Method, where the value is simply derived from the lost monetary benefits (e.g., lost timber value as a result of forest conservation).

In the policy context these valuation techniques can be useful to estimate the change in some of the values of the ecosystem services resulting from climate change mitigation and adaptation, as well as biodiversity conservation and sustainable use, projects and policies. This requires understanding how ecosystem services change in response to a project or policy and then estimating the corresponding change in use and non-use values for all services provided by the ecosystem. These techniques can also be used to assess distributional issues, i.e., how the value of ecosystems changes under different management regimes for the society as a whole or for sub-sets of society. In addition, the analysis can be used to estimate the impact on current and future flows of ecosystem services; that is, to assess the intergenerational aspects of a policy option.

5.6 CRITERIA AND INDICATORS FOR PROJECT DESIGN, BASELINE DESCRIPTION, MONITORING AND EVALUATION

In the context of the UNFCCC, its Kyoto Protocol, and the CBD, there are two primary reasons for establishing a monitoring and evaluation process in regard to biodiversity, the sustainable use of natural resources and other aspects of sustainable development:

(a) To quantify the impact of climate change on inter-alia, biodiversity and other environmental and social aspects of sustainable development, including employment, human health, poverty and equity; and
(b) To assess the impact of energy and LULUCF mitigation and adaptation projects and policies undertaken by Parties to the UNFCCC on greenhouse gas emissions on the basis of the revised Good Practice Guidance of the Intergovernmental Panel on Climate Change (1996), and the Good Practice Guidance for LULUCF (in preparation), and other aspects of sustainable development.

Whether climate change mitigation and adaptation projects and policies have beneficial or adverse consequences for biodiversity and other environmental and social aspects of sustainable development depends upon:

(a) The choice of project or policy;
(b) The management options related to the project or policy intervention;
(c) The biological and physical conditions of the area influenced by the project or policy; and
(d) The socio-economic conditions of the region influenced by the project or policy

The Intergovernmental Panel on Climate Change identified six principles/criteria to strengthen the sustainability of Land Use Land Use Change and Forestry projects:

1) Consistency of project activities with international principles and criteria of sustainable development;
2) Consistency of project activities with nationally defined sustainable development and/or national development goals, objectives, and policies;
3) Availability of sufficient institutional and technical capacity to develop and implement project guidelines and safeguards;
4) Extent and effectiveness of local community participation in project development and implementation;
5) Transfer and local adaptation of technology; and
6) Application of sound environmental and social assessment methodologies to assess sustainable development implications;

The most important aspect of monitoring and evaluation is the choice of suitable and meaningful criteria and indicators. For the purposes of this report, a criterion is a state of an ecosystem or interacting social system and should be formulated to allow an evaluation of the degree to which a project or policy intervention meets its objectives. Indicators are needed at each stage in the decision-making process, recognizing that different spatial and temporal scales may require different indicators. Two kinds of indicators are normally used for monitoring and evaluation: implementation performance indicators (project inputs and outputs) and project impact indicators. Project impact indicators can be quantitative or qualitative variables, which can be measured or described and which, when observed periodically, demonstrate trends in environmental (including different aspects of biodiversity) and social conditions. Indicators link the fields of policy-making and science: policy makers set the environmental and social targets for a project or policy intervention, while experts determine relevant variables, determine baselines, monitor the current state, and develop models to make projections of future status. Some of the most useful criteria and indicators in the field of forestry have often been developed at the national and regional level because they have taken into account local and national concerns and circumstances.

Indicators must be practical, and should, whenever possible, be meaningful at both the national and site level, as well as consistent with the main objectives of the project or policy intervention. To be most useful and effective, the suite of indicators should be complete and those most relevant to a specific project or policy context, and should, to the extent possible:

(a) be cost-effective to monitor (maximum information with minimum sampling time, effort and expenditure);
(b) use well established methods in order to reveal meaningful trends;
(c) determine greenhouse gas emissions on the basis of the revised Good Practice Guidance of the Intergovernmental Panel on Climate Change (1996) and the Good Practice Guidance for LULUCF (in preparation), the state of biodiversity, and other environmental and social aspects of sustainable development as directly as possible;
(d) be precise and unambiguous so that they can be clearly defined and understood the same way by different stakeholders;
(e) to the extent possible, monitoring indicators should be chosen that allow the identification and separation of the effects of climate change and natural climate variability from other pressures;
(f) be amenable to sampling by non-specialists, including user/local communities;
(g) be consistent (comparable) with, if not the same as, national level indicators as well as those used in other protected areas; and
(h) require the involvement of the minimum possible number of individuals and agencies in their evaluation.

Criteria and indicators consistent with national sustainable development objectives are to some degree available for assessing and comparing the impacts of climate change mitigation and adaptation policies and projects on greenhouse gas emissions, biodiversity and other environmental and social aspects of sustainable development. However, monitoring biodiversity is not as simple as monitoring other environmental characteristics, such as greenhouse gas emissions, or air and water quality for which there are relatively well established standards, given the multidimensional scale dependent aspects of biodiversity (genetic, species and ecosystem). Like other environmental variables that exhibit natural variability, the biodiversity of an area undergoes considerable natural fluctuations and is impacted by a range of factors that need to be monitored and understood so that they can be taken into account in evaluating the impact of climate change, or climate change mitigation projects and policies, on biodiversity. Monitoring provides the basis for evaluating whether projects and policies are having their desired effect and whether there are unintended positive or negative effects. In formulating a monitoring and evaluation plan in the context of UNFCCC and its Kyoto Protocol, and to ensure positive synergies with the CBD, the selection of indicators is determined largely by the:

(a) objectives for greenhouse gas and biodiversity management;
(b) nature of the proposed interventions or activities;

(c) feasibility and cost of collecting various types of information and data;
(d) institutional capability for incorporating them into analysis and decision making; and
(e) policy choices enabling comprehensive project design for carbon and non-carbon (biodiversity, ecological and social) benefits.

Many international processes are currently developing specific criteria and indicators in management guidelines for forestry and the associated impacts on biodiversity and social aspects of sustainable development that could be useful for afforestation, reforestation and conservation (avoided deforestation) projects and policies. Over the past decade there have been eight intergovernmental processes that have developed sets of criteria and indicators for sustainable forest management (Box 5.3), that can, if the Parties agree, be readily adapted by the UNFCCC to meet its objectives for climate change forestry activities. Many nations are using international sets of criteria and indicators to develop a more detailed set that is specific to their forests and situation and are being incorporated into legislation. However, the profusion of national and international sets of criteria and indicators suggests the need for harmonization. Some of the sets of criteria, e.g., those developed under the Tarapoto Process, have been designed to evaluate policies at the project, national and global levels (Box 5.4). As an example of indicators, Box 5.5 shows quantitative indicators under the criteria for the maintenance, conservation, and appropriate enhancement of biological diversity in forest ecosystems developed during the Ministerial Conference on the Protection of Forests in Europe (Vienna, Austria; October 2002). The Swiss Agency for Environment, Forests and Landscape has developed a set of ecosystem-level criteria and indicators for assessing the impacts of LULUCF CDM projects on biodiversity based on the area and proportions of each ecosystem which are

Box 5.3. Sustainable forest management processes

International Tropical Timber Organization – 27 tropical countries
Helsinki process – 44 European countries and the EU +13 non-European countries as observers
Montreal process – 12 non-European countries with boreal and temperate forests
Tarapoto process – 8 countries in the Amazon Cooperation Treaty
Lepaterique – 7 Central American countries
Sub-Sahel dry zone Africa – 28 sub-Saharan countries
North Africa and Near East – 20 countries stretching from Morocco to Afghanistan
Central Africa – 13 countries of the African Timber Organization

Box 5.4. Examples of the Tarapoto process criteria for sustainable forest management

Environmental

- Biodiversity (genetic, species, ecological and landscape)
- Ecosystem productivity
- Soil (including erosion)
- Water conservation (quantity and quality)
- Forest ecosystem functioning and processes
- Contribution to carbon sequestration

Socio-economic

- Long-term supply of social benefits
- Long-term output of multiple economic benefits
- Recognition of, and respect for, indigenous rights

Box 5.5. Quantitative indicators for the maintenance, conservation, and appropriate enhancement of biological diversity in forest ecosystems as adopted by the Ministerial Conference on the Protection of Forests in Europe (MCPFE; Expert Level Meeting, 2002).

Tree species composition – area of forest and other wooded land, classified by number of tree species occurring and by forest type.

Regeneration – area of regeneration within even-aged stands and uneven aged-stands, classified by regeneration type.

Naturalness – area of forest and other wooded land, classified by "undisturbed by man", by "semi-natural" or by "plantations", each by forest type.

Introduced tree species – area of forest and other wooded land dominated by introduced tree species.

Deadwood – volume of deadwood and of lying deadwood on forest and other wooded land classified by forest type.

Genetic resources – area managed for conservation and utilization of forest tree genetic resources (*in situ* and *ex situ* gene conservation) and area managed for seed production.

Landscape pattern – landscape-level spatial pattern of forest cover.

Threatened forest species – number of threatened forest species, classified according to IUCN Red List categories in relation to total number of forest species.

Protected forests – area of forests and other wooded lands protected to conserve biodiversity, landscapes and specific natural elements, according to MCPFE assessment guidelines.

intervened, and the type and degree of intervention (Pedroni 2001). The proposition includes criteria and indicators of existing international processes aimed at sustainable forest management (i.e., Montreal, Helsinki, Tarapoto, Lepaterique, Forest Stewardship Council, and International Tropical Timber Organization).

A critical evaluation of the current criteria and indicators developed under the Convention on Biological Diversity, the Ministerial Conference on the Protection of Forests in Europe, and the many other national and international initiatives could assist in assessing their utility to qualitatively and quantitatively evaluate the impact of projects and policies undertaken by Parties to the UNFCCC and the Kyoto Protocol on biodiversity and other environmental and social aspects of sustainable development. This would allow the presentation of an array of eligible standards and procedures for validation and certification that could enable national, regional and international initiatives to select a scheme that best serves their project circumstances.

A key question is whether an international system of criteria and indicators needs to be developed under the Kyoto Protocol to assess and compare the environmental and social impacts across alternative mitigation and adaptation options. If a standard set of criteria and indicators were developed they may need to be modified to account for national, regional and biome-specific conditions.

Table 5.1: Categories of indicators proposed and examples for each category

Set	Category	First-track example	Second-track example
State	Ecosystem quantity	Self-regenerating and man-made area as percentage of total area.	Self-regenerating area per habitat type as percentage of 1993 and of postulated pre-industrial baseline
	Ecosystem quality – species abundance relative to postulated baseline	Distribution or abundance of a few selected species as a percent of postulated baseline per country	Extended list of selected species which provide a more detailed and representative picture of the change in biodiversity per country
	Ecosystem quality – ecosystem structure	Area of sustainable managed forest (%).	
	The relative number of threatened and extinct species	Number of threatened and extinct species as a percent of particular considered group per country	As first track, but with extended data
Pressure	Habitat loss	Annual conversion of self-generating area by habitat type as % of remaining area	A range of region-specific variables and decision rules
	Harvest	Total amount harvested per unit effort	Total amount harvested relative to estimate of sustainable offtake levels
	Species introductions	Total number of non-indigenous species as a % of a particular group per country	Relative abundance/biomass of non-indigenous species as a % of a particular group
	Pollution		Average exceedence of soil water and air standards (critical loads) of particular pollutants.
	Climate change	Change in mean temp. per 50x50km grid cell averaged per country over 20-years	Change in max. and min. temperature and precipitation per 50x50km grid cell over 20 years
Use	Ecosystem goods	Total amount harvested per species and grand total over time.	Percent of wild species with known or potential medicinal uses
	Ecosystem services	Total and per km^2 carbon stored within forests per country referenced to baseline	Percent of transboundary watershed area assessed as "low risk of erosion"

Project proponents would probably be more comfortable with a system under which they are free to select, among an array of eligible standards and procedures of validation, certification, and the scheme that suits best their national and project needs.

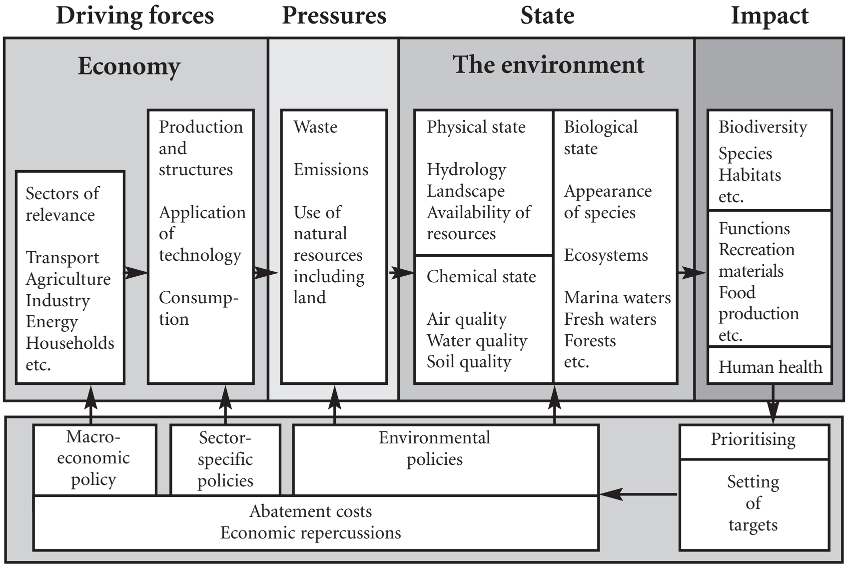
The pressure-state-response framework has been used to develop a set of biological indicators that are of utility at the national and global scale to assess the impact of climate change on biodiversity and the impact of climate change mitigation and adaptation policies on biodiversity. A CBD expert group developed recommendations for a core set of biodiversity indicators (UNEP/CBD/SBSTTA/3/9) using a two-track approach (Table 5.1 shows indicators for state and pressure, but not response). The assessment method for biodiversity indicators in this report uses the pressure-state-response framework wherein the "pressures" are the socio-economic factors which affect biological diversity, "state" is the state of biological diversity, and "responses" are the measures which are taken in order to change the current or projected state. The first track for immediate implementation considers existing and tested state and pressure indicators related to the conservation of biological diversity and to the sustainable use of its components. The second track, for longer-term implementation, should consider not only the state and pressure indicators, but also the identification, development and testing of response indicators for the three objectives of the CBD: (i) the conservation of biological diversity; (ii) the sustainable use of its components; and (iii) the fair and equitable sharing of the benefits arising out of the utilization of genetic resources. The second track should also aim at continuous improvement of the state and pressure indicators for the first two objectives of the Convention. These indicators are most suitable for the assessment of national and global trends in biodiversity (Herold et al. 2001), hence they may be most useful for assessing how biodiversity is affected by climate change and how national climate change mitigation and adaptation policies impact on biodiversity. However, they are too general to provide the kind of information that would be suitable for assessing the impact of individual climate change and adaptation projects on biodiversity. In addition, Gillison (2001), in a Review of the Impact of Climate Change on Forest Biological Diversity (UNEP/CBD/AHTEG-BDCC/1/2), questioned the use of the pressure-state-response framework, noting that the assumptions about ecosystem 'state' are questionable due to unknown, unmeasurable, and ongoing environmental lag effects.

The driver, pressure, state, impact and response framework, which has evolved from the pressure-state-response framework, should help decision makers to implement effective environmental policy actions. The driver, pressure, state, impact and response framework (DPSIR) develops the idea of the PSR framework further by including a societal element describing the causes on environmental pressure (called drivers) and an element for the effects of the environmental problems into society (called impacts). The DPSIR is a general framework for organising information about the state of the environment and its relation to human activities. It has widely been applied internationally, in particular for organising a system of indicators in the context of environment and further sustainable development. The framework assumes cause-effect relationships between interacting components of social, economic, and environmental systems, which can be seen in Box 5.6. The DSPIR framework can be used to conduct integrated environmental assessments (Figure 5.3). Table 5.2 gives some examples how DPSIR framework could be used in the case of biodiversity and climate policies (EEA 1995).

Box 5.6. Driver, Pressure, State, Impact and Response (DPSIR) framework components

- **D**riving forces of environmental change (e.g. economic growth)
- **P**ressures on the environment (e.g. harvest of timber)
- **S**tate of the environment (e.g. habitat loss)
- **I**mpacts on population, economy, ecosystems (e.g. erosion)
- **R**esponse of the society (e.g. legislation)

Figure 5.3: Integrated Environmental Assessment in the DPSIR Framework



Response (policies)

The driver, pressure, state, impact and response framework has a number of limitations as the real world is usually far more complicated than can be expressed in simple causal relations. There is variability between the environmental system and the human system, and, moreover, many of the mechanisms between the human system and the environmental system are not sufficiently understood or are difficult to capture in a simple framework (Smeets and Weterings 1999). The DPSIR framework can require very detailed statistics and the indicator systems have their problems: (i) there can often be a lack of data; (ii) the data sources are not clear; and (ii) the defined criteria for the different elements at operational level are not clear. To be an efficient framework, the data collected should be easily available and the costs of collecting the data should be low. The challenge with the DPSIR model is to translate the data of indicators to natural systems entities and vice versa in a meaningful way.

It is important to recognize the different spatial and temporal scales of monitoring that will be required to assess the implications of the range of possible climate change mitigation and adaptation projects and policies. For example, changes in greenhouse gas emissions resulting from mitigation projects and policies may need frequent monitoring, while climate change adaptation and biodiversity conservation activities, which impact on ecological processes, may need less frequent monitoring given that changes in biodiversity (e.g., changes in numbers of a population of a key species, or changes in species composition) may be slow. This suggests the need to establish a system that will simultaneously contribute to monitoring the short- and long-term effects of individual projects as well as national policy changes.

Monitoring and evaluation plans and identification of relevant indicators should, as much as possible, be meaningful and involve those communities and institutions likely to be affected by project and policy interventions. Given the importance of making the indicators meaningful to local people, it is essential to include socio-economic and cultural indicators in additional to biological indicators to quantify the impact of climate change mitigation and adaptation projects and policies on the national and regional economy and employment, and as instruments for securing and maintaining equitable opportunities for the public in decision making.

Table 5.2: Example of indicators related to biodiversity and climate policies and organized in the DPSIR framework.

Set	Category	First-track example	Second-track example
Driving Forces	Economic development and population growth	Value added in agriculture	Value added in cultivation practices
	Economic development and population growth	Value added in forestry	Value added in forest industry
	Economic development and population growth	Value added in energy production	Use of fossil fuels
	Economic development and population growth	Land use change	Deforested area
Pressure	Agricultural intensity	Total cultivated land area	Pesticide use per cultivated hectare
	Harvest of timber	Harvested area of total forest area	Harvested area relative to sustainable harvesting
	Species introduction	Total number of non-indigenous species as a % of particular group per country	Relative abundance/biomass of non-indigenous species as a % of particular group per country
	Greenhouse gas emissions	Changes in the amount of domestic and transboundary emissions	Changes in the deposit of domestic and transboundary emissions
	Climate change	Change in mean temperature per 50x50 km grid cell averaged per country over 20 years	Change in max and min temp and precipitation per 50x50 km grid cell averaged per country over 20 years
	Increase of urban areas and roads	Increase of built-up area as a % of total area	Increase of built-up area as a % of total area by intensity groups
State	Ecosystem quantity	Self-regenerating and man-made area as a % of total area	Self-regenerating area per habitat type as a % of 1993 and of postulated pre-industrial baseline
	Ecosystem quality – species abundance relative to postulated baseline	Distribution of abundance of few selected species as a % of postulated baseline per country	Extended list of selected species which provide a more detailed and representative picture of the change in biodiversity per country
	Ecosystem quality – ecosystem structure	Area of sustainable managed forest (%)	Area of sustainable managed forest (%) by bio-type
	Relative number of threatened and extinct species	Number of threatened and extinct species as a % of particular considered group per country	As first-track but with extended data
	Habitat loss	Annual conversion of self-regenerating area as a % of remaining area	Annual conversion of self-regenerating area by habitat type as a % of remaining area
	Ecosystem quality – amount of micro-organisms in soil	Amount of micro-organisms in a specific area	As first-track but with extended data
	Air quality	Level of SOx and NOx gases in the air	Acidity of rainwater in different areas
Impacts	Ecosystem goods	Change in total amount of harvested per species and grand total over time	Percent of wild species with known or potential medicinal uses

Set	Category	First-track example	Second-track example
Impacts *(cont.)*	Human health	Increase of tropical diseases (e.g. malaria)	
	Sea level rise	Loss of agricultural land area	Loss of agricultural land area by crop type
	Erosion	Increased erosion due to decreasing land cover or monoculture plantations	Increased erosion due to decreasing land cover by species type
Response	Greenhouse gas mitigation	Climate strategies adopted	Policies and measures adopted
	Biodiversity policy	Share of protected areas of the total land area	Share of protected areas of the total land area by different bio-types
	Education	Expenditure on education	Expenditure on education of nature protection
	Environmental taxation	Amount of environmental taxes as a % of all taxes	Taxes aimed at decreasing the greenhouse gas emissions
	Legislation	Amount of environmental laws	Amount of environmental laws in specific areas related to biodiversity and climate change
	Environmental management and auditing systems	Total number of environmental auditing systems implemented in a country	Total number of environmental auditing systems implemented in a specific sector

The identification of meaningful indicators and appropriate sampling regimes should also take into account existing monitoring programs and data sets at the local and national level, capacity at these levels, and the need to establish agreed sampling and recording protocols at the national level. Consistency of monitoring approaches across local areas and protected area systems should have a high priority.

Determining the impact of climate change projects and policies on biodiversity is, in some instances, likely to remain problematical given the long-lag time between the intervention and the response of the system e.g., species populations and composition. Hence, long-term monitoring to determine changes in biodiversity will be necessary (see examples of these impacts from possible LULUCF activities in Table 5.3).

5.7 RESEARCH NEEDS AND INFORMATION GAPS

There are many gaps in information. In many cases it is primarily a question of exercising and applying the tools mentioned in this chapter, rather than more fundamental research:

(a) Systematic application of EIAs, SEAs, DAFs and valuation techniques in the context of climate change and biodiversity;
(b) Application of EIAs modified to take account of issues such as non-permanence and leakage;
(c) Improved understanding of the DSPIR relationships, i.e., between:
  - the drivers of change (e.g., economy, demography, population and socio-political) and pressures (e.g., demands for natural resources, emissions and introductions)
  - pressures and ecosystem state (i.e., the physical and biological state)
  - state (physical and biological) and impacts (e.g., the provisioning, regulating, cultural and supporting ecosystem goods and services)
  - the response (policies) and the drivers of change and the pressures

(d) Increased data to apply the EIAs, SEAs, DAFs and DSPIR frameworks; and
(e) Improving the development of indicators, especially for biodiversity

Table 5.3: **List of possible LULUCF projects with potential effects on biodiversity (from Herold et al. 2001).**

Possible LULUCF projects	Characteristics for positive impacts on biodiversity	Characteristics for negative impacts on biodiversity or other aspects of sustainable development
Conservation of natural forests	Generally positive characteristics for a positive impact	
Conservation and restoration of wetlands	Generally positive characteristics for a positive impact	Could result in an increase in greenhouse gas emissions
Afforestation and reforestation *(note: these are the only eligible LULUCF activities under the CDM)*	• On degraded lands • If natural regeneration and native species are used, reflecting the structural properties of surrounding forests • If clearing of pre-existing vegetation is minimized • If chemical use (e.g., fertilizers, herbicides and pesticides) is minimized • If areas for habitats for different species are considered • If rotation lengths are extended • If tree density respects biodiversity needs • If low impact harvesting methods are used	• On areas where natural ecosystems are destroyed • If monocultures of exotic species are used on large areas • If other vegetation is cleared before and during the activity • If chemicals (e.g., fertilizers, herbicides and pesticides) are used abundantly • If no habitats are created • If short rotation periods are used • If tree density is very high • If harvesting operations clear complete vegetation • If sites with special significance for the in-situ conservation of agrobiodiversity are afforested.
Restoration of degraded lands and ecosystems	Generally positive characteristics for a positive impact, depending upon the extent of degradation	• Habitats of species conditioned to extreme conditions could be destroyed • Possible emissions of nitrous oxide if fertilizers are used
Forest Management	If natural forest regeneration occurs and "sustainable forest management" harvesting practices are applied	If monocultures of exotic species are planted and natural regeneration suppressed
Agroforestry	Generally positive characteristics for a positive impact unless established on areas of natural ecosystems	Negative if natural forests or other ecosystems are replaced
Cropland management	If reduced tillage is used without increased use of herbicides	• If increased use of herbicides and pesticides • If established on areas of natural ecosystems
Grassland and pasture management	• Mainly positive if no natural ecosystems are destroyed • If no exotic species are used • If fire management respects natural fire regeneration cycles	• If established on areas that contained natural ecosystems • If non-native species are introduced
Adaptation activities	Generally positive characteristics for a positive impact if the activities conserve or restore natural ecosystems	

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6. SELECTED CASE STUDIES: HARMONIZATION OF CLIMATE CHANGE MITIGATION AND ADAPTATION ACTIVITIES, WITH BIODIVERSITY CONSIDERATIONS

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INTRODUCTION

This chapter builds on the conceptual and empirical basis for harmonizing and optimizing benefits arising from climate change mitigation and adaptation activities with the conservation of biological diversity as presented in Chapters 4 and 5. Based on a review of 10 case studies, it provides insights on key practical challenges and opportunities when implementing projects with multiple objectives, including climate and biodiversity considerations. The individual and collective experience from these case studies also provides some succinct lessons for improving the design of future projects.

Section 6.1 provides an overview of the key issues and overall lessons from the analyses of the case studies. Information gaps and research needs are identified in section 6.2. A full description of each case study is provided in section 6.3.

6.1 OVERVIEW OF KEY ISSUES AND LESSONS LEARNED FROM THE CASE STUDIES

The case studies presented here are being implemented at various spatial scales (site, national and regional). Two of these case studies are focused on developed (Annex 1) countries (see section 4.2 for definitions) by applying tools and methodologies to advance the integration of climate issues into policy and planning processes. Another four case studies focus on developing countries and illustrate the challenges of addressing multiple stakeholders and multiple objectives (including climate and biodiversity considerations), into project design and/or implementation. A further four case studies demonstrate partnerships between developing countries and Annex 1 countries and/or private investors and showcase the application of the different flexibility mechanisms allowed for under the Kyoto Protocol.

Box 6.1. List of Case Studies

1. **Uganda and The Netherlands/Private investor:** Mount Elgon National Park
2. **Costa Rica:** Ecomarkets
3. **Finland:** Environmental Assessment of the National Climate Strategy
4. **Madagascar:** Masaola National Park Integrated Conservation and Development Program
5. **Belize and the United States:** Rio Bravo Climate Action Project
6. **Sudan:** Community Based Rangeland Rehabilitation for Carbon Sequestration
7. **Britain and Ireland:** Climate Change and Nature Conservation
8. **Central America and Mexico:** Mesoamerican Biological Corridor
9. **Uganda and Norway/Private investor:** Tree plantations for Carbon Credits
10. **Romania and Prototype Carbon Fund (PCF):** Afforestation of Degraded Agricultural Land Project

Some of the case studies reviewed are pilot projects launched in anticipation of the Kyoto Protocol; others preceded the Kyoto discussion. For example, the Mesoamerican Biological Corridor project [8][31] was not conceived with climate considerations in its design, but it showcases the potential for synergies to be explored. Others (e.g. Uganda-Netherlands/Private investor [1], Costa Rica [2], Finland [3], Belize [5], Uganda-Norway/Private investor [9]) represent pioneering efforts undertaken by governments, private investors, and consortiums, to learn and better prepare themselves for future opportunities. A caution with respect to the case studies addressing afforestation and avoided deforestation is that it is not definite that any of these projects will in fact be

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[31] Numbers refer to the case studies listed in Box 6.1.

validated as Clean Development Mechanism (CDM) projects under the Kyoto Protocol, as modalities are still under development. Further, it is recognised that avoided deforestation, pursued through forest conservation, is not yet eligible under the CDM, but some of the pilot experiences reported in this chapter have included this aspect in the design of their projects.

6.1.1 Potential benefits for biodiversity conservation through the application of different flexibility mechanisms allowed for under the Kyoto Protocol

Various flexibility mechanisms allowed for under the Kyoto Protocol are described in the case studies, particularly joint implementation (JI; see section 4.2 for definitions), and the potential application of afforestation, reforestation and avoided deforestation through the Clean Development Mechanism (CDM; see section 4.4). The Romania case study [10] showcases joint implementation between an Annex 1 country and a consortium of donors under the auspices of an umbrella manager (the World Bank Prototype Carbon Fund). The two Uganda cases [1,9] are examples of potential CDM projects done in partnership with private investors in developed countries, while the Costa Rica case [2] is illustrative of a unilateral CDM. The Belize case [5] is designed as an 'Activity Implemented Jointly' following earlier terminology (which would in current Kyoto Protocol terminology be an example of CDM). The interventions include afforestation (e.g., Sudan [6], Uganda-Norway/Private investor [9], and Romania [10]), reforestation (e.g., Uganda-Netherlands/Private investor [1], Costa Rica [2], Belize [5], Romania [10]), and avoided deforestation (e.g. Costa Rica [2], Belize [5], Romania [10]).

The case studies examined reveal that there is scope for the harmonization of afforestation and reforestation options with biodiversity conservation. Several cases improved the conservation of protected areas, including the Romania project where degraded parts of a Ramsar site will be reforested [10]; Uganda, where Mount Elgon National Park will be reforested [1]; and the extension of the Rio Bravo Conservation Area in Belize [5]. These and other projects also included specific design features to optimize conservation benefits through the use of native species for planting, reduced impact logging to ensure minimal ecosystem disturbance, and the establishment of biological corridors. In addition, sustainable use of forests was also strengthened through various incentive measures, particularly in the cases of Sudan [6], Costa Rica [2] and Uganda-Netherlands/Private investor [1]. Nevertheless, there is room for improvement in existing projects to further explore synergies between climate mitigation and adaptation activities with biodiversity conservation. For example, the Mesoamerican Biological Corridor Project [8], originally conceived as a regional strategy for biodiversity conservation, and not to address climate change, clearly has significant potential and scope for mitigation and adaptation options to be designed into the particular national-level implementation of projects.

Lesson 1: There is scope for afforestation, reforestation, improved forest management and avoided deforestation activities as mitigation and adaptation options to be harmonized with biodiversity conservation benefits.

6.1.2 Use of the Clean Development Mechanism (CDM) as a tool to advance sustainable development and biodiversity conservation in developing countries

Sustainable development, which forms the basis of CDM, in the context of developing countries, could be achieved if the projects are designed to pay explicit attention to environmental, social and economic dimensions. According to the Kyoto Protocol, projects under CDM must be consistent with the sustainable development priorities of the host country, as determined by the host country. This provides a mechanism for developing countries to screen projects on the basis of social, economic and environmental considerations, which support sustainable development, in order to maximize the benefits of CDM projects. Biodiversity considerations should be a critical consideration in this suite of issues.

Biodiversity conservation and sustainable use of its components is often closely aligned to community livelihoods and their sustainable development. For example, the "success" of the Sudan project [6] stems from combining key local development and livelihood concerns with those relating to carbon sequestration and biodiversity conservation. The spontaneous replication of the activities and techniques of this project by neighboring villages is testimony to this success. Similarly, in the Costa Rica case [2], small-scale farmers were provided with financial resources to conduct forest reforestation and conservation activities that would generate carbon credits that would subsequently be sold in international markets. In contrast, the restrictions imposed on the livelihoods of the local communities in the Uganda-Netherlands/Private investor [1] case almost led to project failure.

Lesson 2: The linkages between conservation and sustainable use of biodiversity with community livelihood options provides a good basis for projects supported under the Clean Development Mechanism to advance sustainable development.

6.1.3 Adequate attention to the social, environmental and economic aspects for effective and sustained benefits for climate change and biodiversity conservation

Social, environmental and economic considerations are critical elements for effective and sustained benefits for climate change and biodiversity conservation. For example, the omission of social and environmental issues in the Uganda-Norway/Private investor project [9] during planning and negotiation of agreements resulted in losses to key stakeholders: land conflicts which undermined the security of carbon credits for the investor, livelihood loss for local communities, and unsustainable forest management for the Ugandan forest authorities. The lack of a process to address the local tenure and settlement issues continues to undermine the successful carbon sequestration and biological conservation benefits originally envisaged. This was also initially the case in the Uganda-Netherlands/Private investor project [1], although later the project took a proactive approach to address these issues.

Continued attention to economic and environmental considerations in Costa Rica [2] has proved to be useful for balancing the carbon and biodiversity objectives; after an initial period, reforestation contracts were excluded because the higher financial rewards for these contracts over those for forest conservation were serving as a disincentive for conservation.

Lesson 3: The neglect and/or omission of social, environmental and economic considerations can lead to conflicts which could undermine the overall success of carbon mitigation projects, and long-term biodiversity conservation.

6.1.4 Balanced partnerships through capacity building and transparency

The Kyoto Protocol is relatively new, and thus the "playing field" is still not leveled. There appears to be a need to equip countries and key stakeholders with the necessary information, tools, and capacity to understand, negotiate and reach agreements over CDM projects. This empowerment could ensure that the CDM projects will be balanced with respect to the national needs and priorities, as well as conservation and carbon sequestration goals. The Uganda-Norway/Private investor project [9], highlights the challenges of implementing agreements from the perspectives of the host country, project investors, and local communities: the tensions between key stakeholders and wavering commitment to the agreement can be partly attributed to the asymmetry of information and understandings of their roles and responsibilities at the time of finalizing the deal. It is critical that all stakeholders understand the benefits and the costs of proposed interventions to each partner, including the opportunities and synergies to be achieved with conservation. In this regard, Costa Rica's experience [2] has been more positive in part due to the country's institutional and policy environment, and its capacity to deal with key project issues and key stakeholders as equal partners.

Just as the host country of a CDM project would seek to ensure that the project is consistent with its sustainable development priorities, it may be useful to consider a process by which the parent country of private investor entities sets some minimum norms (or guiding framework) for such entities, especially since the carbon credits purchased would subsequently be used to offset emissions in the parent country. Without such minimum norms, e.g., between 'private investors/parent countries', projects could still be able to claim carbon credits even when they have detrimental environmental and/or social impacts, as indicated by the Uganda-Norway/Private investor project [9].

Lesson 4: Countries and key stakeholders need to have the necessary information, tools and capacity to understand, negotiate, and reach agreements under the Kyoto Protocol to ensure that the resulting projects are balanced with respect to environment, social and development goals.

Lesson 5: Some minimum environmental and social norms (or guiding frameworks) when purchasing carbon credits through CDM projects could avoid perverse outcomes.

6.1.5 Application of tools and instruments for informed decision making and adaptive management

In most cases, only a sub-set of the available tools discussed in chapter 5 were used in designing the projects. However, several of the case studies illustrate the application of at least one of the analytical tools and instruments, which in turn influenced key stages of the project or program. The application of cost-benefit analysis at a specific site in Madagascar [4] provided the rationale for retaining the Masaola forest as a national park instead of converting it to a logging concession, but concluded that conservation would only succeed in the long term if the benefits outweigh costs –a condition that the study noted could potentially be met if, for example, avoided deforestation becomes an eligible activity under the Kyoto Protocol. The comprehensive approach taken by Costa Rica [2] is also exemplary in that it combined various tools (valuation, strategic sector-level analysis, and decision analytical frameworks) to meet multiple objectives.

At the policy level, the application of the strategic environmental assessment at a national level in Finland [3] revealed that the scenarios initially chosen for the climate change strategy had been too narrowly defined, and the Parliament has since requested widening the scope of analyses. A strategic modeling approach to inform the adaptation of nature conservation policy and management practice to climate change impacts was undertaken in Britain and Ireland [7].

Lesson 6: The application of appropriate analytical tools and instruments can provide constructive frameworks for ex-ante analysis to guide decision making; provide adaptive management options during implementation; and provide a basis for learning and replication through ex-post evaluations.

6.1.6 Monitoring and verification processes for carbon and biodiversity related management

The case studies examined show a mixed record on monitoring and verification processes. The Sudan project [6] had monitoring processes in place to measure carbon sequestration (although it lacked a rigorous field verification program), but the biodiversity inventory and monitoring component was dropped due to resource constraints. The Belize and Costa Rica projects [2,5] are simultaneously monitoring and measuring carbon and certain aspects of biodiversity, although the need for ground-truthing (verification) of Costa Rica's monitoring system has been raised. Nevertheless, Costa Rica has managed to some extent to use its monitoring processes for improving management (e.g., withdrawing reforestation contracts).

For the Kyoto Protocol, the amount of carbon reduced or sequestered is of utmost importance, while there are no obligatory requirements for conservation targets under the CBD. It may be important that biodiversity baselines, inventories and monitoring also gets done, in addition to the carbon accounting, to allow for longer-term management of biodiversity.

Lesson 7: Measuring the impact of Clean Development Mechanism and Joint Implementation projects on biodiversity requires baseline data, inventories and monitoring systems.

6.1.7 The Ecosystem Approach of the CBD as a holistic management strategy

The overall analyses of the case studies suggests that several projects benefited either from the consideration Principles of the Ecosystem Approach (see section 4.3 and Box 4.1), or from their explicit application. For example, the Costa Rica project [2] appropriately applied Principles 2 and 9 of the Ecosystem Approach in that it was quick to withdraw financial incentives when they undermined some key objectives of the project. Part of the success of the case study from Britain and Ireland [7] can be attributed to the application of Principle 12 of the ecosystem approach when a consortium of government agencies, NGOs and research institutes worked to conduct scientific research to inform the adaptation of nature conservation policy and management practice to climate change impacts. Some projects that applied Principle 4 appropriately (Sudan [6]; and Costa Rica [2]) prevented local conflicts, while other projects that did not, subsequently faced challenges (Uganda [1,9]).

Lesson 8: The Ecosystem Approach provides a good basis to guide the formulation of climate change mitigation policies/projects and conservation of biodiversity.

6.2 RESEARCH NEEDS AND INFORMATION GAPS

There are some information gaps and research needs emerging from the lessons learnt from the case studies which should be addressed in an effort to optimise and sustain the benefits from biodiversity conservation and climate change mitigation and adaptation options over the long term. These include:

(a) Need for ways and means to equip countries and key stakeholders with the necessary information, tools and capacity to understand, negotiate, and reach agreements under the Kyoto Protocol to ensure that the resulting projects are both balanced with respect to climate change and biodiversity considerations and consistent with national priorities.
(b) A process for Annex 1 countries to set some minimum norms (or guiding frameworks) for private investor entities participating in CDM projects.
(c) Systematic piloting of projects that apply various analytical tools and instruments (EIAs, DAFs, valuation; see chapter 5) and a strategy for encouraging their replication.
(d) Pilot projects that explore synergies in the monitoring processes for CDM and JI projects (for compliance with the Kyoto Protocol) and sustained biodiversity conservation.

Table 6.1: Summary of selected case studies: harmonization of climate change mitigation and adaptation activities with biodiversity considerations

Title of case	Key features	Main Lessons Learnt	Tools and monitoring processes	Relevance to UNFCCC and CBD
1. Uganda and The Netherlands/ Private Investor: Mount Elgon National Park	• Partnership between private investor in developed (Annex 1) country and conservation department in developing country (non-Annex 1). • Potential for use of carbon credits to meet emissions reduction targets in Annex 1 country. • Illustrates critical need to consider community and social dimensions in design of the project	• The omission of social issues in the original design can result in conflicts which impact adversely on local livelihoods, which could in turn undermine the success of the project. • Adaptive management can help to mitigate conflicts as they emerge, and ensure that the objectives can be met successfully	• Adaptive management. • Environmental and social impact considered – posthumously. • Certification and verification by independent entity	• An example of a potential reforestation project under CDM (Article 12 of Kyoto Protocol). • Programme Element 1 of the CBD expanded programme of work on forest biological diversity (Annex to COP decision VI/22) • Incentive measures (COP decision VI/15).
2. Costa Rica: Ecomarkets	• Illustrates a strategic approach at a sector level to optimize conservation benefits and climate change mitigation within the context of national sustainable development • Environment Service Payments (ESPs) used to mitigate greenhouse gas emissions, and for biodiversity conservation. • Sale of certified tradable offsets or carbon bonds from forest ecosystems. • Prerequisite of good database on land-use, land ownership and tenure coupled with efficient monitoring and indicator processes.	• A holistic, broad based approach to environmental issues has allowed the country to mobilise markets from environmental services at both the national and global level. • Sound institutional arrangements and reliable databases and monitoring processes enable a country to capitalise on new innovations and opportunities (e.g., Kyoto Protocol., environmental services, certification).	• Not explicitly stated, but potentially could have used Strategic Environmental Assessments • Valuation as a basis for designating ESPs • Efficient monitoring and tracking indicator. • Regular field monitoring of contracts, although need for validation through ground-truthing.	• An example of a potential unilateral project under the CDM (Article 12 of Kyoto Protocol) of UNFCCC. • Programme Element 1 of the CBD expanded programme of work on forest biological diversity (Annex to COP decision VI/22) • Incentive measures (COP decision VI/15 CBD).

Title of case	Key features	Main Lessons Learnt	Tools and monitoring processes	Relevance to UNFCCC and CBD
3.Finland: Environmental Assessment of the national climate strategy	• Illustrates the application of Strategic Environmental Assessment approach in developing a national climate strategy. • Results revealed that the scenarios for the climate strategy were narrow in scope limiting a thorough assessment of all concerns on possible energy futures. • The Parliament has requested for more scenarios and longer term analyses be undertaken. The process is now part of the government's program.	• The design of an analytical framework for the assessment (or ex-ante evaluation) was important for the whole assessment. The peer and expert review of the steering group was important for focusing on key issues. • The multidimensional analytical framework for the assessment, which included explicit links to environmental, economic, technical and social aspects of the strategy and scenarios gave a basis for dealing with problems and solutions in an adequate manner and displayed essential characteristics of the strategy and the chosen scenarios. • The public and transparent presentation of the assessment results supported a review process in the form of public discussions. This kind of review process is important for a public discussion on climate strategies.	• Adaptive management. • Environmental and social impact considered – posthumously. • Certification and verification by independent entity	• An example of a potential reforestation project under CDM (Article 12 of Kyoto Protocol). • Programme Element 1 of the CBD expanded programme of work on forest biological diversity (Annex to COP decision VI/22) • Incentive measures (COP decision VI/15).
4.Madagascar: Masaola National Park Integrated Conservation and Development Program	• Applies valuation, and cost benefit analyses to analyze the benefits to greenhouse gas mitigation through avoided deforestation. • Trade-offs calculated at local, national and global levels of different management options for the Masaola National Park.	• An *ex-ante* valuation allowed for more informed land-use choices to be made. • Valuation in itself does not generate a revenue stream; there is a need to put appropriate market mechanisms in place. • Recommendation for application of a split-incentive costs to secure greenhouse gas mitigation and conservation concurrently.	• Cost-benefit analysis, • Economic valuation: total economic value framework (use, non-use values, goods and services)	• Potential scope for conserving forests through avoided deforestation as a mitigation option. • Responsive to the CBD expanded programme of work on forest biological diversity (Annex to COP decision VI/22).

Title of case	Key features	Main Lessons Learnt	Tools and monitoring processes	Relevance to UNFCCC and CBD
5. Belize and U.S.: Rio Bravo Climate Action Project	• Greenhouse gas mitigation achieved through avoided deforestation and sustainable forest • The conservation and sustainable management of c. 500,000 hectares of forests will sequester c. 2.4 M t of carbon over the project duration (40 years). • Adaptation to climate change projected impacts through conservation and use of corridors in the Rio Bravo forests (i.e. through increased resilience and connectivity) • Consideration of additionality and leakage aspects within project design.	• The baseline information being collected on carbon sequestration in the Rio Bravo tropical forests is critical for continued support for calculation of net carbon removals, as well as replication of this project. • Experiments with innovative sustainable forest-management have assisted local residents find sustainable economic alternatives to destructive logging practices.	• Analysis of land-use options • Monitoring processes in place for forest management plans (independently certified) and for leakage • No evidence of any environmental and/or social impact assessments.	• This is an activity implemented jointly (AIJ) under the UNFCCC and US- Joint Implementation, and not under the Kyoto Protocol. It is not eligible for validation in the first commitment period. • The case illustrates the potential role of avoided deforestation and good forestry practices (reduced impact logging) as potential mitigation options.
6. Sudan: Community Based Rangeland Rehabilitation for Carbon Sequestration	• Project successfully combined needs of the local communities with long-term goal of carbon sequestration. • Highlights the nuances and issues related to carbon accounting, such as establishment of baselines, project boundary, time-scale of project versus carbon benefit, and attribution of carbon benefits from positive leakage. • Demonstrates the potential scope for carbon sequestration in semi-arid areas if extended over larger spatial areas.	• Effectively combining key local development and livelihood concerns with carbon sequestration could lead to successful sustainable outcomes. • Establishing, defensible baselines and monitoring systems for both carbon and biodiversity from the outset is critical if true additionality is to be achieved on both counts. • Weak validation of carbon sequestered can undermine credibility of achievements.	• Participatory Rural Assessment methods. • Carbon accounting methodologies (although the case omitted soil carbon component).	• The project provided baseline information for the First National communication to UNFCCC • Provides information on the potential feasibility of afforestation under CDM in semi-arid areas. • Potential scope for synergies with CBD work program on arid and semi-arid lands (COP decision VI/4) and carbon sequestration.

Title of case	Key features	Main Lessons Learnt	Tools and monitoring processes	Relevance to UNFCCC and CBD
7. Britain and Ireland: Climate change and nature conservation	• Use of a modeling approach to inform the adaptation of nature conservation policy and management practice to climate change impacts. • Results from the first phase indicate the need for a flexible and forward looking approach, with objectives set within a dynamic framework that can adjust to the changing distribution of species and habitat types and to the rate of this change. • For the next phase of research, downscaled versions of the models will be used together with dispersal models and predictions for land cover change to assess the likelihood of species keeping pace with potential climate change and occupying their future climate space.	• A science-based approach has greater likelihood in informing and influencing policy than generalities and speculative statements. • The inclusive approach to the research, undertaken by a consortium of government agencies, NGOs and research institutes has the added strength of bringing diverse views, concerns and perspectives into the analysis from the outset and influencing policy.	• The bioclimatic classification (spatial and temporal) for present distributions. • Modelling changes in climate space for species • Modelling dispersal characteristics of species • Predicting changes in land-use • Modelling changes in ecosystem function	• Methodology and outputs applicable to delivery of species and habitat commitments under CBD (and other international and national legislation and agreements). • Potentially useful analysis to feed into ongoing discussion in the bodies of UNFCCC (SBSTA and COP)
8. Central America and Mexico: Mesoamerican Biological Corridor	• The spatial scale of the program provides significant potential for adaptation of species to the impact of climate change: both in latitude and altitudinal terms. • Highlights the potential scope for climate mitigation options (avoided deforestation, reforestation, afforestation, agroforestry) to be designed into an ongoing program addressing biodiversity conservation. • Scope for enhanced community involvement	• Opportunities and synergies between biodiversity and climate change are being missed because of a biodiversity focus being applied to the program. • The CBD and UNFCCC could leverage significant collateral benefits at the scale of the Mesoamerican Biological Corridor project.	• Regional agreements, various planning exercised, and consultation workshops. • Priority setting exercises for conservation areas.	• Showcases the potential for synergies to be explored with regard to the CBD and UNFCCC through explicitly addressing adaptation and mitigation options in its design features. • The project is responsive to all three objectives of the CBD.

Title of case	Key features	Main Lessons Learnt	Tools and monitoring processes	Relevance to UNFCCC and CBD
9. Norway and Uganda/Private investor: Tree plantations for carbon credits	• The case study highlights the challenges of entering CDM type agreements from the perspectives of the host country, investors and local communities. • Disregard of social and environmental issues during planning and negotiation of agreements resulted in land conflicts that undermine the security of the forest plantations for carbon credits for the investors, livelihood security of the communities, and sustainable forest management for the Ugandan forest authorities. • Raises questions of the role and conduct of private entities that are likely to be important brokers in the emissions trading of carbon credits purchased through CDM projects.	• Need to address information and capacity asymmetry between developing countries and Annex 1 countries (or investors) so that the agreements reached can be respected by all stakeholders over the duration of the project • The sustainable development objective for developing countries - which form the basis of CDM projects- could be achieved if the projects are designed to pay explicit attention to environmental, social and economic dimensions. • There is a need for a clear process for conflict resolution, arbitration, as well as adaptive management built into project design.	• No evidence of any environmental and/or social impact assessments	• Pilot project designed in anticipation of the Kyoto Protocol through afforestation. • Good lessons for the formulation of guidelines of CDM projects.
10. Romania and Prototype Carbon Fund (PCF): Afforestation of Degraded Agricultural Land Project	• Use of carbon finance to restore forests on degraded land. • Climate change mitigation through afforestation and reforestation for above and below ground biomass and soils. • Conservation of a Ramsar site through reforestation of its degraded parts.	• Secure financing source provides certainty and planning for the afforestation. • Application of Environmental Impact Assessments to meet the safeguard policies relating to the social issues will likely avoid conflicts afterwards. • The demonstration effect of this project for Romania's longer-term afforestation plans is expected to be significant	• Environmental Impact Assessments • Valuation: cost benefit analysis likely to be utilised in designing alternative livelihoods for the compensation of local communities.	• Joint implementation (under Art. 6 of the Kyoto Protocol) between an Annex 1 country and a consortium of donors (under the auspices of the Prototype Carbon Fund).

6.3 ANNEX: DESCRIPTION OF THE CASE STUDIES

6.3.1 Case study 1. Uganda and The Netherlands/Private investor: Mount Elgon National Park

Mount Elgon was designated as a National Park in 1993, prior to which it was forest reserve, and since 1996 it comes under the jurisdiction of the Uganda Wildlife Authority (UWA), which is responsible for protected area in the country. The General Management Plan for the park recognizes a wide range of conservation values which have to be taken into management considerations: including watershed, biological, aesthetic, tourist, cultural, communal uses, plantations resources, resources used by communities, and its value as a carbon sink. The Management plan notes collaboration with external partners as a means to support the park management.

The UWA-FACE project (Forest Absorbing Carbon Emissions) funded by a Dutch foundation supports the replanting of indigenous trees in areas of the National Park that were previously encroached. This project started in 1994, and the FACE Foundation of Netherlands could potentially claim carbon credits equivalent to the amount of carbon sequestered in the reforestation area. These credits would in that case be offset against CO_2 emissions by the Foundation's clients, which include power generating companies and other industrial and business clients in Europe. The credits will assist companies in complying with emissions reduction targets set by the Kyoto Protocol of the United Nations Framework Convention on Climate Change. This project potentially represents an example of a reforestation project under the CDM project through the Kyoto Protocol but as indicated in section 6.1, it is subject to validation once the CDM modalities are finalized.

The early phases of the project focused exclusively on the goals of the two partners, namely, carbon sequestration achieved by maximizing biomass production on the site for the FACE foundation; and biodiversity conservation achieved by restoring forests in the National Park for the Uganda Wildlife Authority. When community needs for subsistence forest resources conflicted with the project goals, carbon sequestration and biodiversity conservation took precedence. People were banned from harvesting firewood, thatching grass and other subsistence resources on the grounds that this would reduce the total carbon accumulation on the site. This brought the authorities into conflict with local people, who destroyed tree seedlings in a number of cases. Concerns over the long-term security of the reforested areas led the authorities to review their policy of excluding local people. At the same time, Uganda Wildlife Authority (UWA) was experimenting with new community-based approaches to protected area management. With the assistance of IUCN, UWA pilot tested collaborative management approaches with local communities on Mt. Elgon that involved providing access to resources in exchange for self-regulation and resource protection by the community.

The use of incentive schemes was a critical dimension of the revised approach that has proven successful and has been expanded to areas reforested under the FACE project. People are now able to enter into formal written agreements with the authorities to harvest a wide variety of resources such as firewood, wild fruit and vegetables, thatching grass, vines, wild honey and bamboo. The agreements are designed to permit sustainable levels of harvest and to empower the communities to regulate their use of the forest. The communities have agreed in return to monitor forest use and protect the forest from destruction or unsustainable use. It is expected that this will ultimately reduce the need for protection by the Authority and better security for the forest in the long-term.

Tools and monitoring processes

The project was certified by a third party in 2002 against the Forest Stewardship Council (FSC)

Principles and Criteria on social, economic and environmental issues. As part of the accreditation requirements, the third party certifier needs to visit and perform annual monitoring of the management and conservation activities. The assessment and the monitoring include indicators on social issues such as on the involvement of local and indigenous population to the resource management, on biodiversity aspects such as species used for reforestation and the proportion of areas under protection, and indicators on benefits of the projects to the local population such as economic impacts and non timber forest resources being managed and used.

The project is financed by the Netherlands FACE Foundation and implemented by the Uganda Wildlife Authority. The project commenced in 1994 and is still ongoing.

Sources of information

http://www.facefoundation.nl/Eng/fshomeE.html
http://www.stichtingface.nl/disppage.php
Uganda Wildlife Authority (2000) Mt. Elgon National Park – General Management Plan.

6.3.2. Case study 2. Costa Rica: Ecomarkets

In 1996 Costa Rica adopted Forestry Law 7575, which explicitly recognized four environmental services provided by forest ecosystems: (i) mitigation of greenhouse gas emissions; (ii) hydrological services, including provision of water for human consumption, irrigation, and energy production; (iii) biodiversity conservation; and (iv) provision of scenic beauty for recreation and ecotourism.

In this context, the Environmental Service Payments (ESP) program, aims to protect primary forest and allow secondary forest to flourish on deforested land, and promote forest plantations to meet industrial demand for lumber and paper products. These goals are met through site-specific ESP contracts with individual small and medium sized farmers. ESP contracts are based on two factors: (1) the value of the environmental services provided by primary and secondary forests; and (2) the management costs specific to each type of contract. There is a serious concern however, that the high cost of producing a ton of carbon may in fact favor large-scale projects, who are able to manage due to the already significant income from timber sales.

There are four types of ESP contract, each disbursing a fixed amount per hectare over a five-year period.

- Forest conservation contracts: US$200 per hectare for forest conservation easements.
- Sustainable forest management contracts: US$13 per hectare for sustainable forest management easements.
- Reforestation A contracts: US$513 per hectare, with commitments to maintain reforested areas for 15 to 20 years, depending on the tree species – only native species are allowed to be planted. 5% of these contracts are on degraded and abandoned agricultural land.
- Reforestation B contracts: US$200 per hectare, for those landowners that have established forest plantations with their own resources. These constitute less than 1% of ESP contracts.

Reforestation has in fact recently been excluded from the scheme because the higher rewards given for this compared to forest conservation contracts were a disincentive to go into conservation. This represents an important lesson, as it demonstrates that such schemes are dynamic and need to be responsive to the overall goals and objectives of the program.

Principal sources of funding for the program include a tax on fuel sales, payments to FONAFIFO (National Forest Financing Fund) from private sector renewable energy producers for the conservation of critical watersheds, and through the sale of Certified Tradable Offsets or carbon bonds derived from forest ecosystems[32]. Landowners cede their

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[32] However, a study recently published in the Proceedings of the National Academy of Science documents that forests in Costa Rica that were monitored between 1994 and 2000 may have switched from "carbon sinks" to "carbon sources"; indicating that there is still significant lack of understanding of carbon cycles in tropical forests.

greenhouse emissions reduction rights to FONAFIFO to sell to the international market. Financing is also coming from municipalities, and companies in need of a reliable supply of clean water. The Ecomarkets project is funded by the Government of Costa Rica, the World Bank, the GEF, and bilateral development agencies. The project commenced in 2000 and is ongoing.

Tools and monitoring processes

Geographic information systems are used to visualize, manipulate, analyze and display spatial data. The key attribute of the system is that it links databases to maps and is interactive. In other words, one can ask questions of the system (such as compliance with contracts with the individual landowners – on management plan, prevention of forest degradation, control of illegal hunting). There is, however, a need for more direct monitoring and tracking.

Some broader level program indicators, which have been tracked include:

- 100,000 hectares of land contracted as conservation easements in the Mesoamerican Biological Corridor project in Costa Rica (corridors, connectivity, reduced fragmentation; see case study no. 8)
- indicators to track increased participation of women landowners and indigenous communities in the ESP program over time
- increased local capacity to value and market environmental services, as measured through technical studies and introduction of market mechanisms

Sources of information

The World Bank (May 2000). "Appraisal Document on a Proposed IBRD Loan of US$32.6 million and A Grant from the GEF Trust Fund of $8 million to the Government of Costa Rica for the Ecomarkets Project".

6.3.3 Case study 3. Finland: Environmental Assessment of the national climate strategy

Finland is committed to meet the targets for the reduction of greenhouse gases based on the Kyoto Protocol and as agreed in the burden sharing decision within the European Union (EU). A suite of measures was envisioned to meet these targets. According to Section 24 of the Finnish legislation on environmental impact assessment "Environmental impact shall be investigated and assessed to a sufficient degree when an authority is preparing policies, plans and programmes which may have significant environmental impact once implemented...". A national climate strategy meets by definition the condition of significant environmental impacts and hence emphasise the need for a broad assessment of the possible impact of the strategy (see also chapter 5). This case illustrates the strategic environmental assessment approaches applied in Finland when the national climate strategy was developed.

Under the guidance of an inter-Ministerial group, a concrete framework was conceived which included three basic scenarios (a baseline and two alternatives) for the preparation of the national climate strategy. These scenarios were quantified in technical and economic terms by expert institutions. The assessment framework was developed under the guidance of a steering group with representatives of all key ministries and in co-operation with those responsible for the technical and economic assessments. This resulted in a review process that focused the assessment and ensured its scientific quality. It also meant that the overall assessment became multi-dimensional with explicit links between environmental, technical, economic and social aspects. The environmental assessment was based on the very same scenarios but required further a selection of the variables to be assessed and a specification of methods to be used. The environmental assessment covered all measures of the key sector Ministries (Environment, Agriculture and Forestry, Transport and Telecommunications, Trade and Industry). Stakeholder participation was a critical part of the assessment and provided information on perceived characteristics of the scenarios and also on risks and opportunities associated with the scenarios. All assessments, plans and results were made public.

The baseline scenario was developed assuming a yearly economic growth of 2.3 %, including a growth in production industries (such as paper, cardboard and steel). Population growth is assumed to be low, increasing from 5.19 million to 5.29 million in 2020. Assumptions were also made concerning the price of oil (USD 25/barrel until 2010, thereafter gradual increase to 30 USD in 2020) and the price of natural gas (20 % increase until 2010, 48 % until 2020 compared with the price level in 2000). The alternative scenarios were developed by assuming a program supporting the development of renewable energy resources and a program aiming at saving energy in buildings and households. In one scenario an additional 1300 MW nuclear power plant was assumed whereas the other included an explicit prohibition to use coal in the production of electricity. To complete the scenarios energy taxation was raised in order to meet the Kyoto Protocol targets by 2010 as agreed in the burden sharing decision within the EU. This means that the difference between the two alternative scenarios amounted to alternative ways of producing additional energy and to relatively small differences in the energy taxation.

The technical, economic and environmental assessments provided an analysis of the energy use, greenhouse gas emissions, costs and environmental effects of the different scenarios until 2020. A synthesis of the available information was produced using the strategic SWOT (strengths, weaknesses, opportunities, and threats) analysis approach. A general observation was that the measures planned in the alternative scenarios would be generally beneficial compared to the baseline. However, the differences between the alternative scenarios were small when done over a 10-year period, and were slightly larger when the analysis was extended to 20 years, but still limited. The SWOT analysis further confirmed that the two alternatives did not make a great difference; but rather the factors assumed constant in the model (such as level and structure of energy taxation, electricity imports) would change the course of developments more than the measures assumed. The technical and economic assessments were linked and thus the different aspects of the climate strategy could be subject to a simultaneous and balanced public review instead of dealing with one issue (environment, technology, economics, social) at a time.

The assessment revealed that the scenarios were variations on a theme rather than explorative of distinctly different situations. The assessment concluded that the scenarios were myopic and too narrow in scope, and unable to capture all concerns and arguments on possible energy futures – thus limiting the scope for a broad public discussion. The Parliament made extensive use of the SWOT results in its discussions of the strategy and confirmed that the proposed strategy was myopic. It has since requested some widening of the scope of analyses. This work is now part of the government's programme.

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Kemppi, H., Perrels, A., and Lentilä, A. 2001. Suomen kansallisen ilmasto-ohjelman taloudelliset vaikutukset. [The economic effects of the Finnish national climate strategy]. Government Institute for Economic Research, VATT-Research Reports 75, 114 p.

6.3.4 Case study 4. Madagascar: Masaola National Park Integrated Conservation and Development Program

The Masaola National Park in Madagascar is composed of 2300 km^2 of primary rain forest and is surrounded by a 1000 km^2 buffer of unprotected forests. Slash and burn farming for subsistence rice production represent the current principal threat to these forests. To counter deforestation, the Masaola Integrated Conservation and Development Project's (ICDP) strategy is to create economic incentives for conservation, by working with local communities. Besides local incentives, incentives at the national and global scales are also important considerations. Several timber companies were prospecting for concession in the Masaola Peninsula during the time the National Park was being established, and the government nearly abandoned the park project in favor of a logging company. The conservation and diplomatic community played a large role in persuading the government to reject the logging proposal However, conservation is most likely to succeed only when benefits outweigh costs at the scales of all relevant stakeholders.

The authors estimated the cost of conservation from local, national and global perspectives for the National Park. Conservation generated significant benefits over logging and agriculture locally and globally. Nationally, however, financial benefits from industrial logging exceeded the ICDP's conservation value even when the lowest estimates of revenue generated by logging were used.

The loss of Masaola's forest would be a significant economic cost to the international community ($68 million to $645 million). This estimate is based on the damages avoided by preventing greenhouse gas emissions from the deforestation that would otherwise occur in the ICDP, using a damage cost of $20/ t C based on conservative assumptions. Based on a unit cost of conserving carbon of between $ 0.84/tC and $ 15.9/tC; and a partitioning of these costs into global cost (foreign aid for forest protection) and Madagascar's cost (opportunities foregone) they estimate that regardless of opportunity costs scenarios, when Madagascar conserves forests, it is paying 57% to 96% of the total costs, while it would benefit relatively little from reduced greenhouse gas emissions.

The authors conclude that similar split-incentive situations exist, and that the Kyoto Protocol could secure net local, national and global benefits equitably by recompensing nation for the opportunity costs of conservation through global transfers under the CDM. However, under current CDM rules, avoided deforestation is not eligible during the first commitment period, and the earliest this could be a possibility would be in 2012 when the rules for the next commitment period will commence.

Local, national and global net benefits for ICDP

Discount rate	3%		10%		20%	
Time span	10 years	20 years	10 years	20 years	10 years	20 years
			$ 1996 x 10^3			
Impact of ICDP: Local economy net benefit	206	527	143	237	92	114
National net benefit	-82	-264	-50	-108	-27	-41
Global net benefit	181	645	116	254	68	100

Notes: Local economy net benefit estimate includes: sustainable community forestry, ecotourism, non-timber forest products (NTFPs), hill rice, and opportunity cost of large scale forests; National net benefit estimate includes: donor investments, ecotourism, sustainable community forestry/biodiversity products, sustainable use of NTFPs, watershed protection value, park/buffer management costs, opportunity cost: industrial logging, and hill rice farming; Global net benefit estimate includes: carbon conservation value, and donor investment.

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6.3.5. Case study 5. Belize and the United States: Rio Bravo Climate Action Project

The Rio Bravo climate action project involves the conservation and sustainable management of more than 123,000 acres of mixed lowland, moist subtropical broadleaved forest in northwest Belize. It is estimated that the project will sequester approximately 2 million metric tons of carbon during the next 40 years by preventing deforestation and ensuring sustainable forest management. This demonstration project is implemented under the UNFCCC pilot phase Activities Implemented Jointly (AIJ) through registration with U.S. Initiative on Joint Implementation (as opposed to the JI under article 12 of the Kyoto Protocol that is between Annex 1 countries).

Programme for Belize (PfB), a local NGO, was launched in 1989. It manages the project and has over the years started to progressively acquire land. Currently, the Rio Bravo Conservation Management Area comprises four parcels of land, acquired between 1989 and 1995. The project has a duration of 40 years. A number of energy producers provided $5.6 million in funding for the first 10 years. Investors include Cinergy Corporation, The Detroit Edison Company, Nexen Inc., PacifiCorp, Suncor Energy Inc., Utilitree Carbon Company and Wisconsin Electric Power Company. Long-term funding mechanisms, including establishment of an endowment fund, will help to support the project beyond its initial funding.

The Rio Bravo Conservation and Management Area is situated amid the biologically rich Mayan forest. It is part of a million-acre corridor that is key to biodiversity conservation in Central America and one of the Conservancy's top conservation priorities. The area is home to the endangered black howler monkey and jaguar, numerous migratory birds, mahogany and other important tree species. It contains forest cover types protected nowhere else in Belize. The project site was under imminent threat of conversion to agriculture. Studies undertaken before the project began indicated that without further protection, up to 90 percent of the forest cover would have been converted to agricultural use. The conservation of this area, and the connectivity provided by the biological corridor may increase the resilience and adaptation of the species to climate change impacts.

The project is expected to reduce, avoid or mitigate an estimated 2.4 million tons of carbon through two primary approaches: (a) Program for Belize purchased 33,000 acres of upland forest and added it to the existing protected area. Estimated carbon emissions avoided from this component are 1.7 million tons over the duration of the project (b) Sustainable forest management and regeneration: on approximately 90,000 acres of land, a combination of improved timber operations and ecosystem management practices will sequester more than 600,000 tons of carbon. Management practices include creation of undisturbed buffer areas and protection zones; reduced-impact harvesting techniques; and enhanced fire management and site security.

Various project activities provide jobs and training in forestry, forest management and park security. Improved road maintenance and other infrastructure improvements benefit communities that border the area.

Tools and monitoring processes

Program for Belize employs a rigorous monitoring protocol designed by Winrock International. Data on forest growth and recovery are collected periodically from nearly 200 permanent sample plots and analyzed to determine the net carbon benefit of the project.

Certification. The forest management plan is certified by Smart Wood and Woodmark. The field assessment for the application of certification guidelines included a reflection of the social and environmental conditions found in Belize. Control of fire and illegal wood harvesting in the project area help reduce unintended loss of forest and new emissions of carbon dioxide.

Additionality. The carbon benefits are clearly additional to what would have occurred without the project. Other parties would have purchased the newly acquired land and converted it to agricultural production. Also the land now under natural forest management plan would have been logged under customary practices.

Leakage. The project ensures that all carbon benefits achieved within the project boundaries are not negated by actions off site caused by the project. Working with local communities allows PfB to track logging and agricultural activities outside the project site that might result in leakage.

Sources of information

http://www.pfbelize.org
http:/www.nature.org/aboutus/projects/climate/work

6.3.6 Case study 6. Sudan: Community Based Rangeland Rehabilitation for Carbon Sequestration

The Community Based Rangeland Rehabilitation Project conducted within Gireigikh rural council of Bara Province of North Kordofan State has two main objectives. The first objective was to create a locally sustainable natural resource management system that would both prevent overexploitation of marginal lands and rehabilitate rangelands for the purpose of carbon sequestration, preservation of biodiversity, and reduction of atmospheric dust. The second objective was to reduce the risk of production failure in the drought-prone area by increasing the number of alternatives for sustainable production strategies, thereby leading to greater stability for the local population.

From a local villager perspective, global warming is clearly not a major concern: whereas food and water security are overriding concerns. One of the attractive features of the project's design is that it pursued several key areas in parallel, namely poverty alleviation, natural resource management, technology transfer, and women in development. By identifying local obstacles and challenges to securing long-term carbon storage in rural communities, this pilot project provides some very useful lessons for the ongoing discussions on the CDM front. Specific measures which have contributed to the villagers' near term needs include fodder production, livestock restocking, development of village-level irrigated gardens, improved cook stoves, introduction of revolving credit systems, and drought contingency planning. The spontaneous replication of the project activities beyond the selected villages is testimony of the benefits to communities.

From the perspective of delivery of biodiversity and carbon benefits there are some very useful lessons. The consideration and tracking of biodiversity improvements in the project are lacking, and rest on the premise that enhanced biodiversity will be a co-benefit of project activities. Although the ecology of the rangelands was improved through the various interventions targeted to resource management, the systematic attention to biodiversity issues: oversight, monitoring and evaluation has not been satisfactory. In fact, the biodiversity goals of the project were further compromised due to budgetary constraints.

The attention given to carbon sequestration was more defined. In this context, the project provides some useful lessons on the ongoing discussion and debate relating to carbon accounting. For example, when defining the end of project situation regarding carbon storage, an implicit though unstated assumption in the project document was that no further land degradation would take place in the project area over the next 20 years. That is, incremental carbon sequestration benefits were measured against a static baseline, thus underestimating potential benefits of the project. The table below provides a summary of carbon sequestration benefits claimed in the project document. The evaluation of the project concluded that only the direct benefit of 5 400 t of carbon is firm, subject to evaluation and verification. The remaining levels of carbon sequestration that claimed are evaluated in qualitative terms only. The lack of a suitably designed and vetted program to quantify the carbon sequestration benefits achieved by project activities calls into question the credibility of project claims in this regard. There is insufficient evidence, at the present time, to quantify with confidence the linkage between the supportive development activities and actual levels of carbon sequestered. Nevertheless the project provides some useful lessons on the ongoing discussion and debate relating to carbon accounting

Summary of carbon sequestration benefits (in tons of carbon) claimed in the project document

	"Direct" Benefits[33]			"Indirect" Benefits		
Project Activity	At end of project	Expected after 20 years	Total (after 20 years)	Expected after 20 years	Inferred after 20 years	Total (after 20 years)
Rangeland management	0	10,128	10,128	27,731	0	27,73
Rangeland improvement	3,000	0	3,000	4,000	0	4,000
Dune stabilization	210	405	615	2,835	5,265	8,10
Windbreaks	2,190	2,450	4,640	4,220	4,690	8,910
Total	5,400	12,983	18,383	38,786	9,955	48,741

The most pressing conclusion emerging from the terminal evaluation is that the project strategy to rehabilitate and improve marginal lands has demonstrated the potential to enhance carbon sequestration. The appeal of carbon sequestration in semi-arid areas as in Sudan lies in its spatial potential rather than its carbon intensity per unit of land area. That is, even though carbon sequestration levels are low in semi-arid rangelands in Sudan compared to tropical forests, potential carbon storage levels could be very large given the enormous rural land resources available. Investors under future CDM regime may consider investments in Sudan attractive if they can be persuaded that the vast spatial potential is not only accessible but also amenable to alternative, long-term, and verifiable rangeland management strategies.

The project commenced in 1995 and concluded in 2001. The project received a grant of $1.5 million from GEF and had co-financing of $90,000.

Sources of information

Sudan: Community Based Rangeland Rehabilitation for Carbon Sequestration and Biodiversity. Project Document (1992). GEF, Washington, D.C.

Dougherty, B; Abusuwar, A; Razik, K.A. (2001) Community Based Rangeland Rehabilitation for Carbon Sequestration and Biodiversity. Report of the Terminal Evaluation. UNDP.

6.3.7 Case study 7. Britain and Ireland: Climate Change and Nature Conservation

In seeking to understand the implications of climate change for nature conservation policy and practice in Britain and Ireland, a consortium of government agencies and NGOs began a major program of research, ‘Modeling Natural Resource Responses to Climate Change’ (MONARCH),

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[33] Direct benefits are those from the selected villages; indirect benefits from positive leakage. The project duration is 5 years, and carbon benefits estimate for 20 years.

in August 1999. The consortium is led by English Nature (the government nature conservation agency in England) and the research carried out by a team of scientists brought together by the Environmental Change Institute, University of Oxford.

The MONARCH project is a phased investigation into the impacts of climate change on the nature conservation resources of Britain and Ireland. The main objective of the first phase of the study was to develop an understanding of the broad-scale responses of key species and habitat types across England, Wales, Scotland and Ireland. This was investigated by linking established impact models with coherent bioclimatic classes. Definitions of 21 bioclimatic classes were developed using sophisticated statistical techniques, and for each class a range of nature conservation attributes (including characteristic habitat types, geological and geomorphological features, and percentage cover of designated nature conservation sites) were obtained. Existing simulation models were then adapted for application in terrestrial, freshwater and coastal environments, and conceptual models produced for geological/geomorphological features and the marine environment. The impacts on these were studied by applying the range of climate scenarios to the models to the range of climate change scenarios for the 2020s and 2050s produced by the UK Climate Impacts Programme in 1998. An important part of this work involved mapping the available climate space under each scenario for around 50 species associated with priority habitat types.

The outputs of the first phase of the project include a technical report, a summary report and, because of the innovative nature of the research, a series of papers in Journal for Nature Conservation. The technical report describes the methods used in the study, the range of impact scenarios produced, and an interpretation of the results. The latter has raised some fundamental challenges to current policies for conserving biodiversity and the long-term management of the nature conservation resource, both in designated sites and the wider countryside:

Nature conservation policies must be more flexible and forward looking, with objectives set within a dynamic framework that can adjust to the changing distribution of species and habitat types and to the rate of this change. International collaboration will be needed to assist in the conservation of some species and discussions between countries on the implications of climate change for conservation policy should be encouraged. In particular, the mechanisms for conserving biodiversity (e.g. habitat recreation) should make provision for possible species' movements and changes in habitat composition as climate continues to change. Awareness of climate change impacts needs to be raised amongst policy-makers, planners, practitioners and the general public.

The resilience of existing designated sites should be improved through management and buffer zones to minimize stresses on existing species and to provide opportunities for the development of new communities. Greater integration is needed between nature conservation and other land uses, which themselves should address the implications of climate change. Optimum locations, sizes and shapes for new nature conservation sites also need consideration. The effectiveness of species' translocations, wildlife corridors and stepping-stones in the context of climate change requires further research. Consideration should also be given to the conservation of species ex situ (e.g. in botanic gardens). The issue of non-native species, their potential spread, their contribution or threat to conservation value, and their source and rate of influx needs to be addressed.

The methodologies developed in the first phase of MONARCH were aimed at broad-scale assessment and understanding. Whilst this was an essential 'first step', it was always recognized that the approach would need further development if potential changes in species' distribution and dispersal were to be captured at a range of spatial and temporal scales, and the implications for ecosystem function understood. Therefore, in a second phase of MONARCH, downscaled versions of the models used in MONARCH 1 and a dispersal model, which will be used in conjunction with predictions for land cover change, are being developed. These will be used to assess the likelihood of species keeping pace with potential climate change and occupying their future climate space. In addition, the implications of changing species' distributions for ecosystem composition and processes are being explored by linking model outputs with conceptual models of ecosystem function. This work began in October 2001 and, following refinement, will be tested in a number of case study areas in Britain and Ireland - using the UK Climate Impacts Programme's 2002 climate change scenarios. The second phase of MONARCH should be completed in spring 2004 and will further inform the adaptation of nature conservation policy and management practice to climate change impacts.

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6.3.8 Case study 8. Central America and Mexico: Mesoamerican Biological Corridor

In Mesoamerica — Southern Mexico and the seven countries of Central America — 44 hectares of forest are lost every 60 seconds, mostly to satisfy the demand for firewood. If this were to continue unabated, the area would be virtually without forest in a decade and a half. The Mesoamerican Biological Corridor (MBC), crossing a diverse landscape of approximately 768,990 square km, accounts for about 8% of the earth's biodiversity. The goal of the MBC program is the recovery of "the chain of forests that up to a few years ago united South and North America and which at this time appears as a series of barren patches threatened by indiscriminate felling". While directed towards revitalizing the natural corridor from Mexico in the north to Panama in the southeast, the initiative "is by no means focused exclusively on protecting the animals, plants and microorganisms which inhabit the tropical forests, but will provide benefit on a priority basis to the people who live there, to all Mesoamericans and, by extension, to the entire world". The project is anticipated to be an 8-year program (1998-2005), and had initial funding for about $24 million, with about $ 11 million from the GEF.

To achieve all these things, the program is being built upon two main pillars. The first and better known is biodiversity conservation. This includes strengthening the existing protected areas and building links among them. The second pillar is the sustainable use of the resources of the region. Environmentally friendly agricultural pursuits — including organic food production — as well as ecotourism, pharmaceutical prospecting and reforestation have been identified as possible areas of activity and investment. This project builds upon all regional and in-country initiatives to collaboratively form conservation and sustainable use programs and harmonization of regional policies.

331. Technically, biological corridors are geographic extensions whose function is to connect areas in order to sustain the distribution of fauna and flora and provide natural conditions that assure their conservation and that of essential habitats. These habitats are those ecosystems which are (a) used by the biota in at least one critical stage of its life cycle; (b) composed of a significant combination of abiotic characteristics (e.g. hydrology, geology, geomorphology) and biotic characteristics (e.g. high biodiversity, productivity); (c) of great structural complexity; and (d) areas that are used for reproduction, mating, nourishment and protection.

332. The MBC has been conceived as a super-corridor enveloping many corridors, or as a program encompassing many projects. At the moment, it is still hard to understand fully the areas of overlap and disagreement, as a series of dichotomies may be observed, between the regional and the national, and between local environmental management by the communities themselves or by an external agency. The idea of the corridor has been well received by the local communities, but until now, the local impact has been weak from a social and economic point of view. The principal future challenge of the initiative will be to decide how national sustainable development strategies can be linked to the regional scope. There has been progress on this front. The operational planning exercises performed in 2001 resulted in the decision that the implementation of the project will be defined at the national level.

The physical scale and extent of the MBC program would in reality provide species significant scope to adapt to impact of climate change by providing them the latitude and altitudinal habitats to do so. However, to date the scope for the MBC to contribute to adaptation has not been considered systematically at a programmatic level. It is important that the scientific work and experiments for such adaptation is commences as soon as possible. The scope for this program to contribute also to greenhouse gas mitigation through avoided deforestation (in the protected areas), afforestation, reforestation; as well as agroforestry is significant. These options too have not yet been addressed explicitly or aggressively in the national and regional components of the program.

334. Although the MBC represents a regional link to sustainable development with the objectives of the CBD, it has tremendous opportunity to leverage action from the UNFCCC.

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6.3.9. Case study 9. Uganda and Norway/Private investor: Tree plantations for carbon credits

Tree Farms (TF), a private Norwegian company, piloted a tree plantation scheme in Uganda in anticipation of the Kyoto Protocol and its CDM. The aim here was to seek afforestation and reforestation of lands. The project commenced in 1996 and is ongoing. TF's subsidiary in Uganda, Busoga Forestry Company Ltd., entered into an agreement with the Ugandan authorities to lease for a period of 50 years, an area of 5,160 ha in the Bukaleba Forest Reserve. It is anticipated that 4,260 ha will be plantations, and the rest used for infrastructure and protection of existing natural forests. The rest of the 8,000 ha reserve is under lease to a German company. TF has the option to renew the contract for another 50 years. The Ugandan forest authorities will receive a one-off sum of $500,000 shillings (NOK 2,600) for the contract as well as an annual rent of 5,000 shillings for each hectare planted with forest. This rent would be adjusted every 10 years to reflect inflation. The rental agreement implies commitment to planting forest and conducting modern forestry within the concession area. No rent is paid for areas not planted with trees.

Tree Farms has planted about 600 hectares, mainly with fast growing pines (Pinus caribaea, P. oocarpa, P. tecunumani) and eucalypts (Eucalyptus grandis). On some smaller plots, the company has also planted the local tree species musizi (Aesopsis emini), mahogany (Khaya anthoiheca) and Musambya (Macadanua lutea). The total investment to date by TF has been NOK 5-6 million. The issues from the perspectives of the key stakeholders' vis-à-vis the agreement as it stands are as follows:

- The lack of information and understanding of the Kyoto Protocol and carbon trading on the part of the host government when negotiating the terms of the agreement has resulted in a feeling that they had been taken advantage of and have ended up with low prices on a land lease of fairly long duration (50 years). The realization that opportunity cost of the land had not been factored in, nor the potentially lucrative returns from carbon trading has resulted in tensions that have mounted further due to some of the activities of the investors. In particular, the investors have been planting parts of the leased land (within the F.R.) with maize but for which the authorities receive no rent, as the agreement requires payment only when trees are planted. This practice of planting maize in a forest reserve selling the maize in the market, and competing with local farmer produce is not viewed positively.
- The Bukaleba Forest Reserve has been used by the local communities since the 1960s; and although they were evicted in the early 1990s they have over the years continued to move back into the reserve, with some claiming ownership of some of the reserve land. The authorities do not have the capacity to control this movement, and a study in 1999 estimated about 8,000 people living in the reserve. What is interesting, is that the efforts of the farmers in preparing the land for farming benefits the TF as it prepares the land for tree planting (since a taungya system is practiced in the leased land – i.e. trees are planted with an understory of crops). While the farmers are not paid for their labor, they are required to pay rent to TF for farming the leased land. With a lack of alternative livelihoods, the Tree Farms project is viewed as a threat tot the locals.
- It is estimated that the carbon profits after the 25-year period based on CICERO (Centre for International Climate and Environmental Research Oslo) figures could range anywhere from NOK 85-266 million[34], depending on the price per ton of CO_2. In contrast the rent to the Ugandan authorities will be NOK 2.8 million[35]. TF will also have further income from the sale of timber and wood. It is anticipated that the profits may be less than anticipated due to a variety of reasons, although the asymmetry of gains between the two partners is still likely to be significant.
- There is great uncertainty as to the net amount of carbon that will be sequestered, especially in the face of an estimated 8,000 people who may clear new areas and forests in order to earn a living. The trees have suffered from constant pruning, uprooting of tree seedlings, termite attacks and insufficient weeding. The planting of new areas is behind schedule, and with profits being questionable, people have sought to plant maize to generate some short-term profits. All of this may lead to carbon sequestration lower than expected by project developers.
- If this project were to contribute to sustainable development, which is seen as an objective for developing countries to undertake CDM type projects, the design of this project would have benefited from explicit attention to environmental, social and economic dimensions.

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[34] 4,260 ha x 500 tons of CO2 x NOK 125 (or 85 for the lower scenario)

[35] 4,260 ha x NOK 26 x 25 years.

It is evident that the key partners either did not have all the necessary information, nor did they address these issues explicitly and directly when designing the project. Disregard of social and environmental issues during planning and negotiation of agreements has resulted in land conflicts that undermine the security of the forest plantations for carbon credits for the investors, and livelihood security of the communities, and sustainable forest management for the Ugandan forest authorities. There is also no clear process for conflict resolution, arbitration, or adaptive management to help resolve the problems.

- This project is not yet validated for carbon credits as the modalities of CDM are still under discussion. But it does showcase some of the challenges not just in terms of information asymmetry, but perhaps the need for some minimum standards of conduct of private entities when purchasing credits used towards emission reductions back in their parent country. Just as the host country of a CDM project would set the acceptable Environmental Impact Assessment —as well as social standards—of a project, it may be useful for the parent country of private entities to set some minimum norms or rules of conduct to guarantee the use of these credits towards national targets.

Sources of information

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6.3.10. Case study 10: Romania and Prototype Carbon Fund (PCF): Afforestation of Degraded Agricultural Land Project

The Afforestation of Degraded Agricultural Land Project proposes to afforest 6,852 ha of State-owned degraded agricultural lowlands in 7 counties in the southwest and southeast of the Romanian Plain. In the southwest, the Project would stabilize soils through the planting of semi-naturalized species (Robinia pseudoacacia). In the southeast, ecological reconstruction of 10 islets making up a natural park and Ramsar site in the Lower Danube (Small Island of Braila) would occur through the planting of native species (Pupulus alba, Pupulus nigra, Salix spp., Quercus spp.). Strictly speaking under the rules of Article 3 of the Kyoto Protocol, afforestation will occur on land deforested for at least 50 years, i.e. on most of the lands in the southwest, while reforestation will take place on lands deforested within the last 50 years but before December 31, 1989. The main features of the project are:

Climate change mitigation through carbon sequestration: It is estimated that the project will sequester around 1 million tonnes of carbon dioxide equivalent, or around 278,000 tC over a period of 15 years. Field samples made on comparable plantations suggest that these estimates are conservative. About 80 percent of this tonnage would be stored in vegetation, the rest in soils.

Use of carbon finance to restore forests on degraded land: Romania has a very ambitious policy of expanding its forest cover by 100,000 hectares of degraded land in the coming years. However, statistics for the past decade reveal that afforestation volumes are grossly inadequate to meet that goal (over the period 1991-2001, the average area afforested annually was just under 400 hectares). One of the key explanatory factors is simply the lack of financing to the National Forest Administration (NFA), which is the public, yet financially autonomous, agency entrusted with the management of public forests.

Romania was the first industrialized (Annex 1) country to ratify the Kyoto Protocol and is now becoming the host to a few investment projects under Article 6 of the Protocol (joint implementation). Under Article 6, another industrialized country financier (in this case the countries to which the 23 Prototype Carbon Fund Participants belong) makes it possible for a climate mitigation project to occur, in return for which it acquires the titles to the offsets that are generated by the project in the host country (in this case Romania).

The Prototype Carbon Fund (PCF) administered by the World Bank on behalf of 23 public and privates entities is the agent of such buyers. The PCF will sign an Emission Reductions Purchase Agreement (ERPA), a long-term contract providing for the delivery by the NFA to the PCF of just over one million tonnes of carbon dioxide equivalent at an agreed-upon price. The PCF's financial contribution gives the NFA the financial incentive to undertake the necessary $10 million investment. The project commenced in 2002, and has a 15-year crediting period (until 2017).

Tools and monitoring processes

The project will rely on a very detailed Monitoring Plan designed by the NFA and the PCF, at the heart of which is the NFA's annual regeneration control. Monitoring is crucial to this project as the PCF will execute its payments to the NFA on the annual delivery of independently certified tonnes of carbon. Without monitoring, this output-based system collapses.

- Monitoring will occur for the whole duration of the project, i.e. 15 years.
- Carbon sequestration is the main but not the only monitoring indicator in the project. The Monitoring Plan provides for one indicator of biodiversity enhancement to be monitored, namely the number of bird species in project sites.
- Social benefits will be monitored as well. In addition, compliance with World Bank Safeguard Policies (Box 5.2) entailed some requirements under the Bank's Policy on Involuntary Resettlement. Given that the project will render the earlier creation of a natural park binding and adversely impact the livelihoods of a few local communities practicing seasonal animal grazing on the Small Island of Braila, the Policy mandates that a special participatory process be followed to determine how the affected population could be compensated.
- Additionality. The carbon and biodiversity benefits are clearly additional to what would have occurred in the baseline scenario, as the evidence for the past decade suggests.
- Leakage. The project ensures that all carbon benefits achieved within the project boundaries do not come at the expense of similar benefits already achieved in the baseline scenario. A level of 400 ha of afforestation of degraded land will have to be maintained in addition to the project's achievement.

Sources of information

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APPENDIX I.

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APPENDIX II.
GLOSSARY OF TERMS

Adaptation
Adjustment in natural or human systems to a new or changing environment. Adaptation to climate change refers to adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation.

Adaptive capacity
The ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.

Aerosols
A collection of airborne solid or liquid particles, with a typical size between 0.01 and 10 mm that reside in the atmosphere for at least several hours. Aerosols may be of either natural or anthropogenic origin. Aerosols may influence climate in two ways: directly through scattering and absorbing radiation, and indirectly through acting as condensation nuclei for cloud formation or modifying the optical properties and lifetime of clouds.

Afforestation
Planting of new forests on lands that historically have not contained forests.

Agroforestry
Planting of trees and crops on the same piece of land.

Albedo
The fraction of solar radiation reflected by a surface or object, often expressed as a percentage. Snow covered surfaces have a high albedo; the albedo of soils ranges from high to low; vegetation covered surfaces and oceans have a low albedo. The Earth's albedo varies mainly through varying cloudiness, snow, ice, leaf area, and land cover changes.

Benthic
Referred to the collection of organisms living on or in sea or lake bottoms.

Biofuel
A fuel produced from dry organic matter or combustible oils produced by plants. Examples of biofuel include alcohol (from fermented sugar), black liquor from the paper manufacturing process, wood, and soybean oil.

Biomass
The total mass of living organisms in a given area or volume; recently dead plant material is often included as dead biomass.

Biome
A grouping of similar plant and animal communities into broad landscape units that occur under similar environmental conditions.

Bog
A poorly drained area rich in accumulated plant material, frequently surrounding a body of open water and having a characteristic flora (such as sedges, heaths, and sphagnum).

Boreal forest
Forests of often dominated pine, spruce, fir, and larch stretching from the east coast of Canada westward to Alaska and continuing from Siberia westward across the entire extent of Russia to the European Plain.

C_3 plants
Plants that produce a three-carbon compound during photosynthesis, including most trees and agricultural crops such as rice, wheat, soybeans, potatoes, and vegetables.

C_4 plants
Plants that produce a four-carbon compound during photosynthesis (mainly of tropical origin), including grasses and the agriculturally important crops maize, sugar cane, millet, and sorghum.

CH_4
See methane

Carbon dioxide (CO_2)
A naturally occurring gas, and also a by-product of burning fossil fuels and biomass, as well as land-use changes and industrial processes. It is the principal anthropogenic greenhouse gas that affects the Earth's radiative balance.

Carbon dioxide (CO_2) fertilization
The enhancement of the growth of plants as a result of increased atmospheric carbon dioxide concentration.

Climate
Climate in a narrow sense is usually defined as the "average weather" or more rigorously as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period is 30 years, as defined by the World Meteorological Organization (WMO). These relevant quantities are most often surface variables such as temperature, precipitation, and wind. Climate in a wider sense is the state, including a statistical description, of the climate system.

Climate change
Climate change refers to a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer). Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use. Note that the United Nations Framework Convention on Climate Change (UNFCCC), in its Article 1, defines "climate change" as: "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods." The UNFCCC thus makes a distinction between "climate change" attributable to human activities altering the atmospheric composition, and "climate variability" attributable to natural causes. See also climate variability.

Climate model (hierarchy)
A numerical representation of the climate system based on the physical, chemical, and biological properties of its components, their interactions and feedback processes, and accounting for all or some of its known properties. The climate system can be represented by models of varying complexity—that is, for any one component or combination of components a "hierarchy" of models can be identified, differing in such aspects as the number of spatial dimensions, the extent to which physical, chemical or biological processes are explicitly represented, or the level at which empirical parametrizations are involved. Coupled atmosphere/ocean/sea-ice general circulation models (AOGCMs) provide a comprehensive representation of the climate system. There is an evolution towards more complex models with active chemistry and biology. Climate models are applied, as a research tool, to study and simulate the climate, but also for operational purposes, including monthly, seasonal, and interannual climate predictions.

Climate projection
A projection of the response of the climate system to emission or concentration scenarios of greenhouse gases and aerosols, or radiative forcing scenarios, often based upon simulations by climate models. Climate projections are distinguished from climate predictions in order to emphasize that climate projections depend upon

the emission/concentration/radiative forcing scenario used, which are based on assumptions, concerning, for example, future socio-economic and technological developments that may or may not be realized, and are therefore subject to substantial uncertainty.

Climate scenario
A plausible and often simplified representation of the future climate, based on an internally consistent set of climatological relationships, that has been constructed for explicit use in investigating the potential consequences of anthropogenic climate change, often serving as input to impact models. Climate projections often serve as the raw material for constructing climate scenarios, but climate scenarios usually require additional information such as about the observed current climate. A "climate change scenario" is the difference between a climate scenario and the current climate.

Climate system
The climate system is the highly complex system consisting of five major components: the atmosphere, the hydrosphere, the cryosphere, the land surface and the biosphere, and the interactions between them. The climate system evolves in time under the influence of its own internal dynamics and because of external forcings such as volcanic eruptions, solar variations, and human-induced forcings such as the changing composition of the atmosphere and land-use change.

Climate variability
Climate variability refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all temporal and spatial scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability). See also climate change.

Community
The species (or populations of those species) that occur together in space and time, although this cannot be separated from Ecosystems. See ecosystems.

Coral bleaching
The paling in color of corals resulting from a loss of symbiotic algae. Bleaching occurs in response to physiological shock in response to abrupt changes in temperature, salinity, and turbidity.

Deforestation
Conversion of forest to non-forest.

Ecosystem
A system of dynamic and interacting living organisms (plant, animal, fungal, and micro-organism) together with their physical environment. The boundaries of what could be called an ecosystem are somewhat arbitrary, depending on the focus of interest or study. Thus, the extent of an ecosystem may range from very small spatial scales to, ultimately, the entire Earth.

Ecosystem services
Ecological processes or functions that have value to individual humans or societies.

El Niño Southern Oscillation (ENSO)
El Niño, in its original sense, is a warm water current that periodically flows along the coast of Ecuador and Peru, disrupting the local fishery. This oceanic event is associated with a fluctuation of the intertropical surface pressure pattern and circulation in the Indian and Pacific Oceans, called the Southern Oscillation. This coupled atmosphere-ocean phenomenon is collectively known as El Niño Southern Oscillation, or ENSO. During an El Niño event, the prevailing trade winds weaken and the equatorial countercurrent strengthens, causing warm surface waters in the Indonesian area to flow eastward to overlie the cold waters of the Peru current. This event has great impact on the wind, sea surface

temperature, and precipitation patterns in the tropical Pacific. It has climatic effects throughout the Pacific region and in many other parts of the world.

Endemic
Restricted to a locality or region. With regard to human health, endemic can refer to a disease or agent present or usually prevalent in a population or geographical area at all times.

Erosion
The process of removal and transport of soil and rock by weathering, mass wasting, and the action of streams, glaciers, waves, winds, and underground water.

Evapotranspiration
The combined process of evaporation from the Earth's surface and transpiration from vegetation

Extinction
The complete disappearance of a species.

Forest
A minimum area of land of 0.05-1.0 hectares with tree crown cover (or equivalent stocking level) of more than 10-30 per cent with trees with the potential to reach a minimum height of 2-5 m at maturity in situ. A forest may consist either of closed forest formations where trees of various storeys and undergrowth cover a high proportion of the ground or open forest. Young natural stands and all plantations which have yet to reach a crown density of 10-30% or tree height of 2-5 m are included under forest, as are areas normally forming part of the forest area which are temporarily unstocked as a result of human intervention such as harvesting, or natural causes, but which are expected to revert to forest (as defined by the Marrakesh Accords).

Fossil fuels
Carbon-based fuels from fossil carbon deposits, including coal, oil, and natural gas.

Fragmentation
Breaking an area, landscape or habitat into discrete and separate pieces often as a result of land-use change.

Gene
A unit of inherited material-a hereditary factor

Global mean surface temperature
The global mean surface temperature is the area-weighted global average of (i) the sea surface temperature over the oceans (i.e., the sub-surface bulk temperature in the first few meters of the ocean), and (ii) the surface air temperature over land at 1.5 m above the ground.

Greenhouse gas
Greenhouse gases are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, the atmosphere, and clouds. This property causes the greenhouse effect. Water vapor (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), and ozone (O_3) are the primary greenhouse gases in the Earth's atmosphere. Moreover there are a number of entirely human-made greenhouse gases in the atmosphere, such as halocarbons and other chlorine- and bromine-containing substances.

Habitat
The particular environment or place where an organism or species tend to live; a more locally circumscribed portion of the total environment.

Ice cap
A dome shaped ice mass covering a highland area that is considerably smaller in extent than an ice sheet.

Ice sheet
A mass of land ice that is sufficiently deep to cover most of the underlying bedrock topogra-

phy, so that its shape is mainly determined by its internal dynamics (the flow of the ice as it deforms internally and slides at its base). There are only two large ice sheets in the modern world, on Greenland and Antarctica, the Antarctic ice sheet being divided into East and West by the Transantarctic Mountains; during glacial periods there were others.

Indigenous peoples
People having a historical continuity with pre-invasion and pre-colonial societies that developed on their territories, consider themselves distinct from other sectors of societies now prevailing in those territories, or parts of them. They form at present non-dominant sectors of society and are determined to preserve, develop, and transmit to future generations their ancestral territories, and their ethnic identity, as the basis of their continued existence as peoples, in accordance with their own cultural patterns, social institutions and legal systems.

Invasive species
An native or (locally) non-native species that invades natural habitats.

Landscape
Groups of ecosystems (eg. forests, rivers, lakes, etc) that form a visible entity to humans.

Land use
The total of arrangements, activities, and inputs undertaken in a certain land cover type (a set of human actions). The social and economic purposes for which land is managed (e.g., grazing, timber extraction, and conservation).

Land-use change
A change in the use or management of land by humans, which may lead to a change in land cover. Land cover and land-use change may have an impact on the albedo, evapotranspiration, sources, and sinks of greenhouse gases, or other properties of the climate system, and may thus have an impact on climate, locally or globally.

Local peoples
People who practice traditional lifestyles (typically rural) whether or not indigenous to region.

Mean Sea Level (MSL)
Mean Sea Level is normally defined as the average relative sea level over a period, such as a month or a year, long enough to average out transients such as waves.

Methane (CH_4)
A hydrocarbon that is a greenhouse gas produced through anaerobic (without oxygen) decomposition of waste in landfills, animal digestion, decomposition of animal wastes, production and distribution of natural gas and oil, coal production, and incomplete fossil-fuel combustion. Methane is one of the six greenhouse gases to be mitigated under the Kyoto Protocol.

Mitigation
An anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases.

N_2O
Nitrous oxide

Net Biome Productivity (NBP)
Net gain or loss of carbon from a region. NBP is equal to the Net Ecosystem Production minus the carbon lost due to a disturbance (e.g., a forest fire or a forest harvest) over a certain time period (normally 1 year).

Net Ecosystem Productivity (NEP)
Net gain or loss of carbon from an ecosystem. NEP is equal to the Net Primary Production minus the carbon lost through heterotrophic respiration over a certain time period (normally 1 year).

Net Primary Productivity (NPP)
The increase in plant biomass or carbon of a unit of area (terrestrial, aquatic, or marine). NPP is

equal to the Gross Primary Production minus carbon lost through autotrophic respiration over a certain time period (normally 1 year).

Non-native species
A species occurring in an area outside its historically known natural range as a result of accidental dispersal or deliberate introduction by humans (also referred to as "exotic species" or "alien species" or "introduced species").

North Atlantic Oscillation (NAO)
The North Atlantic Oscillation consists of opposing variations of barometric pressure near Iceland and near the Azores. On average, a westerly current, between the Icelandic low pressure area and the Azores high pressure area, carries cyclones with their associated frontal systems towards Europe. However, the pressure difference between Iceland and the Azores fluctuates on time scales of days to decades, and can be reversed at times. It is the dominant mode of winter climate variability in the North Atlantic region, ranging from central North America to Europe.

Phenology
The study of natural phenomena that recur periodically (e.g., blooming, migrating) and their relation to climate and seasonal changes.

Photosynthesis
The process by which plants take carbon dioxide (CO_2) from the air (or bicarbonate in water) to build carbohydrates, releasing oxygen (O_2) in the process. There are several pathways of photosynthesis with different responses to atmospheric CO_2 concentrations.

Phytoplankton
The plant forms of plankton (e.g., diatoms). Phytoplankton are the dominant plants in the sea, and are the bast of the entire marine food web. These single-celled organisms are the principal agents for photosynthetic carbon fixation in the ocean.

Population
A group of individuals of the same species which occur in an arbitrarily defined space/time and are much more likely to mate with one another than with individuals from another such group.

Precautionary principle
When dealing with environmental policy, the precautionary principle states that: "when an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause-and-effect relationships are not fully established scientifically".

Primary forest
A forest that has never been logged and that has developed following natural disturbances and under natural processes, regardless of its age.

Rangeland
Unimproved grasslands, shrublands, savannahs, and tundra.

Reforestation
Planting of forests on lands that have previously contained forests but that have been converted to some other use.

Regeneration
The renewal of a stand of trees through either natural means (seeded onsite or adjacent stands or deposited by wind, birds, or animals) or artificial means (by planting seedlings or direct seeding).

Reservoir
A component of the climate system, other than the atmosphere, which has the capacity to store, accumulate, or release a substance of concern (e.g., carbon, a greenhouse gas, or a precursor). Oceans, soils, and forests are examples of reservoirs of carbon. Pool is an equivalent term (note that the definition of pool often includes the atmosphere). The absolute quantity of substance of concerns, held within a reservoir at a specified

time, is called the stock. The term also means an artificial or natural storage place for water, such as a lake, pond, or aquifer, from which the water may be withdrawn for such purposes as irrigation, water supply, or irrigation.

Resilience
Amount of change a system can undergo without changing state.

Scenario (generic)
A plausible and often simplified description of how the future may develop, based on a coherent and internally consistent set of assumptions about key driving forces (e.g., rate of technology change, prices) and relationships. Scenarios are neither predictions nor forecasts and sometimes may be based on a "narrative storyline." Scenarios may be derived from projections, but are often based on additional information from other sources.

Sea-level rise
An increase in the mean level of the ocean. Eustatic sea-level rise is a change in global average sea level brought about by an alteration to the volume of the world ocean. Relative sea-level rise occurs where there is a net increase in the level of the ocean relative to local land movements.

Sensitivity
Sensitivity is the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea-level rise).

Sequestration
The process of increasing the carbon content of a carbon reservoir other than the atmosphere. Biological approaches to sequestration include direct removal of carbon dioxide from the atmosphere through land-use change, afforestation, reforestation, and practices that enhance soil carbon in agriculture. Physical approaches include separation and disposal of carbon dioxide from flue gases or from processing fossil fuels to produce hydrogen- and carbon dioxide -rich fractions and long-term storage in underground in depleted oil and gas reservoirs, coal seams, and saline aquifers.

Sink
Any process, activity or mechanism that removes a greenhouse gas, an aerosol, or a precursor of a greenhouse gas or aerosol from the atmosphere.

Source
Any process, activity, or mechanism that releases a greenhouse gas, an aerosol, or a precursor of a greenhouse gas or aerosol into the atmosphere.

Storm surge
The temporary increase, at a particular locality, in the height of the sea due to extreme meteorological conditions (low atmospheric pressure and/or strong winds). The storm surge is defined as being the excess above the level expected from the tidal variation alone at that time and place.

Streamflow
Water within a river channel, usually expressed in m3 sec-1.

Tectonic
Related to the movement of the earth's crust.

Thermocline
A layer in a large body of water, such as a lake, that sharply separates regions differing in temperature so that the temperature gradient across the layer is abrupt.

Thermohaline circulation
A global ocean circulation that is driven by differences in the density of the sea water which in turn is controlled by temperature and salinity.

Time scale
Characteristic time for a process to be expressed. Since many processes exibit most of their effects early, and then have a long period during which they gradually approach full expression, for the purpose of this report the time scale is numerically defined as the time required for a perturbation in a process to show at least half of its final effect.

Tundra
A level, or gently undulating plain characteristic of arctic and subarctic regions dominated by small woody and herbaceous plants.

Uptake
The addition of a substance of concern to a reservoir. The uptake of carbon-containing substances, in particular carbon dioxide, is often called (carbon) sequestration.

Vector
An organism, such as an insect, that transmits a pathogen from one host to another.

Vulnerability
The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity.

Also available

Issue 1: Assessment and Management of Alien Species that Threaten Ecosystems, Habitats and Species

Issue 2: Review of The Efficiency and Efficacy of Existing Legal Instruments Applicable to Invasive Alien Species

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Issue 4: The Value of Forest Ecosystems

Issue 5: Impacts of Human-Caused Fires on Biodiversity and Ecosystem Functioning, and Their Causes in Tropical, Temperate and Boreal Forest Biomes

Issue 6: Sustainable Management of Non-Timber Forest Resources

Issue 7: Review of the Status and Trends of, and Major Threats to, the Forest Biological Diversity

Issue 8: Status and trends of, and threats to, mountain biodiversity, marine, coastal and inland water ecosystems: Abstracts of poster presentations at the eight meeting of the Subsidiary Body on Scientific, Technical and Technological Advice of the Convention on Biological Diversity.

Issue 9: Facilitating Conservation and Sustainable Use of Biodiversity, Abstracts of poster presentations on protected areas and technology transfer and cooperation at the ninth meeting of the Subsidiary Body on Scientific, Technical and Technological Advice