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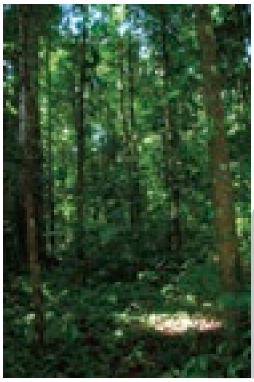
CBD Technical Series No. 41



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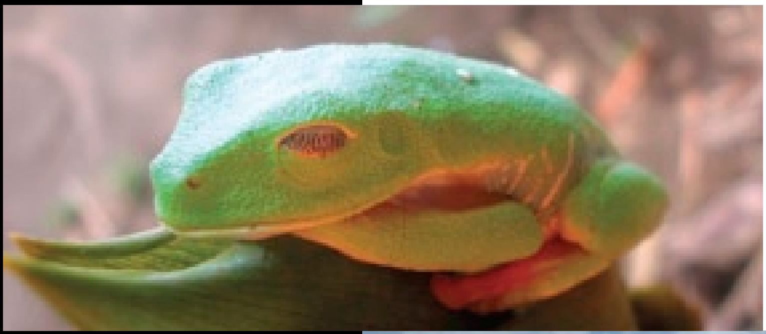
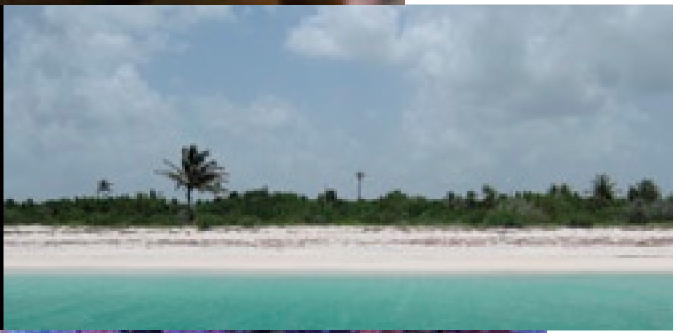
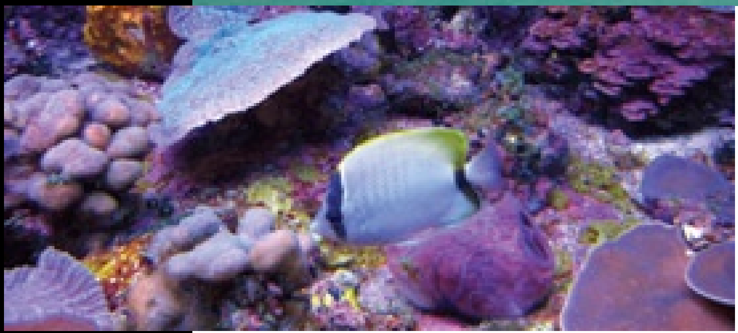
CONNECTING BIODIVERSITY AND CLIMATE CHANGE MITIGATION AND ADAPTATION:



Report of the Second Ad Hoc Technical Expert Group on Biodiversity and Climate Change





Convention on
Biological Diversity

UNEP

CBD Technical Series No. 41

Connecting Biodiversity and Climate Change Mitigation and Adaptation[i]

Report of the Second Ad Hoc Technical Expert Group on Biodiversity and Climate Change

i This report has been approved by the Bureau of the Conference of the Parties to the Convention on Biological Diversity. A full review by all Parties to the Convention on Biological Diversity will occur during the fourteenth meeting of the Subsidiary Body on Scientific, Technical and Technological Advice.

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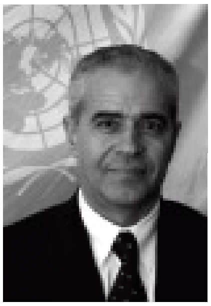
FOREWORD



The Convention on Biological Diversity (CBD) has, as its three objectives, the conservation of biodiversity, the sustainable use of its components, and the fair and equitable sharing of the benefits from the use of genetic resources. Efforts towards the achievement of these objectives are, however, coming under threat from one of the world's other major environmental, social and economic challenges…climate change.

Climate change is threatening individual species such as the King Protea in South Africa and the polar bear in the Arctic. Climate change is also threatening entire ecosystems such as the cloud forests of South America and the coral reefs of South-east Asia. Climate change will affect where species live, when they move and how they interact.

Where species and ecosystems are well protected and healthy, natural adaptation may take place, as long as the rate of change is not too rapid and the scale of change is not too great. However, where climate change stacks as an additional threat upon other stresses such as pollution, overuse or invasive alien species, natural adaptive capacity may be exceeded. It is important, therefore, to ensure that climate change is not considered in isolation.

In fact, the links between biodiversity and climate change flow both ways. Biodiversity, and associated ecosystem services are the cornerstone of sustainable development. This relationship has long been recognized through the decisions of the Conference of Parties to the CBD and through the adoption of Millennium Development Goal number seven on environmental sustainability. Biodiversity also has a very important role to play in climate change mitigation and adaptation. The importance of this relationship is only now coming to light, spurred by decision IX/16 of the Conference of the Parties to the CBD.

The good management of ecosystems such as wetlands and forests, remains an effective mitigation option given the high sequestration potential of natural systems. The permanence of carbon sinks is also tied to the maintenance or enhancement of the resilience of ecosystems.

With regards to climate change adaptation, healthy, intact ecosystems have long provided critical ecosystem services, providing people with food and shelter, protecting communities from drought and floods, and building the basis of much of our traditional knowledge, innovations and practices. As climate change threatens food security, increases exposure to natural disasters and changes the very nature of the environment in which we live, these ecosystem services will become even more important and valued.

This document has been produced by a suite of world-renowned experts in the fields of biodiversity and climate change. It was welcomed by the fifth meeting of the Bureau of the Conference of the Parties to the CBD and helps up to better understand how these two great challenges interact and how we can best work together to achieve our common goals. The scientific information contained in this report clearly demonstrates that the synergies among the three Rio Conventions are no longer an option but an urgent necessity. A joint work programme among the three Rio Conventions is an idea whose time has come.

Ahmed Djoghlaf
Executive Secretary
Convention on Biological Diversity

List of Acronyms

AHTEG: Ad-Hoc Technical Expert Group
AR4: Fourth Assessment Report (of the IPCC)
CATIE: Tropical Agricultural Research and Higher Education Center
CBA: cost-benefit analysis
CBD: Convention on Biological Diversity
CBNRM: community-based natural resource management
CMP: Conservation Measures Partnership
CO_2: Carbon dioxide
CTI: Coral Triangle Initiative
CTI-CFF: Coral Triangle Initiative - Fisheries and Food Security
EIA: environmental impact assessments
ENSO: El Niño Southern Oscillation
GCMs: general circulation models
GHG: greenhouse gas
GIS: geographic information systems
GMOs: genetically modified organisms
GNP: gross national product
GPP: gross primary productivity
Gt C: gigatons of carbon
ICARDA: International Centre for Agricultural Research in Dry Areas
INBio: Conservation International, National Institute of Biodiversity
IPCC: Intergovernmental Panel on Climate Change
IPCC SRES: Intergovernmental Panel on Climate Change Special Report on Emissions Scenarios
LCA: life-cycle analysis
MA: Millennium Ecosystem Assessment
MPAs: marine protected areas
MSBP: Millennium Seed Bank Project
NGOs: non-governmental organizations
NPP: net primary productivity
PAs: protected areas
REDD: reducing emissions from deforestation and forest degradation
SBSTA: Subsidiary Body for Scientific and Technological Advice
SBSTTA: Subsidiary Body on Scientific, Technical and Technological Advice
SCS: strategic cyclical scaling
SEA: strategic environment assessment
SFM: sustainable forest management
SINAC: National System of Conservation Areas
SIDS: small island developing States
SLR: sea-level rise
TEEB: The Economics of Ecosystems and Biodiversity
TEV: total economic value
TNC: The Nature Conservancy
UNFCCC: United Nations Framework Convention on Climate Change
WTO: World Trade Organization
WTP: willingness to pay
WTA: willingness to accept

CONTENTS

PREFACE

The conservation and sustainable use of biodiversity and the equitable sharing of the benefits from the use of genetic resources underpin sustainable development and human well being. Biodiversity, through the ecosystem services[ii] it supports, makes an important contribution to both climate-change mitigation and adaptation. Biodiversity is also affected by climate change, with negative consequences for human well-being. Consequently conserving and sustainably managing biodiversity is critical to addressing climate change.

The interlinkages between biodiversity, climate change, and sustainable development, have been recognized within both the United Nations Framework Convention on Climate Change (UNFCCC) and the Convention on Biological Diversity (CBD) as well as other international fora. Article 2 of the UNFCCC, for example, recognizes the importance of limiting climate change to a level that would allow ecosystems to adapt naturally to climate change. The CBD has adopted a number of decisions on biodiversity and climate change, and in 2001 formed an Ad Hoc Technical Expert Group (AHTEG) on Biodiversity and Climate Change, to consider the possible negative impacts of climate change related activities on biodiversity, identify the role of biodiversity in climate change mitigation and identify opportunities for achieving climate change and biodiversity co-benefits.

Since the first AHTEG completed its work, the scientific information and degree of certainty regarding the relationship between biodiversity and climate change has expanded significantly. In order to support additional work on this issue, the second AHTEG on Biodiversity and Climate Change was convened in 2008 in response to paragraph 12 (b) of decision IX/16 B of the Conference of the Parties to the CBD.

The second AHTEG was established to provide biodiversity-related information to the UNFCCC process through the provision of scientific and technical advice and assessment on the integration of the conservation and sustainable use of biodiversity into climate change mitigation and adaptation activities, through *inter alia*:

(a) Identifying relevant tools, methodologies and best practice examples for assessing the impacts on and vulnerabilities of biodiversity as a result of climate change;
(b) Highlighting case-studies and identifying methodologies for analysing the value of biodiversity in supporting adaptation in communities and sectors vulnerable to climate change;
(c) Identifying case-studies and general principles to guide local and regional activities aimed at reducing risks to biodiversity values associated with climate change;
(d) Identifying potential biodiversity-related impacts and benefits of adaptation activities, especially in the regions identified as being particularly vulnerable under the Nairobi work programme (developing countries, especially least developed countries and small island developing States);
(e) Identifying ways and means for the integration of the ecosystem approach in impact and vulnerability assessment and climate change adaptation strategies;
(f) Identifying measures that enable ecosystem restoration from the adverse impacts of climate change which can be effectively considered in impact, vulnerability and climate change adaptation strategies;
(g) Analysing the social, cultural and economic benefits of using ecosystem services for climate change adaptation and of maintaining ecosystem services by minimizing adverse impacts of

ii In this document the term "ecosystem services" is used as defined in the Millennium Ecosystem Assessment. Ecosystem services as used in this manner includes both good and services.

climate change on biodiversity.

(h) Proposing ways and means to improve the integration of biodiversity considerations and traditional and local knowledge related to biodiversity within impact and vulnerability assessments and climate change adaptation, with particular reference to communities and sectors vulnerable to climate change.

(i) Identifying opportunities to deliver multiple benefits for carbon sequestration, and biodiversity conservation and sustainable use in a range of ecosystems including peatlands, tundra and grasslands;

(j) Identifying opportunities for, and possible negative impacts on, biodiversity and its conservation and sustainable use, as well as livelihoods of indigenous and local communities, that may arise from reducing emissions from deforestation and forest degradation;

(k) Identifying options to ensure that possible actions for reducing emissions from deforestation and forest degradation do not run counter to the objectives of the CBD but rather support the conservation and sustainable use of biodiversity;

(l) Identifying ways that components of biodiversity can reduce risk and damage associated with climate change impacts;

(m) Identifying means to incentivise the implementation of adaptation actions that promote the conservation and sustainable use of biodiversity.

In order to fulfil its mandate, the first meeting of the second AHTEG took place in London from 17 to 21 November 2008; the second meeting took place in Helsinki from 18 to 22 April 2009. A third meeting was held in Cape Town, South Africa, from 20 to 24 July 2009, in order to incorporate peer-review comments submitted by 10 Parties and 17 other organizations.

The final report of the AHTEG has been guided by relevant outcomes from the Conference of the Parties and the subsidiary bodies of the UNFCCC as well as the programmes of work and cross-cutting issues under the CBD. The report builds on the findings of the first AHTEG, which are published as CBD Technical Series No. 10 and No. 25 and draws on the reports of the Millennium Ecosystem Assessment and the Intergovernmental Panel on Climate Change, including the Fourth Assessment Report and Technical Report V[1] on Climate Change and Biodiversity.

A draft report, including main messages as compiled by the AHTEG was initially made available to participants to the fourteenth session of the Conference of the Parties to the UNFCCC and, an expanded set of key messages was made available at the thirtieth session of the Subsidiary Body for Scientific and Technical Advice to the UNFCCC. The final report will be made available to the fifteenth session of the Conference of the Parties to the UNFCCC, including the thirty-first session of its Subsidiary Body for Scientific and Technical Advice, and the fourteenth meeting of the Subsidiary Body on Scientific, Technical and Technological Advice under the Convention on Biological Diversity.

KEY MESSAGES

A. BIODIVERSITY AND CLIMATE CHANGE INTERACTIONS

The issues of climate change and biodiversity are interconnected, not only through climate change effects on biodiversity, but also through changes in biodiversity that affect climate change

- Conserving natural terrestrial, freshwater and marine ecosystems and restoring degraded ecosystems (including their genetic and species diversity) is essential for the overall goals of the UNFCCC because ecosystems play a key role in the global carbon cycle and in adapting to climate change, while also providing a wide range of ecosystem services that are essential for human well-being and the achievement of the Millennium Development Goals.
    - About 2,500 Gt C is stored in terrestrial ecosystems, an additional ~ 38,000 Gt C is stored in the oceans (37,000 Gt in deep oceans i.e. layers that will only feed back to atmospheric processes over very long time scales and ~ 1,000 Gt in the upper layer of oceans[2]) compared to approximately 750 Gt C in the atmosphere. On average ~160 Gt C cycle naturally between the biosphere (in both ocean and terrestrial ecosystems) and atmosphere. Thus, small changes in ocean and terrestrial sources and sinks can have large implications for atmospheric CO_2 levels. Human induced climate change caused by the accumulation of anthropogenic emissions in the atmosphere (primarily from fossil fuels and land use changes) could shift the net natural carbon cycle towards annual net emissions from terrestrial sinks, and weaken ocean sinks, thus further accelerating climate change.
    - Ecosystems provide a wide range of provisioning (e.g. food and fibre), regulating (e.g. climate change and floods), cultural (e.g. recreational and aesthetic) and supporting (e.g. soil formation) services, critical to human well-being including human health, livelihoods, nutritious food, security and social cohesion.
- While ecosystems are generally more carbon dense and biologically more diverse in their natural state, the degradation of many ecosystems is significantly reducing their carbon storage and sequestration capacity, leading to increases in emissions of greenhouse gases and loss of biodiversity at the genetic, species and ecosystem level;
- Climate change is a rapidly increasing stress on ecosystems and can exacerbate the effects of other stresses, including from habitat fragmentation, loss and conversion, over-exploitation, invasive alien species, and pollution.

B. IMPACTS OF CLIMATE CHANGE ON BIODIVERSITY

Observed changes in climate have already adversely affected biodiversity at the species and ecosystem level, and further changes in biodiversity are inevitable with further changes in climate

- Changes in the climate and in atmospheric CO_2 levels have already had observed impacts on natural ecosystems and species. Some species and ecosystems are demonstrating some capacity for natural adaptation, but others are already showing negative impacts under current levels of climate change (an increase of 0.75°C in global mean surface temperature relative to pre-industrial levels), which is modest compared to future projected changes (2.0-7.5 °C by 2100 without aggressive mitigation actions).

- Aquatic freshwater habitats and wetlands, mangroves, coral reefs, Arctic and alpine ecosystems, and cloud forests are particularly vulnerable to the impacts of climate change. Montane species and endemic species have been identified as being particularly vulnerable because of narrow geographic and climatic ranges, limited dispersal opportunities, and the degree of other pressures.
- Information in Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR4) suggests that approximately 10% of species assessed so far will be at an increasingly high risk of extinction for every 1°C rise in global mean temperature, within the range of future scenarios modelled in impacts assessments (typically <5°C global temperature rise).
- Continued climate change will have predominantly adverse and often irreversible impacts on many ecosystems and their services, with significant negative social, cultural and economic consequences. However, there is still uncertainty about the extent and speed at which climate change will impact biodiversity and ecosystem services, and the thresholds of climate change above which ecosystems are irreversibly changed and no longer function in their current form.
- Risks to biodiversity from climate change can be initially assessed using available vulnerability and impact assessment guidelines. However, further development and validation of tools is necessary because uncertainties limit our ability to project climate change impacts on biodiversity and ecosystem services.

C. REDUCING THE IMPACTS OF CLIMATE CHANGE ON BIODIVERSITY

The resilience of biodiversity to climate change can be enhanced by reducing non-climatic stresses in combination with conservation, restoration and sustainable management strategies

- Conservation and management strategies that maintain and restore biodiversity can be expected to reduce some of the negative impacts from climate change; however, there are rates and magnitude of climate change for which natural adaptation will become increasingly difficult.
- Options to increase the adaptive capacity of species and ecosystems in the face of accelerating climate change include:
  - Reducing non-climatic stresses, such as pollution, over-exploitation, habitat loss and fragmentation and invasive alien species.
  - Wider adoption of conservation and sustainable use practices including through the strengthening of protected area networks.
  - Facilitating adaptive management through strengthening monitoring and evaluation systems.
- Relocation, assisted migration, captive breeding, and *ex-situ* storage of germplasm could contribute to maintaining the adaptive capacity of species, however, such measures are often expensive, less effective than *in situ* actions, not applicable to all species, usually feasible only on small scales, and rarely maintain ecosystem functions and services. In the case of relocation and assisted migration, unintended ecological consequences need to be considered.

D. ECOSYSTEM-BASED ADAPTATION

Ecosystem-based adaptation, which integrates the use of biodiversity and ecosystem services into an overall adaptation strategy, can be cost-effective and generate social, economic and cultural co-benefits and contribute to the conservation of biodiversity

- Ecosystem-based adaptation uses biodiversity and ecosystem services in an overall adaptation strategy. It includes the sustainable management, conservation and restoration of ecosystems to provide services that help people adapt to the adverse effects of climate change.
- Examples of ecosystem-based adaptation activities include:
  - Coastal defence through the maintenance and/or restoration of mangroves and other coastal wetlands to reduce coastal flooding and coastal erosion.
  - Sustainable management of upland wetlands and floodplains for maintenance of water flow and quality.
  - Conservation and restoration of forests to stabilize land slopes and regulate water flows.
  - Establishment of diverse agroforestry systems to cope with increased risk from changed climatic conditions.
  - Conservation of agrobiodiversity to provide specific gene pools for crop and livestock adaptation to climate change.
- Ecosystem-based adaptation can be a useful and widely applicable approach to adaptation because it:
  - Can be applied at regional, national and local levels, at both project and programmatic levels, and benefits can be realized over short and long time scales.
  - May be more cost-effective and more accessible to rural or poor communities than measures based on hard infrastructure and engineering.
  - Can integrate and maintain traditional and local knowledge and cultural values.
- Ecosystem-based adaptation, if designed, implemented and monitored appropriately, can also:
  - Generate multiple social, economic and cultural co-benefits for local communities.
  - Contribute to the conservation and sustainable use of biodiversity.
  - Contribute to climate change mitigation, by conserving carbon stocks, reducing emissions caused by ecosystem degradation and loss, or enhancing carbon stocks.
- Ecosystem-based adaptation may require managing ecosystems to provide particular services at the expense of others. For example, using wetlands for coastal protection may require emphasis on silt accumulation and stabilization possibly at the expense of wildlife values and recreation. It is therefore important that decisions to implement ecosystem-based adaptation are subject to risk assessment, scenario planning and adaptive management approaches that recognise and incorporate these potential trade-offs.

E. IMPLICATIONS OF REDUCING EMISSIONS FROM DEFORESTATION AND FOREST DEGRADATION (REDD) AND OTHER LAND-USE MANAGEMENT ACTIVITIES ON BIODIVERSITY AND CLIMATE CHANGE MITIGATION

A portfolio of land-use management activities including REDD can cost-effectively contribute to mitigating climate change and conserving biodiversity

- A portfolio of land use management activities, including the protection of natural forest and peatland carbon stocks, the sustainable management of forests, the use of native assemblages of forest species in reforestation activities, sustainable wetland management, restoration of degraded wetlands and sustainable agricultural practices can contribute to the objectives of both the UNFCCC and CBD. These activities, in addition to stringent reductions in fossil fuel emissions of greenhouse gases, play an important role in limiting increases in atmospheric greenhouse gas concentrations and human-induced climate change.
- The potential to reduce emissions and increase the sequestration of carbon from land use management activities is estimated to range from 0.5-4 $GtCO_2$-eq per year for forestry activities (REDD, afforestation, forest management, agroforestry), and 1-6 $GtCO_2$-eq per year for agricultural land

activities. Achieving this potential is dependent upon the design and mode of implementation of these activities, and the extent to which they are supported and enabled by technology, financing and capacity building.

- Primary forests are generally more carbon-dense and biologically diverse than other forest ecosystems, including modified natural forests and plantations. Accordingly, in largely intact forest landscapes where there is currently little deforestation and degradation occurring, the conservation of existing forests, especially primary forests, is critical both for preventing future greenhouse gas emissions through loss of carbon stocks and ensuring continued sequestration, and for conserving biodiversity. The application of even sustainable forest management practices to previously intact primary forests could lead to increased carbon emissions.
- In forest landscapes currently subject to harvesting, clearing and/or degradation, mitigation and biodiversity conservation can be best achieved by addressing the underlying drivers of deforestation and degradation, and improving the sustainable management of forests.
- In natural forest landscapes that have already been largely cleared and degraded, mitigation and biodiversity conservation can be enhanced through reforestation, forest restoration and improved land management which, through the use of native assemblages of species, can improve biodiversity and its associated services while sequestering carbon.
- While protected areas are primarily designated for the purpose of biodiversity conservation they have additional value in storing and sequestering carbon (about 15% of the terrestrial carbon stock is currently within protected areas). Effectively managing and expanding protected area networks could contribute to climate change mitigation by reducing both current and future greenhouse gas emissions, and protecting existing carbon stocks, while at the same time protecting certain biodiversity.
- In general, reducing deforestation and degradation will positively impact biodiversity conservation, but this will be negated if deforestation and degradation is displaced from an area of lower conservation value to one of higher conservation value or to other native ecosystems.
- Afforestation activities can have positive or negative effects on biodiversity and ecosystem services depending on their design and management and the present land use. Afforestation activities that convert non-forested landscapes with high biodiversity values and/or valuable ecosystem services, increase threats to native biodiversity. However, afforestation activities could help to conserve biodiversity if they, for example, convert only degraded land or ecosystems largely composed of exotic species, include native tree species, consider the invasiveness of non-natives, and are strategically located within the landscape to enhance connectivity.
- The design of REDD will have key implications for where and how REDD is implemented and the associated impacts on biodiversity. Some relevant issues are:
  - Implementing REDD activities in areas identified as having both high biodiversity value and high carbon stocks can provide co-benefits for biodiversity conservation and climate change mitigation;
  - Addressing forest degradation is important because degradation leads to loss of carbon and biodiversity, decreases forest resilience to fire and drought, and can lead to deforestation;
  - Both intra-national and international leakage under REDD can have important consequences for both carbon and biodiversity, and therefore needs to be prevented or minimized;
  - REDD methodologies based only on assessments of net deforestation rates could fail to reflect actual changes in carbon stocks and fail to deliver conservation co-benefits;
  - Addressing the underlying drivers of deforestation and degradation will require a wide variety of ecological, social and economic approaches;
  - If REDD is to achieve significant and permanent emissions reductions, it will be important to provide alternative livelihood options (including employment, income and food security) for those people who are currently the agents of deforestation and degradation.

- While it is generally recognized that REDD and other sustainable land management activities for mitigation have potential benefits, including critical ecosystem services, for forest-dwelling indigenous peoples and local communities, a number of conditions are important for realizing these co-benefits, e.g., indigenous peoples are likely to benefit more from REDD and other sustainable land management activities for mitigation where they own their lands; where there is the principle of free, prior and informed consent, and where their identities and cultural practices are recognized and they have space to participate in policy-making processes. Involving local stakeholders, in particular women, and respecting the rights and interests of indigenous and local communities will be important for the long-term sustainability of the efforts undertaken.
- There is a range of activities in the agricultural sector including; conservation tillage and other means of sustainable cropland management, sustainable livestock management, and agroforestry systems that can result in the maintenance and potential increase of current carbon stocks and the conservation and sustainable use of biodiversity.
- Policies that integrate and promote the conservation and enhanced sequestration of soil carbon, including in peatlands and other wetlands as well as in grasslands and savannahs, can contribute to climate change mitigation and be beneficial for biodiversity and ecosystem services.

F. IMPACTS OF ADAPTATION ACTIVITIES ON BIODIVERSITY

Activities to adapt to the adverse impacts of climate change can have positive or negative effects on biodiversity, but tools are available to increase the positive and decrease the negative effects

- Adaptation to the adverse impacts of climate change can have both positive and negative consequences for biodiversity and ecosystem services, depending on the way in which such strategies are implemented, for example:
    - Increasing the diversity of landscapes and interconnecting agro-ecosystems, natural floodplains, forests and other ecosystems can contribute to the climate resilience of both human communities and biodiversity and ecosystem services.
    - Hard infrastructure in coastal areas (e.g. sea walls, dykes, etc.) can often adversely impact natural ecosystem processes by altering tidal current flows, disrupting or disconnecting ecologically related coastal marine communities, and disturbing sediment or nutrition flows.
- In most cases there is the potential to increase positive and reduce negative impacts of adaptation on biodiversity. Tools for identifying these impacts include strategic environmental assessments (SEA), environmental impact assessments (EIA), and technology impact assessments that facilitate the consideration of all adaptation options.
- The planning and implementation of effective adaptation activities that take into account impacts on biodiversity, can benefit from:
    - Considering traditional knowledge, including the full involvement of indigenous peoples and local communities.
    - Defining measurable outcomes that are monitored and evaluated.
    - Building on a scientifically credible knowledge base.
    - Applying the ecosystem approach.[iii]

iii The ecosystem approach includes twelve steps for the integrated management of land, water and living resources to promote conservation and sustainable use in an equitable way. Further details on the ecosystem approach are presented on the CBD website (http://www.cbd.int/ecosystem) and in box.2 on page 31 below.

- To optimize their effectiveness and generate biodiversity co-benefits, adaptation activities should:
    - Maintain intact and interconnected ecosystems to increase resilience and allow biodiversity and people to adjust to changing environmental conditions.
    - Restore or rehabilitate fragmented or degraded ecosystems, and re-establish critical processes such as water flow to maintain ecosystem functions.
    - Ensure the sustainable use of renewable natural resources.
    - Collect, conserve and disseminate traditional and local knowledge, innovations and practices related to biodiversity conservation and sustainable use with prior and informed consent from traditional knowledge holders.

G. IMPACTS OF ALTERNATIVE ENERGY AND GEO-ENGINEERING ON BIODIVERSITY

Some renewable energy sources, which displace the use of fossil fuels, and geo-engineering techniques, can have adverse effects on biodiversity depending on design and implementation

- Renewable energy sources, including onshore and offshore wind, solar, tidal, wave, geothermal, biomass and hydropower, in addition to nuclear power, can displace fossil fuel energy, thus reducing greenhouse gas emissions, but have potential implications for biodiversity and ecosystem services.
    - While bioenergy can contribute to energy security, rural development and mitigating climate change, there is evidence that, depending on the feedstock used and production schemes, some first generation biofuels (i.e., use of food crops for liquid fuels) are accelerating land use change, including deforestation, with adverse effects on biodiversity.[3] In addition, if a full life cycle analysis is taken into account, biofuels production may not currently be reducing greenhouse gas emissions[iv].
    - Hydropower, which has substantial unexploited potential in many developing countries, can potentially mitigate greenhouse gas emissions by displacing fossil fuel production of energy, but large scale hydropower systems can have adverse biodiversity and social effects.
    - The implications of wind and tidal power for biodiversity are dependent upon siting and other design features.
- Artificial fertilization of nutrient limited oceans to increase the uptake of atmospheric carbon dioxide is increasingly thought to have limited potential for climate change mitigation and uncertain impacts on biodiversity.
- Other geo-engineering techniques, such as the intentional and large- scale manipulation of the radiative balance of the atmosphere through injecting sulphate aerosols into the troposphere or stratosphere, have not been adequately studied and hence their impact on ecosystems is unknown.

H. VALUATION AND INCENTIVE MEASURES

The consideration of economic and non-economic values of biodiversity and ecosystem services, and related incentives and instruments can be beneficial when implementing climate change related activities

- It is important to ensure that the economic (market and non-market) and non-economic values of biodiversity and ecosystem services are taken into account when planning and undertaking climate change related activities. This can best be achieved by using a range of valuation techniques.

iv The expert from Brazil disassociated himself from this statement.

- Ecosystem services contribute to economic well-being and associated development goals, such as the Millennium Development Goals, in two major ways – through contributions to the generation of income and material goods (e.g., provisioning of food and fiber), and through the reduction of potential costs of adverse impacts of climate change (e.g., coral reefs and mangrove swamps protect coastal infrastructure).
- Both economic and non-economic incentives could be used to facilitate climate change related activities that take into consideration biodiversity, while ensuring conformity with provisions of the World Trade Organization and other international agreements:
    - Economic measures include:
        - Removing environmentally perverse subsidies to sectors such as agriculture, fisheries, and energy;
        - Introducing payments for ecosystem services;
        - Implementing appropriate pricing policies for natural resources;
        - Establishing mechanisms to reduce nutrient releases and promote carbon uptake; and
        - Applying fees, taxes, levies, and tariffs to discourage activities that degrade ecosystem services.
    - Non-economic incentives and activities include improving or addressing:
        - Laws and regulations;
        - Governance structures, nationally and internationally;
        - Individual and community property or land rights;
        - Access rights and restrictions;
        - Information and education;
        - Policy, planning, and management of ecosystems; and
        - Development, deployment, diffusion and transfer of technologies relevant for biodiversity and climate change adaptation (e.g. technology that makes use of genetic resources, and technology to manage natural disasters)
    - Assessing policies in all sectors can reduce or eliminate cross-sectoral impacts on biodiversity and ecosystem services.
- Incentives for climate-change-related activities should be carefully designed to simultaneously consider cultural, social, economic and biophysical factors while avoiding market distortions, such as through tariff and non-tariff barriers.

INTRODUCTION

1. Scientific evidence shows that climate change is likely to challenge the realization of sustainable development including the Millennium Development Goals.[4] In particular, climate change is projected to reduce the livelihood assets of vulnerable people, especially those that are dependent on biodiversity and ecosystem services such as access to food, water and shelter. Climate change is also expected to have a negative impact on traditional coping mechanisms and food security[5] thereby increasing the vulnerability of the world's poor to famine and perturbations such as drought, flood and disease. Finally, the impacts of climate change on natural resources[6] and labour productivity are likely to reduce economic growth, exacerbating poverty through reduced income opportunities.

2. Anthropogenic climate change is also threatening biodiversity and the continued provision of ecosystem services. Hence the global community has issued an urgent call for additional research and action towards reducing the impacts of climate change on biodiversity and increasing synergy of biodiversity conservation and sustainable use with climate change mitigation and adaptation activities. Furthermore, in the face of multiple and increasing challenges and their likely cost implications, a need has been identified for additional research on ways and means to ensure that biodiversity conservation and sustainable use can provide co-benefits for other sectors, including for climate change mitigation and adaptation.

3. In light of the above, the present document has been prepared by the Second Ad Hoc Technical Expert Group on Biodiversity and Climate Change. The document addresses a range of topics as reflected in the terms of reference of the Expert Group. Section 1 of the document examines the observed and projected impacts of climate change on biodiversity. The section further considers issues of uncertainty and presents suggestions for additional research needed to qualify complex processes and interactions and increase the degree of certainty with regards to both impacts and vulnerability.

4. Section 2 examines the links between biodiversity and climate change adaptation including the contribution of biodiversity to effective adaptation and the potential risks and benefits of adaptation activities for biodiversity. The section elaborates on the concept and practice of ecosystem-based adaptation and presents suggestions on how broader adaptation activities to address the adverse effects of climate change can be designed and implemented in order to strengthen the adaptive capacity of biodiversity, maximize co-benefits across sectors and avoid unintended negative consequences on ecosystem services.

5. Section 3 examines the links between biodiversity and climate change mitigation with a particular focus on land use management activities and reducing emissions from deforestation and forest degradation. The section explores the potential contribution of biodiversity conservation and sustainable use to mitigation efforts and suggests ways in which co-benefits can be enhanced. Finally, the section examines the potential positive and negative impacts of mitigation activities on biodiversity (e.g. renewable energy technologies) while highlighting those mitigation approaches, such as geo-engineering, for which additional research is required.

6. Finally, section 4 provides information on techniques for valuing biodiversity highlighting that applying these techniques can quantify costs and benefits, opportunities and challenges and thus can improve decision making with regards to climate change related activities. The section further presents options on incentive measures that could be adopted so as to further elaborate the links between biodiversity and climate change related activities.

7. Throughout the document, case-studies are used to illustrate good-practice examples and lessons learned. Furthermore, wherever possible, tools and methodologies are elaborated in order to provide concrete and practical scientific and technical advice.

SECTION 1: BIODIVERSITY-RELATED IMPACTS OF ANTHROPOGENIC CLIMATE CHANGE

8. Anthropogenic climate change is already having observable impacts on biodiversity and ecosystem services. In addition, projections of future climate change impacts indicate further impacts, which may exceed the current adaptive capacity of many species and ecosystems. Section 1, therefore, examines the observed and projected impacts of climate change on biodiversity.

1.1 THE CARBON CYCLE AND OBSERVED AND PROJECTED CHANGES IN CLIMATE

9. The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR4)[7] revealed a global mean surface temperature increase from 1850-1899 to 2001-2005 of 0.76°C with the warming trend escalating over the past 50 years, land areas warming more than the oceans, and high latitudes warming more than the tropics.

10. The IPCC AR4 also reported that, in the absence of climate mitigation policies the global mean surface temperature is projected to increase by 1.1°C to 6.4°C by the end of the 21st century relative to the 1980-1999 baseline, accompanied by changes in the spatial and temporal distribution of precipitation with a tendency of wet areas getting wetter and arid and semi-arid areas getting drier.

11. Even with climate-mitigation policies, significant climate change is inevitable due to lagged responses in the Earth climate system (so-called unrealized warming). A further increase in global mean surface temperature of about 0.5°C is inevitable even if the atmospheric concentration of greenhouse gases could be stabilized immediately.

12. Stabilization of the atmospheric concentration of greenhouse gases at 450, 550 and 650 ppm CO_2eq would provide about a 50% chance of limiting projected changes in global mean surface temperature to 2°C, 3°C, and 4°C, respectively.

13. Carbon is sequestered and stored by terrestrial and marine ecosystems, and the processes which constitute and sustain this ecosystem service are inseparably linked to biodiversity. About 2,500 Gt C is stored in terrestrial ecosystems, compared to approximately 750Gt C in the atmosphere.[8] An additional ~ 38,000 Gt C is stored in the oceans (37,000 Gt in deep oceans i.e. layers that will only feed back to atmospheric processes over very long time scales, ~ 1,000 Gt in the upper layer of oceans.[9] On average ~160 Gt C cycle naturally between the biosphere (both ocean and terrestrial ecosystems) and atmosphere. Thus, rather small changes in ocean and terrestrial sources and sinks can have large implications for atmospheric CO_2 levels.

14. The current accumulation of anthropogenic emissions in the atmosphere could shift the net natural carbon cycle towards annual net emissions from terrestrial sinks, and weaken ocean sinks, thus further accelerating climate change. It is generally agreed one of the main feedbacks to the climate system will be through the increase in soil respiration under increased temperature,[10] particularly in the Arctic, with the potential to increase the rate of CO_2 emissions by up to 66% as a result of global soil carbon loss and forest dieback in Amazonia as a consequence of climate change[11] which will also cause increased seasonal water stress in the Eastern Amazon which could increase susceptibility to fire.[12]

1.2 OBSERVED AND PROJECTED IMPACTS OF CLIMATE CHANGE ON BIODIVERSITY

Anthropogenic changes in climate and atmospheric CO_2 are already having observable impacts on ecosystems and species; some species and ecosystems are demonstrating apparent capacity for natural adaptation, but others are showing negative impacts. Impacts are widespread even with the modest level of change observed thus far in comparison to some future projections.

15. **Climate change is a rapidly increasing stress on ecosystems and can exacerbate the effects of other stresses**, including from habitat fragmentation and conversion, over-exploitation, invasive alien species, and pollution.

16. **Observed signs of natural adaptation and negative impacts include:**

- **Geographic distributions:** The geographic ranges of species are shifting towards higher latitudes and elevations.[13] While this can be interpreted as natural adaptation, caution is advised, as the ecological effects of related community compositional change, the net effect of such range shifts on range area (i.e. the balance between range contraction and expansion for any given species), and related species extinction risk,[14] is difficult to project; and there are geographic and dispersal rate limits, physical barriers,[15] and anthropogenic barriers to species range expansion.[16] Range shifts have mostly been studied in temperate zones,[17] due to the availability of long data records; changes at tropical and sub-tropical latitudes will be more difficult to detect and attribute due to a lack of time series data and variability of precipitation. Nevertheless, biodiversity losses have already been reported in some tropical areas.[18]
- **Timing of life cycles (phenology):** changes to the timing of natural events have now been documented in many hundreds of studies and may signal natural adaptation by individual species. Changes include advances in spring events (e.g. leaf unfolding, flowering, and reproduction) and delays in autumn events.[19]
- **Interactions between species:** evidence of the disruption of biotic interactions is emerging. For example, differential changes in timing are leading to mismatches between the peak of resource demands by reproducing animals and the peak of resource availability. This is causing population declines in many species, including increasing the herbivory rates[20] by insects as a result of warmer temperatures, and may indicate limits to natural adaptation.
- **Photosynthetic rates, carbon uptake and productivity in response to CO_2 "fertilization" and nitrogen deposition:** models and some observations suggest that global gross primary production (GPP) has increased. Regional modelling efforts project ongoing increases in GPP[21] for some regions, but possible declines in others. Furthermore, in some areas, CO_2 fertilization is favouring fast growing species over slower growing ones and changing the composition of natural communities while not appreciably changing the GPP.[22]
- **Community composition and ecosystem changes:** observed structural and functional changes in ecosystems are resulting in substantial changes in species abundance and composition.[23] These have impacts on livelihoods and traditional knowledge including, for example, changing the timing of hunting and fishing and traditional sustainable use activities, as well as impacting upon traditional migration routes for people.

During the course of this century the resilience of many ecosystems (their ability to adapt naturally) is likely to be exceeded by an unprecedented combination of change in climate, associated disturbances (e.g., flooding, drought, wildfire, insects, ocean acidification) and

in other global change drivers (especially land-use change, pollution and over-exploitation of resources), if greenhouse gas emissions and other changes continue at or above current rates.[v]

17. **Many of the mass extinctions that have occurred over geologic time were tied, at least in part, to climate changes that occurred at rates much slower than those projected for the next century.** These results may be seen as potentially indicative but are not analogues to the current situation, as continents were in different positions, oceanic circulation patterns were different and the overall composition of biodiversity was significantly different. It should also be kept in mind that these extinctions occurred with the temperature change taking place over tens of thousands of years[vi 24]. This is in contrast to the much more rapid rate of temperature change observed and projected today[25].

18. **Further climate change will have increasingly significant direct impacts on biodiversity.** Increased rates of species extinctions are likely[26], with negative consequences for the services that these species and ecosystems provide. Poleward and elevational shifts, as well as range contractions and fragmentation, are expected to accelerate in the future. Contractions and fragmentation will be particularly severe for species with limited dispersal abilities, slower life history traits, and range restricted species such as polar and alpine species[27] and species restricted to riverine[28] and freshwater habitats[29]. Local extinction of species often occurs with a substantial delay following habitat loss or degradation. Accumulating evidence suggests that such extinction debts pose a significant but often unrecognized challenge for biodiversity conservation across a wide range of taxa and ecosystems[30]. Shifts in distributions of native species as an adaptive response to climate change will challenge current wildlife and conservation management practices and approaches.

Hawksbill turtles, Nicaragua, Photo courtesy of Sonia Gautreau

19. **Increasing CO_2 concentrations are altering the basic physical and chemical environment underpinning all life, especially temperature, precipitation, and acidity.** Atmospheric concentrations of CO_2, which are approximately 38% higher today than the average over the past 2.1 million years[31], can themselves have important direct influences on biological systems, which can reinforce or act counter to responses to climate variables and complicate projection of future responses. The direct effects of elevated atmospheric CO_2 are especially important in marine ecosystems, including as a result of increased ocean acidification[32], and in terrestrial systems that are not strongly resource limited[18]. Elevated CO_2 can also have large effects on the production, diversity, structure and function of water-limited systems, by improving plant-water relations[33] .

20. **Climate change will also affect species indirectly, by affecting species interactions.** Individualistic responses of species to climate and atmospheric change may result in novel species combinations

v This statement is extracted verbatim from IPCC WG2 Chapter 4 conclusions.

vi It should be noted that past climate changes, especially at glacial terminations, may have been rapid (e.g. the Greenland Summit warmed 9 ± 3°C over a period of several decades, beginning 14,672 years ago, according to ref 22), but associated extinctions are either not well quantified or clearly attributed to climate drivers.

and ecosystems that have no present-day analogue (a finding supported by paleoecological studies). These impacts on communities may be more damaging in some regions than the direct effects of climate changes on individual species, and may compromise sustainable development. The impacts of climate change on species will have cascading affects on community associations and ecosystems leading to non-linear responses, with thresholds that are not yet well understood.

21. **Climate change will interact with other pressures acting on natural systems, most notably land use and land-use change, invasive alien species and disturbance by fire.** Land-use change and related habitat loss are currently major threats to biodiversity worldwide. Climate change is also very likely to facilitate the spread and establishment of invasive alien species[34]. These pressures amplify climate change effects by causing fragmentation, degradation and drying of ecosystems, including increased incidence of fire[35], which is often exacerbated during climatic events like El Niño. Thus, it is vital to consider the effects of climate change in the context of interacting pressures and the influence they may exert directly on natural systems and on those systems' abilities to respond to climate change[36].

22. **Climate change will have significant impacts on fire regimes, with effects on the function of many terrestrial ecosystems and with important feedbacks to the climate system[37].** Fire is an essential natural process for the functioning of many ecosystems. In these ecosystems, fire affects the distribution of habitats, carbon and nutrient fluxes, and the water retention properties of soils. However, fire-ecosystem relationships are being altered by climate change, with significant consequences for other ecological processes, including carbon sequestration, and for biodiversity[38]. In ecosystems adapted to fire and dependent on it for functioning, fire exclusion often results in reduced biodiversity and increased vegetation and fuel density, often increasing risks of catastrophic fire over time. It is estimated that ecosystems with anthropogenically altered fire regimes currently encompass over 60% of global terrestrial areas, and only 25% of terrestrial areas retain unaffected (natural) fire regime conditions[39]. Effective biodiversity conservation requires that fire regimes are able to play their role in maintaining ecosystem functioning, but at the same time do not pose a threat to biodiversity or human well-being through excessive occurrence.

Extinction risks associated with climate change will increase, but projecting the rate of extinction is difficult due to lags in species' population responses, incomplete knowledge of natural adaptive capacity, the complex cascade of inter-species interactions in communities, and the uncertainty around down-scaled regional predictions of future climate.

23. Information in IPCC AR4 suggests that approximately 10% of species assessed so far are at an increasingly high risk of extinction for every 1°C rise in global mean temperature[vii], within the range of future scenarios modeled in impacts assessments (typically <5^{0}C global temperature rise). Given the observed temperature rise, this now could place approximately 6-8% of the species studied at an increasingly high risk of extinction. The current commitment to additional temperature increases (at least 0.5°C) could place an additional 5-7% of species at increasingly high risk of extinction (based on single species studies and not including losses of entire ecosystems, and noting the uncertainty inherent in the IPCC AR4 conclusion). However, a more recent study of global bird distributions estimated that each degree of warming could yield an upward non-linear increase in bird extinctions of about 100-500 species[40].

vii Drawn from table 4.2 in the Working Group II report of AR4.

The negative impacts of climate change on biodiversity have significant economic and ecological costs

24. **A key property of ecosystems that may be affected by climate change is the goods and services they provide.** These include provisioning services such as fisheries and timber production, where the response to climate change depends on population characteristics as well as local conditions and may include large production losses.[41] Climate change also affects the ability of ecosystems to regulate water flows, and cycle nutrients.

25. **There is ample evidence that warming will alter the patterns of plant and animal diseases.** Current research projects increases in economically important plant pathogens with warming. There has also been considerable recent concern over the role of climate change in the expansion of plant and animal disease vectors.[42] For example, short-term local experiments have demonstrated the impacts of predicted global change on plant health including rice. Furthermore, studies of the impacts of climate change on the range of East Coast fever, a tick-borne cattle disease, show increases in areas of potential occurrence in Africa.[43]

26. **The impacts of climate change on biodiversity will change human disease vectors and exposure.** Climate change is predicted to result in the expansion of a number of human disease vectors and/or increase the areas of exposure. For example, the increased inundation of coastal wetlands by tides may result in favourable conditions for saltwater mosquito breeding and associated increases in mosquito-borne diseases such as malaria and dengue fever.

27. **Climate change affects the ability of ecosystems to regulate water flows.** The regulation of water quality and quantity is a key ecosystem service worldwide. Higher temperatures, changing insolation and cloud cover, and the degradation of ecosystem structure result in the occurrence of more and higher peak-flows on the one hand and in the mean time, impede the ability of ecosystems to regulate water flow. This has major consequences for both ecosystems and associated species assemblages and people in the scale of whole catchment areas. In addition to freshwater and wetlands, riverine and alluvial ecosystems and many forest types are affected by changes in the hydrological regime.[44]

28. **Climate change will have important impacts on biodiversity with agricultural and other use value.** The wild relatives of crop plants – an important source of genetic diversity for crop improvement – are potentially threatened by climate change.[45] Consideration should also be given to the loss of species of potential use but which are not currently well known for the goods and services that they provide. Such species may be well known to local people, but unknown to science. For example, a plant [called "*shungu panga*"] that grows close to wetlands is used by indigenous communities in the Amazon for multiple cure purposes and is disappearing when wetlands are affected by climate change.[46]

29. **Changes and shifts in the distribution of marine biodiversity resulting from climate change will have serious implications for fisheries.** The livelihoods of coastal communities are threatened by the projected impacts of climate change on coral reefs and other commercially important marine and freshwater species. Fisheries may improve in the short term in boreal regions but they may decline elsewhere with projected local extinctions of some fish species important for aquaculture production. As a result of climate change and in the absence of stringent mitigation, up to 88% of the coral reefs in South-East Asia may be lost over the next 30 years.[47] In addition, ocean acidification may cause pH to decrease by 0.3-0.4 pH units by 2100[48] causing severe die-offs in shellfish and

reef-building corals,[49] affecting fishery production and ecotourism, and with potentially wide ranging ecological impacts.[50]

30. **Biodiversity loss and ecosystem service degradation resulting from climate change has a disproportionate impact on the poor and may increase human conflict.** Many areas of richest biodiversity and high demand for ecosystem services are in developing countries where billions of people directly rely on them to meet their basic needs. Small island developing States and least developed countries are particularly vulnerable to biodiversity-related impacts of changes such as projected temperature and sea-level rise (e.g. impacts on coral reefs), ocean current oscillation changes (e.g. impacts on fisheries) and extreme weather events.

31. **Indigenous people will be disproportionately impacted by climate change because their livelihoods and cultural ways of life are being undermined by changes to local ecosystems.** Climate change is likely to affect the knowledge, innovations and practices of indigenous people and local communities and associated biodiversity-based livelihoods. However, it is difficult to give a precise projection of the scale of these impacts, as these will vary across different areas and different environments. For example, indigenous people and local communities in the Arctic depend heavily on cold-adapted ecosystems. While the number of species and net primary productivity may increase in the Arctic, these changes may cause conflicts between traditional livelihoods and agriculture and forestry. In the Amazon, changes to the water cycle may decrease access to native species and spread certain invasive fish species in rivers and lakes. Furthermore, climate change is having significant impacts on traditional knowledge, innovations and practices among dryland pastoral communities.

32. **Shifts in phenology and geographic ranges of species could impact the cultural and religious lives of some indigenous peoples.** Many indigenous people use wildlife as integral parts of their cultural and religious ceremonies. For example, birds are strongly integrated into Pueblo Indian communities where birds are viewed as messengers to the gods and a connection to the spirit realm. Among Zuni Indians, prayer sticks, using feathers from 72 different species of birds, are used as offerings to the spirit realm. Many ethnic groups in sub-Saharan Africa use animal skins and bird feathers to make dresses for cultural and religious ceremonies. For example, in Boran (Kenya) ceremonies, the selection of tribal leaders involves rituals requiring ostrich feathers. Wildlife, including species which may be impacted by climate change, plays similar roles in cultures elsewhere in the world.

33. **On the global scale, ecosystems are currently acting as a carbon sink, sequestering the equivalent of roughly 30%[51] of anthropogenic emissions annually on average, but if no action is taken on mitigation, this sink will slowly convert to a carbon source.** The reason for this potential conversion from sink to source is linked to temperature rises due, for example, to increasing soil respiration, regional decreases in precipitation or increases in seasonality, thawing of permafrost and deterioration of peatlands, and increasing wildfire frequency and distribution.[52] Some studies suggest that this feedback could increase CO_2 concentrations by 20 to 200 ppm, and hence increase temperatures by 0.1 to 1.5°C in 2100. The level of global warming which would be required to trigger such a feedback is uncertain, but could lie in the range of an increase in global mean surface temperature of between 2-4°C above pre-industrial levels according to some models outlined in the IPCC AR4.[53] Furthermore:

- Local conversion of forests from sinks to sources would be exacerbated by deforestation and degradation, which increases the vulnerability of forest to climate change by, *inter alia*, reducing microclimatic buffering and rainfall generation. Some models predict that the Amazon forest is particularly vulnerable to such processes[54] [55] but there is evidence that by limiting deforestation and degradation the Amazon would have sufficient resilience against climate change impacts into the twenty-second century[56]. Currently, between 25-50% of rainfall is recycled from the Amazon forest, forming one of the most important regional ecosystem services. Deforestation of 35-40% of the Amazon basin, especially in eastern Amazonia, could shift the forest into a permanently drier climate, increasing the risk of fire and carbon release.

- Arctic ecosystems, boreal and tropical peatlands, could become strong sources of carbon emissions in the absence of mitigation. Recent studies estimate that unmitigated climate change could lead to thawing of Arctic permafrost releasing at least 100Gt C by 2100, with at least 40Gt coming from Siberia alone by 2050. Such increases will not be offset by the projected advance of the boreal forest into the tundra.[57]
- Reduced rainfall may change the equilibrium between vegetation, hydrology and soil in peatlands. In areas where there will be insufficient precipitation peat formation will reduce or stop.

34. ***Certain types of extreme climate events, which may be exacerbated by climate change, will be damaging to biodiversity.*** Extreme temperature or precipitation events can have more significant impacts on species than gradual climatic changes. Extreme temperatures exceeding the physiological limits of species have caused mortality in Australian flying-fox species[58] and other species. As another example, floods have caused catastrophic, species-specific mortality in desert rodents resulting in rapid population and community-level changes.[59]

1.3 TOOLS FOR IMPACT, RISK[viii] AND VULNERABILITY[ix] ASSESSMENTS

Assessments of impacts of climate change on biodiversity and related risks and vulnerabilities using currently available tools are dependent on the integration of data on the distribution and ecological characteristics of species, with spatially explicit climate data, and other physical process data, for a range of climate change scenarios

35. **There are different scales of exposure to risk** ranging from gross exposure (e.g., to climate factors, listed in Table 1 under exposure) to minor or more localized exposures (e.g., behavioural traits, listed under adaptive capacity). The amount of genetic and behavioural plasticity (as components of adaptive capacity) of many species is unknown, and may to some degree be a function of exposure to past climatic changes over evolutionary time. It is also important to understand the extent to which behavioural thermoregulation by animals can or cannot buffer them from climate change impacts.[60] For example, one recent study found that limb length in one species is temperature-dependent and thus would indicate a certain adaptation potential to a range of climates[61]. One possible approach to estimating adaptive capacity would be to estimate exposure to past climate change over evolutionary time in conjunction with dispersive capability. Research has shown that many species have shifted ranges with past climates (showing that the rate of change did not exceed dispersal capability), while others have evolved in climates that have been stable for millions of years. Those species that have evolved *in situ* with a stable climate can show high degrees of specialization and frequently have evolved obligatory mutualistic relationships with other species, such that extinction of one species would lead to extinction of the partner. Such factors should be included in risk assessments concerning the impacts of climate change on biodiversity as outlined in box 1 on page 21 below.[62]

Coastal erosion, Costa Rica
Photo courtesy of Sonia Gautreau

viii Risk can be defined as a function of hazard and vulnerability (UNISDR 2004).

ix Vulnerability is defined by IPCC (2001) as 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.

36. **The understanding of the characteristics that contribute to species' risks of decline or extinction has improved.** Species with restricted distributions and those that occur at low density are at particular risk, as are those with limited dispersal ability. Areas of most concern are the Arctic and Antarctic regions, alpine regions, tropical montane areas, centres of endemism where many species have very narrow geographic and climatic ranges, low-lying regions, wetlands, coral reefs and freshwater systems where species have limited dispersal opportunities. Vulnerability to climate change is also affected by the degree and extent of other human pressures. Recent work suggests that for birds, amphibians and warm-water corals as many as 35-70% of species have life-history traits that make them vulnerable to climate change.[63] In the absence of strong mitigation in all sectors (fossil fuel and land-use), some ecosystems, such as cloud forests and coral reefs, may cease to function in their current form within a few decades.

37. **Risk assessment is a valuable tool used to identify the most vulnerable species and ecosystems for prioritizing adaptation activities.** Following the risk assessment, appropriate adaptation activities can be identified to reduce the risks to the identified species and ecosystems. The process of prioritization and choice of activities should also include consideration of the necessary funding and technologies, capacity building for stakeholders, monitoring and evaluation, and define time-bound, measurable outcomes. The risk assessment should involve two aspects: an assessment of the current and projected adverse impacts of climatic change on biodiversity in general based on consideration of the kinds of impacts expected to occur at a local, national or regional scale; and an assessment of the vulnerability of selected species and ecosystems to the projected climate change hazards.[64] Examples of good practices to address risks to biodiversity from climate change are available in anex II.

BOX 1: Possible steps for assessing risk to biodiversity values from climate change

1. Assess the potential climatic change hazard using available vulnerability and impacts assessment guidelines. Such assessments should also account for climatic variability and uncertainty, and make use of available climate analysis tools such as Climate Wizard (http://www.climatewizard.org), Potsdam DIVA tool (http://www.pik-potsdam.de/diva); Climate change in Australia (http://www.climatechangeinaustralia.gov.au); a key resource is the Compendium on Methods and Tools under the Nairobi Work Programme under the UNFCCC (http://unfccc.int/adaptation/nairobi_workprogramme/compendium_on_methods_tools/items/2674.php).

2. Conduct vulnerability assessments

a. Assess the vulnerability of all ecosystems in a locality or region. Vulnerability should be assessed in terms of observed trends in critical ecosystem states, and relative to a baseline of other threatening processes. Ecosystem vulnerability should be assessed on the basis of the potential for climate change to cause significant changes in ecosystem states (e.g., coral bleaching, desertification) or to key ecosystem processes such as dominant disturbance regimes (e.g., fire, flooding, pest outbreaks, droughts); invasive species; net ecosystem/biological productivity; and changes in ecosystem stocks such as surface and ground water flows, biomass, and nutrients; and other ecosystem services.

b. Identify a subset of species for assessment of their relative vulnerability. Species should be selected for assessments that have particular ecological, cultural or economic values. Prioritized species should include threatened or endangered status, responsibility of a country or region for conservation of a species, economically important, culturally important, dominant, ecological keystone or, sources of crop, stock and medicinal genetic diversity, or those that are dependent on vulnerable ecosystems. (Note that this approach would seem to favour relatively well-understood species and/or ecological systems. Again, there is unlikely to be a single 'correct' approach to assessing risk to biodiversity in all its manifestations.)

c. Assess vulnerability of species on the basis of biological and ecological traits, and other factors, that determine sensitivity, adaptive capacity and exposure to climate change. Such traits include habitat specificity, life history, interactions with other species, biogeography, mobility, intrinsic capacity for phenotypic or micro-evolutionary changes, availability of habitat, and microhabitat buffering. Species vulnerability should be assessed in the context of a baseline vulnerability from other threatening processes such as habitat loss, fragmentation and degradation; invasive species; disease; pollution; over use of living resources; altered fire and hydrology regimes.

38. **There are many techniques that have been used to analyse vulnerability** (see table 1.1 on page 24 below). These include models and expert systems. Table 1.1 does not include the wide range of studies and databases looking at observed changes over time (e.g., phenological networks). Observed changes over time, or changes in response to climate variability potentially offer methods to assess the sensitivity of bioclimatic models. There have been a number of reviews examining how species ranges and timing have changed in a manner consistent with the regional climate changes.

Table 1.1: ***Tools and methodologies used to estimate the components of vulnerability***

Components of vulnerability	Tools and methodologies
Exposure[65]	Projections of changes in physical parameters (including CO_2 concentration; temperature, precipitation, extreme events, climate variability, sea levels, ocean acidification, sea surface temperature)
Sensitivity	**Species level** Bioclimatic models[66] Demographic models[67] Ecophysiological models[68] Population viability models[69]; estimates of threatened status (e.g. Red List status),[70] interactions and co-extinction models (e.g. pollination, predator-prey, competition, host-parasite),[71] dynamic vegetation models; Species-specific energy-mass balance models[72] life history and species trait analysis[73] **Level of communities and ecosystems** Earth system models;[74] projections of productivity; Dynamic vegetation models (including plant functional types)[75]; biogeochemical cycle models[76]; Hydrological, soil and moisture balance, coastal flooding models[77]; estimates of ecosystem health[78]; fire models[79]; trophic relationships[80]; state-transition models
Adaptive capacity	**Genetic level** Selection experiments;[81] experimental estimates of ecotypic variation of response[82] **Species level** Use of natural latitudinal or elevational gradients;[83] estimates of resilience and non-climatic stresses;[84] GIS: analysis of spatial habitat availability, PAs, corridors, barriers, topography; Bioclimatic models; Experimental manipulations of CO_2, water, temperature etc.;[85] translocation/transplant experiments;[86] responses to past or current climate variability;[87] responses to past climates[88] Assessments of current conservation status **Ecosystem level** Estimates of resilience and role of non-climatic stresses;[89] GIS: analysis of spatial habitat availability, PAs, corridors, barriers, topography; state-transition models; responses to past climates Assessments of current conservation status

39. **While there are many risk assessment tools available there** are **also a number of needs or data gaps:**

- *Spatially explicit biodiversity data* – Freely available biodiversity datasets are growing in number and scope, but there is a great need both for increased access to such data, digitization of existing datasets, and the collection of new data in undersampled regions, especially in biodiversity rich areas.

- *Climate data* - Readily available downscaled probabilistic projections at appropriate spatial scales, including projections of extreme events, are required for developing regional and local risk assessments and adaptation options.
- *The predictive ability of bioclimatic models requires quantification and improvement* – The projections of bioclimatic models should be formally tested against observed species range shifts.[90] Ideally, systems need to be developed that link the bioclimatic modelling approach dynamically with other physical and anthropogenic drivers, such as land-use models, fire models, hydrological models, vegetation change models, etc., preferably with the ability to quantify feedbacks. Currently, most bioclimatic models focus on single species, or undifferentiated groups of species (e.g., biomes, plant functional types). Models need to be developed that take account of interactions between species, and between trophic levels.
- *Coupled human-natural systems models* – Models linking climate change and ecosystems can also be coupled to models of human behaviour and decision-making, thus representing key interactions between social and ecological systems.[91] This understanding is critical for a more comprehensive risk assessment.
- *The establishment of multi-purpose monitoring programs that include the impacts of climate change on biodiversity would be beneficial in maximizing the use of limited resources* - A monitoring programme that tracks and reports biodiversity status, within a framework that includes threat status monitoring and the recording the effectiveness of adaptation measures is also recommended.

Studies on multiple pressures in various ecosystems are needed to better define causal relationships

40. **Climate change impact assessments should optimally be integrated with assessments of other stresses on ecosystems such as current and future land-use change, and changes in disturbance regimes where applicable**. The direct effects of land use and land-use change may exceed climate change effects on biodiversity in the short to medium term. Modelling approaches that simulate changes in ecosystem structure and processes may be more mechanistically robust in simulating, for example disturbance regimes such as fire, and should be used where possible to provide alternative or complementary insights into species and ecosystem vulnerability.

41. **Readily available, easy to use, tools for assessing the impacts of multiple drivers are needed.** There are many different tools available to project the potential impacts of climate change on biodiversity. However, these tools are hampered in many areas and for many species by the lack of availability of distribution data. Additionally, these efforts are often undertaken in isolation from other efforts and often only look at one, or a few, climate change scenarios for only one or a few different general circulation models (GCMs) after downscaling. Efforts are now underway to link emission scenarios, multiple GCMs, and multiple species bioclimatic tools to better enable the research community to not only look at impacts using a much broader range of emission scenarios using more GCMs, but to do so in a probabilistic fashion. This will provide better estimates of uncertainty and make it easier for researchers to reanalyze their results once new emission scenarios or new climate change models become available. These same modelling tools are also being used to link the same climate and emissions data with hydrological and sea-level rise models and it is possible that, in the near future, all could be examined simultaneously.

42. **The experimental approach can be used to establish causality and define both the nature and magnitude of cause and effect relationships.** This makes this approach very valuable despite its limitations arising mainly from the limited size of experimental plots. Experiments have already been used

to assess the effects of increased temperature, altered precipitation regime and increased CO_2 level and land use on population biology, species composition, phenology and biogeochemistry in various, mostly low-stature ecosystems. More studies are needed on the combined effects of multiple pressures including temperature, precipitation, CO_2, land-use, invasive species and nitrogen deposition. Finally, broader geographic coverage is necessary to draw globally relevant conclusions, as much of this work has been conducted in temperate, northern Hemisphere ecosystems and tropical forest systems.

1.4 CONFIDENCE LEVELS AND UNCERTAINTY

There is considerable confidence that climate models provide credible quantitative estimates of projected climate change, particularly at continental scales and above. However, at finer spatial scales projections have a high level of uncertainty, particularly outside Polar Regions, and in relation to projections of rainfall change[92].

43. **Confidence in climate change models comes from the foundation of the models in accepted physical principles, and from their ability to reproduce observed features of current climate and past climate changes.** Climate models quantify and bound the errors and identify processes where confidence limits are widest and further research is needed. Confidence in model estimates is higher for some climate variables (e.g., temperature) than for others (e.g., precipitation). There are, however, some limitations in the models. Significant uncertainties are, for example, associated with the representation of clouds leading to uncertainties in the magnitude and timing, as well as regional details, of predicted climate change.

44. **Despite uncertainties, models are unanimous in their prediction of substantial warming under greenhouse-gas increases**. This warming is of a magnitude consistent with independent estimates derived from other sources, such as from observed climate changes and past climate reconstructions.[93] Furthermore, since confidence in the changes projected by global models decreases at smaller scales, other techniques, such as the use of regional climate models, or downscaling methods, have been specifically developed for the study of regional- and local-scale climate change.

45. **Research needs and gaps remain.** The report of the first AHTEG, which was published as CBD Technical Series No.10, outlined a number of research needs and gaps with regards to assessing the impacts of climate change on biodiversity. Some of these gaps have been filled, however many remain. For example, there is still a lack of extensive, readily available quantitative information on many species globally. While efforts to fill this need are under way (e.g., Global Biodiversity Information Facility), more work remains to be done, especially with regards to understanding the conditions under which species are not found (a critical factor in performing many bioclimatic models). Furthermore, information on human land and water use patterns is available for many parts of the world, but is not widely linked into the typical models used for looking at biodiversity impacts.

Key uncertainties that limit our ability to project climate change impacts on ecosystems include projections for precipitation which carry a significantly higher uncertainty than those for temperature and uncertainties regarding key ecological processes, such as the rates of fire, photosynthesis and respiration.

46. **Models currently contain inadequate representations of the interactive coupling between ecosystems and the climate system and of the multiple interacting drivers of global change.** This prevents a fully integrated assessment of climate change impacts on ecosystem services; major biotic

feedbacks to the climate system, especially through trace gases from soils in all ecosystems, and methane from labile carbon stocks such as wetlands, peatlands, permafrost and loess soils.

47. **There is uncertainty with respect to the functional role of individual species and the functioning of complex systems.** Further uncertainties are drawn from:

- The interactive role of invasive alien species and climate change on both biodiversity and ecosystem functioning;
- The limitations of climate-envelope models used to project responses of individual species to climate changes, and for deriving estimations of species extinction risks; the assumption of instantaneous (and often perfect) migration, which biases impact estimates;
- The net result of changing disturbance regimes (especially through fire, insects and land-use change) on biotic feedbacks to the atmosphere, ecosystem structure, function and biodiversity;
- The magnitude of the CO_2-fertilization effect in the terrestrial biosphere and its components over time;
- The effect of increasing surface ocean CO_2 and declining pH on marine productivity, biodiversity, biogeochemistry and ecosystem functioning; and
- The impacts of interactions between climate change and changes in human use and management of ecosystems as well as other drivers of global environmental change in ecosystems including more realistic estimates of lagged and threshold responses.

The complexity of ecosystems may often lead to non-linear responses with thresholds that introduce uncertainty

48. **Short-term responses within ecosystems and among species may considerably differ, and may even be the opposite of longer-term responses.** Ecological changes are not always gradual, but instead may be stepwise, and changes may take place in the form of sudden shifts, whose timing and location largely unpredictable. Non-linear responses include tipping points and thresholds beyond which adaptation may no longer be possible. Sudden shifts may occur as a result of the outbreaks of pests or the decrease of recovery time between extreme disturbance events.

49. **The difficulty in predicting thresholds makes the management of biodiversity an important safeguard.** Biodiversity contributes to the resilience of ecosystem function, and to the maintenance of associated ecosystem services, in light of climate-change impacts.[94] Landscape-scale ecosystem heterogeneity and redundancy may – to some extent – buffer against moderate changes in climate. In particular, the diversity of species, and interactions among them, may provide a range of natural adaptive capacity in the face of a certain level of change.[95]

50. **Information on extreme event impacts is difficult to gather since these occur rarely and unpredictably.** A further difficulty is that climate change scenarios are limited in ability to represent their changing frequency. Widespread and long-duration extreme events may induce a range of damaging impacts on ecosystem functions and biodiversity (e.g., as observed following the 2003 European heat wave).

Investment in key areas that require scientific development would contribute to providing better data that would reduce uncertainty in assessments of the impacts of climate change on biodiversity, the provision of ecosystem services and related impacts on human society

51. **More emphasis on deriving a credible range of precipitation projections and resulting water regime effects is needed.** These should emphasise interactions between vegetation and atmosphere, including CO_2-fertilization effects, in mature forests in the northern hemisphere, seasonal tropical forests, and arid or semi-arid grassland and savannas.

52. **Improved understanding of the role of cumulative impacts of multiple disturbance regimes is needed.** This includes frequency and intensity of episodic events (drought, fire, insect outbreaks, diseases, floods and wind-storms) and that of species invasions, as they interact with ecosystem responses to climate change.

53. **Improvements in the integration of feedback mechanisms are needed in order to address differences between modelled changes and observed impacts.** Such an approach could include studies on impacts of rising atmospheric CO_2 on ocean acidification, and warming on coral reefs and other marine systems, and widening the range of terrestrial ecosystems for which CO_2-fertilization and temperature/moisture-respiration responses have been quantified.

54. **It is important to develop a much clearer understanding of the linkages between biodiversity impacts due to climate change and their implications for human society.** Significant advances have been made recently in quantifying the value of ecosystems and their biodiversity, but these are not yet widely incorporated into climate-change-impact-assessment approaches. One of the most effective approaches has been to integrate climate-change impacts on ecosystems and biodiversity in terms of the related changes in various ecosystem services.

55. **There is no global-scale satellite monitoring programme capable of tracking species-level responses.** Furthermore, ecosystem-change satellite data remains underutilized.[96] Field monitoring efforts could be productively strengthened, harmonised and organised into a global network, especially to include the coverage of areas not studied so far. In monitoring efforts, special attention should be paid to the impacts of extreme events because they may serve as an early warning of future vulnerability.

Observations[97] from indigenous and local communities form an important component of impact assessments and should be conducted with prior informed consent and with the full participation of indigenous and local communities

56. **Indigenous people and local communities are holders of relevant traditional knowledge, innovations and practices, as their livelihoods depend on ecosystems that are directly affected by climate change.** This knowledge is normally of a practical nature, and covers areas such as traditional livelihoods, health, medicine, plants, animals, weather conditions, environment and climate conditions, and environmental management as the basis of indigenous well-being. This knowledge is based on experience based on life-long observations, traditions and interactions with nature. However, further research is needed on impact assessments that involve indigenous people and local communities. This will substantially enhance the understanding of local and regional impacts of climate change.

57. **The potential impacts of climate change on biodiversity and related livelihoods and cultures of indigenous people and local communities remains poorly known.** Furthermore, such impacts are rarely considered in academic, policy and public discourse. In particular, climate models are not well suited to providing information about changes at the local level. Even when observations are included at the species level, there is little research on, for example, impacts on traditional management systems as an important strategy to cope with change. Accordingly, further efforts are required to ensure that

traditional and indigenous knowledge, innovations and practices are respected, properly interpreted and used appropriately in impact assessments through contextually relevant practices in data collection and sharing, development of indicators, assessment validation and feedback, and applications.

58. **Monitoring the impacts of climate change on biodiversity in partnership with indigenous and local communities can benefit from a range of practices.** Examples of supporting activities include:

- Promote the documentation and validation of traditional knowledge, innovations and practices. Most knowledge is not documented and has not been comprehensively studied and assessed. Therefore there is need to enhance links between traditional knowledge and scientific practices.
- Revitalize traditional knowledge, innovations and practices on climate change impacts on traditional biodiversity based resources and ecosystem services through education and awareness-raising, including in nomadic schools.
- Explore uses of and opportunities for community-based monitoring linked to decision-making, recognizing that indigenous people and local communities are able to provide data and monitoring on a whole system rather than single sectors based on the full and effective participation of indigenous and local communities.

SECTION 2: BIODIVERSITY AND CLIMATE-CHANGE ADAPTATION

59. The previous section highlighted the growing impacts of climate change on biodiversity, many of which affect the ecosystem services on which people depend for their well-being. Adaptation strategies that both conserve biodiversity and maintain ecosystem services on which people depend are therefore needed to respond to the full range of adverse impacts of climate change.

60. This section considers the three main interactions between biodiversity and adaptation: firstly the need to adopt adaptation strategies and practices to maintain biodiversity itself in the face of climate change; secondly, the potential impacts of broader adaptation activities on biodiversity, and; thirdly, the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people to adapt to the adverse impacts of climate change.

2.1 REDUCING THE IMPACTS OF CLIMATE CHANGE ON BIODIVERSITY

The resilience of biodiversity to climate change can be enhanced by reducing non-climatic stresses in combination with conservation and management activities that maintain and restore biodiversity.

61. **Changes in species and ecosystems have already been observed and an increasing number of ecosystems, including areas of high biodiversity value, are likely to be further disrupted by a temperature rise of 2°C or more above pre-industrial levels.** Many terrestrial species will be unable to adapt further by moving to higher latitudes or altitudes due to lack of land or other constraints. Coastal and marine ecosystems will also suffer increasing disruption from ocean acidification. Damage to coral reefs is already being observed, and with a 3°C rise, most coral reefs would be expected to convert to algal mats.[98] As temperatures rise, increasing fire frequency will contribute to forest decline worldwide.[99] Were temperatures to reach 4°C above pre-industrial, few ecosystems would be expected to be able to maintain their current functioning, and it is predicted that 50% of protected areas would no longer fulfil their conservation objectives.[100]

62. **Experiences have yielded a number of principles of general applicability that can be used to guide adaptation activities that aim to minimize risks to biodiversity from climate change.** Such adaptation activities will need to address not only individual species and ecosystems, but also the ecological interactions on which species and ecosystem functioning are dependent. For example, it may be necessary to develop adaptations to losses of natural predators, pollinators or seed dispersers. While substituting some of these functions with technical or chemical means may be possible, the alternatives can often be costly. Tables 2.1 and 2.2 outline a number of principles for the design, planning and implementation of adaptation activities to reduce the impacts of climate change on biodiversity.

Table 2.1. ***Principles for adaptation activity planning and implementation***

1. Establish objectives and define expected outcomes for adaptation activities	Objectives should describe: • How adaptation activities are intended to address the climate change impacts on the priority species and ecosystems. • Outcomes should be defined in measurable, time-bound terms so that the efficacy of adaptation activities can be evaluated.
2. Monitor, measure and evaluate the effectiveness of adaptation activities.	Monitoring practices should be designed to: • Verify that the intended objectives of adaptation activities are achieved. • Address uncertainty regarding the timing and magnitude of climate change impacts • Avoid mal-adaptation. • Indicators should be matched to the intended objectives and outcomes of the adaptation activities. • Indicators should be well-defined, practical and measurable so that they provide timely and relevant information. • The specific choice of indicators is flexible and should be tailored to the situation being evaluated.
3. Inform decision making by integrating traditional knowledge, scientific information and evidence about climate change impacts and the effectiveness of adaptation activities.	• A research agenda should be elaborated to address questions about the ecological, social and economic impacts of climate change. • Climate change and impact models are needed to improve the predictive capacity at spatial and temporal scales that are relevant to decision-makers and designers of adaptation activities. • Mechanisms for bringing together lessons learned and for facilitating knowledge transfer (e.g., the Ecosystems and Livelihood Adaptation Network; Nairobi Work Programme databases and Focal Point forum) should be encouraged.
4. Build and strengthen management and technical capacity for biodiversity protection and sustainable use of natural resource by involving local and indigenous communities.	• All relevant stakeholders, especially local and indigenous communities who may be most dependent on adaptation activities, should be involved in management decisions. • This requires robust management institutions that facilitate knowledge transfer (e.g., lessons learned, best practices) among communities, economic sectors, and the general public to ensure informed decision-making. • Appropriate training and capacity development needs to be ensured.

Table 2.2. ***Principles regarding the objectives and outcomes of activities that aim to reduce the impacts of climate change on biodiversity***

1. Fragmented or degraded ecosystems should be restored or rehabilitated, and critical processes should be re-established, to maintain ecosystem services.	Key ecological processes and functions such as habitat connectivity, hydrological flows, fire regimes, and pollination dynamics should be restored or rehabilitated in line with altered conditions.
2. Promote and cooperate in the conservation of ecosystems to help biodiversity and people to adjust to changing environmental conditions.	This can be accomplished by: i) representing, in protected areas and other conservation strategies, genetic, species, community and ecosystem diversity, and ecological redundancy of occurrences; ii) identifying and protecting refugia where climate change impacts are expected to be less; iii) maintaining connectivity at national and, where appropriate, at regional level; and iv) maintaining key ecological attributes within natural ranges of variation. Ecosystem integrity can also be enhanced by reducing other threats (e.g., habitat loss, invasive species). A comprehensive and adequate protected area system can often be an effective backbone of land- and sea-scape wide approaches to conservation, although in some cases connectivity can have detrimental effects on vulnerable species in instances when isolation may buffer them from some types of threats[101]
3. Preserve and enhance protective ecosystem service values that help buffer human communities from floods, storms, erosion and other climate change hazards.	The potential for natural ecosystems to provide physical protection from climate change hazards should be assessed and considered. The social, environmental and economic costs and benefits of maintaining these ecosystem services should be compared to those of other kinds of adaptation activities.
4. Ensure that any use of renewable natural resources is sustainable under impacts of climate change.	The sustainable use of ecosystems may be affected by climate change Business as usual in biodiversity conservation may not be sufficient to conserve species and ecosystems due to changes in biological productivity. Management plans should be updated and harvest or use rates modified on the basis of such assessments to ensure sustainability

BOX 2: Application of the ecosystem approach to adaptation

At its fifth meeting, in 2000, the Conference of the Parties to the Convention on Biological Diversity adopted the ecosystem approach as the primary framework for implementation of the Convention. The ecosystem approach is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way. It is based on the application of appropriate scientific methodologies focused on levels of biological organization which encompass the essential processes, functions and interactions among organisms and their environment. It recognizes that humans, with their cultural diversity, are an integral component of ecosystems.

The ecosystem approach is described by 12 principles:

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 or 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 programme should:
   a) Reduce those market distortions that adversely affect biological diversity;
   b) Align incentives to promote biodiversity conservation and sustainable use; and
   c) Internalize costs and benefits in the given ecosystem to the extent feasible.
5. Conservation of ecosystem structure and functioning, 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.

At its seventh meeting, the Conference of the Parties recognized that "there is no single correct way to achieve an ecosystem approach to management of land, water, and living resources". The underlying principles can be translated flexibly to address management issues in different social contexts for example by (IUCN, 2004):

Step A Determining the main stakeholders, defining the ecosystem area, and developing the relationship between them. (Principles 1, 7, 11, 12)
Step B Characterizing the structure and function of the ecosystem, and setting in place mechanisms to manage and monitor it. (Principles 2, 5, 6, 10)
Step C Identifying the important economic issues that will affect the ecosystem and its inhabitants. (Principles 4)
Step D Determining the likely impact of the ecosystem on adjacent ecosystems. (Principles 3, 7)
Step E Deciding on long-term goals, and flexible ways of reaching them. (Principles 7, 8, 9)
Step F Research, monitoring and adaptive management

63. **As ecosystems are affected by climate change, conservation strategies will also need to change.** Adaptation in the conservation sector will need to involve not only reducing the impacts of climate change on biodiversity but also assessing and, where necessary, adjusting traditional conservation practices and targets in order to reflect changing conditions.

64. **Ecosystems are not static entities: the structure and composition of ecosystems have changed with changing historical climates.** Each species responds to the climate at its own rate and the composition of past ecosystems often has no analogue to present-day ecosystems.[102] Further, recent research suggests that novel climates (for example, new combinations of temperature and precipitation) are likely to arise in many continents.[103]

65. **The aim of conservation strategies in the future will need to include minimising the loss of biodiversity and to maintain ecosystem services in the face of climate change.** However, conservation and adaptation strategies that are flexible and robust in light of uncertainty about the magnitude, direction and rate of climate change will be needed. Strategies that facilitate the autonomous transformation of ecosystems in response to changing conditions, such as adaptive management and scenario planning, are most likely to maintain biodiversity and ecosystem functioning.

66. **Maintenance of current species combinations and ecosystem services in their present form in their present location will, in most cases, be unlikely.** Accordingly, four distinct but complementary strategies for conservation in the twenty-first century are described below: (i) providing beneficial conditions for natural adaptation of species and ecosystems; (ii) adapting restoration practices to respond to climate change; (iii) the assisted relocation of species affected by climate change, and (iv) the *ex situ* conservation of biodiversity that is unable to adapt to climate change. The first two of these are expected to be of highest relevance in most circumstances given existing strategies and practices. Such strategies are complementary and in some respect are interdependent upon the others. For example, restoration work may require species collection and at least short term *ex situ* storage.

(i) Providing beneficial conditions for natural adaptation of species and ecosystems

67. **The most fundamental biodiversity conservation strategy will continue to be promoting the conservation of intact and functioning ecosystems wherever possible**. This can be accomplished through:

- Reducing other stresses on species and ecosystems, including from habitat loss and fragmentation, invasive alien species, pollution, and overharvesting. Reducing these threats is necessary to maximise the resilience of species and ecosystems to climate change.
- Increasing protected area systems and improving the connectivity of protected areas and natural landscapes to provide opportunities for species to adapt to climate change by migration, and to increase the probability of maintaining viable populations of species.
- Identifying locations within landscapes where species have maintained populations in the face of past climate change (past climate refugia) and focus conservation efforts in these locations.
- Identifying existing locations that contain diverse environmental conditions (including latitudinal and elevational gradients, levels of moisture, soil types etc) in which to focus conservation efforts, as these areas are likely to provide the widest range of habitats in the future.
- Examining models to determine areas with future climatic suitability for ecosystems, and treat these areas as potential priorities for conservation.
- Prioritizing areas of high endemism, as many of these have been relatively climatically stable for millions of years and have species with a high degree of specialization. As the communities have largely evolved in situ, the options for relocation may be minimal so intensive efforts to maintain these areas in the face of climate change, or preserve their genetic diversity, may be crucial.
- Actively managing climate-related disturbance events, such as floods or droughts that may alter in both frequency and intensity in the future.

(ii) Adapting restoration practices to respond to climate change

68. **Ecosystem restoration involves activities that transform a degraded ecosystem into an ecosystem that is more natural and better able to provide ecosystem services.** Restoration is considered to be successful once ecosystem resilience has been regained.[104] Although restoration can have significant

economic benefits, it is considerably more cost-effective to conserve ecosystems rather than having to restore them after degradation.

69. **Ecosystem restoration strategies in the future will need to consider a wider set of issues to address the additional stress from climate change.** These will include:

- *The role of extreme events:* Understanding and anticipating potential changes in disturbance regimes that influence successional processes will be a key to restoration of degraded ecosystems.
- *A focus on the restoration of function rather than species composition (i.e., maintaining ecological resilience):* As the climate changes, many species will become increasingly unsuited to conditions within their present day geographic range. Successful restoration of ecosystem functioning will therefore need to focus on restoring functionality, rather than attempting to re-create the original species composition. For example, a given area may continue to be predominated by oaks (*Quercus* spp.) under a future climate but the particular species of oak may differ. Restoring redundancy will also be important in order to support resilience.
- *Genetic provenances used in re-establishment:* A long-held paradigm of restoration ecology is the desirability of re-establishing individuals of local origin i.e. propagation material collected within a narrow radius of the restoration site that is thought to be best-adapted to local conditions. However, under changing climatic conditions, the use of a mixture of genetic provenances collected over a broad range of sites and climates will likely increase the probability of restoration success, and may be an effective form of risk-spreading. However, approaches involving the introduction of new species or individuals of distant provenance into an ecosystem require careful consideration in order to avoid negative impacts on native biodiversity, and should be consistent with relevant negotiations on access and benefit sharing.

(iii) The assisted relocation of species affected by climate change

70. **In cases where there are existing barriers to migration, such as landscape fragmentation, or limits to dispersal capacity, assisted relocation, or migration, of species may be the only approach to ensure their persistence.** There are two general types of relocation: simple assisted relocation, where movements between areas with suitable habitats are facilitated by human intervention; and relocation supported by additional engineering measures, where before a species can be moved, habitat in the new area must first be created or modified to allow the species to survive. In extreme cases this could potentially include modifying organisms (e.g. through selective breeding) to ensure their suitability for introduction. There may be lessons to learn from successful introductions within the crop, livestock, fisheries and forestry sectors, which have a long history of assisted migration.

71. **Although in some instance they may be the only viable option, there are limitations, risks, uncertainties, and often high costs associated with assisted relocation techniques.** Relocated species become "introduced" species to the new habitat, with potential to cause negative impacts on indigenous species. Such impacts, which may include disruptions of predator-prey interactions or symbiotic interactions, changes in parasitism rates and potential competition with existing species for limited resources, need to be assessed in advance of any relocation intervention. In order for relocation to be successful it will often be necessary to move many individuals into the new area at once – increasing the possibility of ecosystem disruption at the new spot. It is also likely that not just one species needs to be relocated but rather multiple components of ecosystems and this assumes that the necessary functions of the components of a natural ecosystem for species to survive and thrive are understood. Lessons from reintroduction experiences suggest that such complex relocation schemes would be very expen-

sive, be only feasible at relatively small scales, and would often stand little chance of success. Relocation measures supported by additional engineering measures to modify an existing ecosystem also face the additional challenge of reducing potential impacts on existing species. The time required for ecosystem modifications may mean that species will have to be held in captivity (see below) for a length of time before the new habitat is ready for the species relocation.[105]

(iv) Ex situ conservation

72. **Given the links between climate change and extinction risks, it may be desirable to store species or genotypes that are likely to be unable to survive under new conditions.** Climate change increases the risk of extinction for many species, and there may be loss of genetic variability even if the species survives (e.g., loss of populations, loss of subspecies). Therefore, it may be desirable to store species or genotypes so that they can be used in reintroductions or assisted migration as appropriate. While there are many reasons for the loss of genetic resources and the need to store species and genotypes, this technique is widely regarded as a final effort. Furthermore, storing species (other than seeds) or simple ecosystem components on the scale that would seem necessary in view of the high proportion of species likely to be affected is likely to be infeasible and extremely expensive. In addition, the storage of species, in seed banks or captive facilities inevitably leads to the loss of the vast majority of ecosystem services supported by those species.

73. **The practice of conservation includes a long history of maintaining species and genetic stock in zoos, aquaria and gene banks.** Recently, efforts have been increased to collect and store agricultural and wild plant seeds or develop gene banks in order to protect against loss of genetic variety or against large-scale crises (e.g. Svalbard Global Seed Vault and the Millennium Seed Bank Project (MSBP) of the Royal Botanic Gardens, Kew). It is anticipated that seeds will have been banked from approximately 10 per cent of the world's wild plant species by the end of the decade, which could allow the reintroduction of those species.

74. **Costs and currently available space are key limitations to captive breeding of threatened animal species, although the *ex-situ* conservation of plants is relatively less expensive.** Existing zoos and off-site breeding facilities can be expected to accommodate no more than a small fraction of the number of species that might be threatened. For example, an estimated 16 snake species and 141 bird species could be accommodated and sustained in accredited North American zoos and aquariums in long-term management programmes.[106] These programmes are also expensive and reintroductions are technically difficult.[107] With regard to plants, however, the costs for *ex situ* conservation are relatively low compared to management of an *in situ* reserve or compared with *ex situ* conservation of fauna. For example, the Millennium Seed Bank holds some 26,142 species from 128 countries, at a current cost of approximately $3,000 per species per year.

2.2 IMPACTS OF ADAPTATION ACTIVITIES ON BIODIVERSITY

Activities to adapt to the adverse impacts of climate change can have positive or negative effects on biodiversity, but tools are available to increase the positive effects and decrease the negative effects.

75. **The impacts of adaptation strategies on biodiversity will vary across sectors and will depend on the way in which such strategies are implemented.** For example, the draining of coastal wetlands may be adopted as an adaptation strategy to expand agricultural production and ensure food security,

however such an activity could reduce breeding and feeding grounds for fish and other marine biodiversity, thereby increasing the vulnerability of marine ecosystems and associated livelihoods such as fisheries, and may become increasing costly in the face of sea level rise. When deciding on measures to address a given climate change impact there is usually a range of available options, as illustrated by the table in annex III. The suitability of these options (taking into account environmental, social and economic implications) will depend on the site-specific environmental and socio-economic setting. Often, a spatially differentiated combination of measures may be appropriate. In most cases there is the potential to increase positive and reduce negative impacts through, for example, applying the ecosystem approach as outlined in box 2, and carrying out environmental impact assessments, technology impacts assessments and strategic environmental assessments. [x]

76. **To ensure that adaptation decisions maximize positive impacts and minimize negative impacts on biodiversity, the following principles are recommended:**

- *The potential of ecosystem-based adaptation options as contrasted with technological solutions should be fully considered* (for illustration, see table 2.2 and annex III).
- *Strategic environmental assessment and environmental impact assessment should be applied* in a way that ensures full consideration of all available alternatives, i.e. not be restricted to consideration of different variants of the same technical option (as often happens).
- *The value of biodiversity and ecosystem services should be considered in decision making processes* including through the use of tools and methodologies presented in section 4.
- *Adaptation decisions should allow for monitoring and adaptive management approaches; these are a prerequisite for adaptation to succeed*, particularly because of the high degree of uncertainty in projections about future impacts on which adaptation decisions are based. The knowledge base with regard to biodiversity especially in developing countries needs to be considerably strengthened.

77. There are specific adaptation options for different sectors, which can maximize positive and minimize negative impacts on biodiversity. Examples are set out in the following paragraphs.

Agriculture

78. The agricultural sector (including both crop cultivation and livestock production) will have to cope with multiple stresses such as higher temperatures, water stress, greater climate variability and frequency of extreme events, changing pest and disease prevalence and saline water intrusion into groundwater. Responses to these projected impacts could include intensification and use of systems which require greater inputs, such as irrigation and increased amounts of fertilizers and other chemicals as well as moving agricultural production to new areas. However, such responses are likely to be maladaptive, for example by increasing soil erosion in the case of extreme events, leading to eutrophication of water courses or shifting pressures from agriculture to new areas.

79. Genetically modified organisms (GMOs) may provide traits (temperature, drought, salinity and pest tolerance) that aid the adaptation of crops and tree plantations to climate change. However, the use of GMOs also presents risks to biodiversity through gene transfer. The use of GMOs should consider technical, legal, socio-economic and environmental aspects. In this regard, it is important to develop comprehensive, science-based and transparent risk assessments, on a case-by-case basis, and to fully respect the national legislation on the matter.[xi]

x Additional details are provided in the Course Manual for Strategic Environmental Assessment (SEA) published by the International Association for Impact Assessment (http://www.iaia.org/training/sea-manual.aspx).

xi The use of modern biotechnology, as defined in the Cartagena Protocol on Biosafety, should apply the provisions and processes as laid down by the Protocol (www.cbd.int/biosafety/).

80. In many cases, it may be possible to use ecosystem-based adaptation in agriculture (see section 2.3 and case-study 6 below). Decisions should be guided by considering the long-term ecosystem effects of potentially maladaptive approaches. The application of agro-ecological approaches aimed at conserving soil moisture and nutrients, applying integrated pest management and diversifying crops and farming systems through the application of multi-cropping or mixed farming systems can increase long-term resilience against climate-change impacts and has many co-benefits such as reducing erosion or eutrophication problems.

Fresh water management

81. Major impacts of climate change that need to be addressed in water management include increasing flood risk, increasing risk of drought and change in timing of flow regimes. Common technical approaches to flood risk include the construction of dykes and dams. Technical solutions are also often applied to address problems of water shortage, including the construction of reservoirs and canals, facilities for water diversion and abstraction from rivers, and alterations to river beds to improve shipping capacity during low-water periods. Hard structures can have significant environmental impacts, such as destruction or alteration of wetlands, reducing connectivity between lakes, rivers and riparian zones, and changing sediment flows. Restoration of upland watersheds and floodplain restoration are ecologically viable alternatives that deserve attention (see case-studies 3 and 4 below).

82. In some cases, it may be possible to consider ecosystem-based alternatives, by taking a broad-scale approach to problems that considers impacts at the watershed level, for example. Ecosystem-based alternatives include watershed management to increase the storage of rainwater in wetlands and forests, and agricultural practices that improve the water storing capacities of soils, e.g., by enhancing soil structure and humus content.

Forestry and forest management

83. There is no universally applicable measure for adapting managed forests to climate change because forest ecosystems, projected disturbances, and ecosystem responses are all highly variable within and among forest biomes and forest types. While forest managers could deploy multiple adaptation measures appropriate for their local situations, many of these measures can have long-term impacts on the system, such as reduced productivity and reduced forest resilience. Possible measures with likely negative consequences for biodiversity could include increased development of plantation forests especially those with non-native species, thinning, increased use of herbicides and insecticides to combat pests, and reduced rotation length. Some of the more controversial techniques that could be used include assisted migration of regional tree species, the importation of invasive alien tree species or the use of genetically modified tree stock. These latter techniques should take into account risks from the development of novel ecosystems, which may have impacts on the endemic species of the area. On the other hand, when used in forest areas that are already managed, such approaches may have some potential to ease the pressure on natural forests.

84. The negative impacts of adaptation in managed forests can be reduced through an increased understanding of forest ecosystems and improved application of the ecosystem approach within forest management.[108] [109] In forests managed primarily for production, sustainable forest management is an important framework (see also case-study 9). Taking into account the rate of growth of forest ecosystems, adaptation to climate change may include applying sustainable forest management principles based on future conditions to enable long-term resilience of forest systems.

85. Although sustainable forest management (SFM) is widely accepted as a framework for managing production forests, there is an acknowledged failure to implement sustainable forest management in many areas of the world[110] due to insufficient financial resources, a lack of capacity and limited access to technologies. This is one factor limiting the capacity of forests and forest-dependent peoples to adapt to climate change.[111]

86. To meet the challenges of adaptation, commitments to achieving the goals of sustainable forest management should be strengthened at the international, national, and, where appropriate, at the community level. In some cases, new modes of governance may be required that enable meaningful stakeholder participation, especially among local communities, and to provide secure land tenure and forest user rights and sufficient financial incentives.

87. The current failure to protect primary forests and avoid fragmentation as well as failure to implement the ecosystem approach in forest areas; in many areas of the world also limits the capacity of forests and forest-dependent peoples to adapt to climate change.[142] Approaches to address this failure, including the protection of primary forests, reducing fragmentation, and increasing landscape connectivity, could form important elements of a portfolio of adaptation options that maximize biodiversity benefits. However, new governance modes to maximize the positive and reduce the negative impacts of adaptation on forest biodiversity require multidisciplinary approaches that are difficult to implement, since they are particular to each community.

Human settlements

88. Adaptation measures in human settlements will have to be implemented to address extreme weather events, erosion, flooding, and increased heat. While many of these impacts will require responses involving hard infrastructure, some ecosystem-based measures can be employed (see case-study 11 below).

89. The biggest danger to biodiversity from adaptation measures comes from changes in environmental conditions, including changes in water table level and disturbances to semi-natural habitats caused by protective hard infrastructure (e.g., dams and dykes). Adaptation strategies to reduce negative impacts on biodiversity that can be applied in the urban environment lie predominantly in creating new potential habitats (e.g. new water bodies, dry and wet polders) as refugia for native plants and animals.

90. Broad adaptation policy measures include planning activities (long-term strategic planning, spatial planning for flood management, adaptive management policy), reducing other stresses in settlements (e.g. air-borne pollutants) or increasing resilience of urban vegetation to extreme weather.

Marine and coastal zone management

91. Like other ecosystems, marine and coastal areas are already adversely impacted by many stresses, which will be exacerbated by climate change (e.g., sea level rise). At the same time, coastal ecosystems ranging from polar regions to small island developing States are essential to our capacity to respond to projected climate change impacts.

92. Many proposed strategies to adapt to climate change impacts in coastal regions consider hard infrastructure approaches (e.g., sea walls, dykes, etc.). Such structures often adversely impact natural ecosystems processes by altering tidal current flows, disrupting or disconnecting ecologically related

coastal marine communities, disrupting sediment or nutrition flows and may cause stagnation in some contexts. Such structures may also impede successful reproduction of some species (e.g., turtles).

93. However, efforts to adapt would benefit from the application of the ecosystem approach, which should consider the need to address all sources of impacts (human and climatic). Approaches to adaptation should also include measures that address needs for coastal area protection while limiting adverse impacts on coastal biodiversity. Ecosystem-based adaptation offers potential for co-benefits in the context of building climate-resilient coastal communities (see case-study 1). However, this approach is often not considered in favour of engineering approaches which can be site-specific in meeting the objective of coastal defence yet more extensive in disrupting ecological services.

2.3 USING BIODIVERSITY TO ADAPT TO THE ADVERSE EFFECTS OF CLIMATE CHANGE ECOSYSTEM-BASED ADAPTATION

Ecosystem-based adaptation, which integrates the sustainable use of biodiversity and ecosystem services into an overall adaptation strategy can be cost-effective and generate social, economic and cultural co-benefits and contribute to the conservation of biodiversity

94. **Ecosystem-based adaptation is the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people to adapt to the adverse effects of climate change.** Ecosystem-based adaptation uses the range of opportunities for the sustainable management, conservation, and restoration of ecosystems to provide services that enable people to adapt to the impacts of climate change. It aims to maintain and increase the resilience and reduce the vulnerability of ecosystems and people in the face of the adverse effects of climate change. Ecosystem-based adaptation is most appropriately integrated into broader adaptation and development strategies.

95. **Ecosystem-based adaptation can be applied at regional, national and local level, at both project and programmatic levels, and over short or long time scales.** Means of implementing ecosystem-based adaptation include:

- Sustainable water management where river basins, aquifers, flood plains and their associated vegetation provide water storage and flood regulation;
- Disaster-risk reduction where restoration of coastal habitats such as mangroves can be a particularly effective measure against storm-surges and coastal erosion;[112;]
- Sustainable management of grasslands and rangelands, to enhance pastoral livelihoods;
- Establishment of diverse agricultural systems, where using indigenous knowledge of specific crop and livestock varieties, maintaining genetic diversity of crops and livestock, and conserving diverse agricultural landscapes secures food provision in changing local climatic conditions; and
- Establishing and effectively managing protected-area systems to ensure the continued delivery of ecosystem services that increase resilience to climate change.

Mangroves, Rìa Lagartos Biosphere Reserve, Mexico
Photo courtesy of Annie Cung

96. **Intact, well functioning ecosystems, with natural levels of biodiversity, are usually more able to continue to provide ecosystem services and resist and recover more readily from extreme weather events than degraded, impoverished ecosystems.** Intact ecosystems are usually better able to provide ecosystem services to support adaptation, and the conservation of such ecosystems and the restoration of degraded ecosystems is an important element of ecosystem-based adaptation.

97. **Ecosystems play an important role in protecting infrastructure and enhancing human security.** More than 1 billion people were affected by natural disasters between 1992 and 2002. In response to these events many countries have adopted plans and programmes recognizing the need to maintain natural ecosystems, as part of a risk reduction strategy. The Global Assessment Report of the United Nations ISDR[113] also recognizes the decline of ecosystems and the associated degradation of ecosystem services as one of the three main drivers of disaster risk.

98. **The value of ecosystems in ameliorating the negative impacts of some extreme events has been demonstrated.** The value of mangroves for coastal protection has been estimated in some areas to be as much as US$ 300,000 per km of coast based on the cost of installing artificial coastal protection. A study of the overall value of wetlands for flood protection provided an estimated benefit of $464 per metre of riverbank.[114] Furthermore, the conservation and sustainable use of biodiversity has a significant role to play in response to drought, including by providing important genetic diversity in livestock and crops.

99. **Despite the relatively high costs as compared to conservation of existing intact ecosystems, restoration of ecosystems can still be part of a cost-effective adaptation strategy.[115]** Restoration activities include limiting activities such as grazing or extraction to allow ecosystems to recover, or restoring ecological components such as connectivity or hydrological regimes, through activities such as re-flooding wetlands. For example, flood plain restoration can be a useful alternative to constructing additional dams or reservoirs for increased flood-water storage, and reforestation of degraded areas can be an effective strategy to enhance land productivity.

100. **Ecosystem-based adaptation options are often more accessible to the rural poor than adaptation interventions based on infrastructure and engineering.** The poor are often the most directly dependent on ecosystem services and thus benefit from adaptation strategies that maintain and enhance those services. Ecosystem-based adaptation can be consistent with community-based approaches to adaptation; can effectively build on local knowledge and needs; and can provide particular consideration to the most vulnerable groups of people, including women, and to the most vulnerable ecosystems.

101. **There can be multiple social, economic and environmental co-benefits for local communities from the use of ecosystem-based adaptation.** Communities that are managing ecosystems specifically to adapt to climate change impacts can also benefit from these interventions in other ways, if they are designed and managed appropriately (table 2.3). For example, the restoration of mangrove systems can provide shoreline protection from storm surges, but also provide increased fishery opportunities, and carbon sequestration. As such, ecosystem-based adaptation can sometimes achieve adaptation benefits for many sectors through a single investment.

102. **Ecosystem-based adaptation can contribute to climate-change mitigation, by conserving carbon stocks, reducing emissions from ecosystem degradation and loss, and enhancing carbon sequestration.** The conservation, restoration and sustainable management of terrestrial and coastal ecosystems is an integral part of both adaptation and mitigation efforts. Ecosystem-based adaptation activities that conserve natural forests, for example, also provide significant climate change mitigation

benefits. Similarly, the conservation and restoration of other natural ecosystems (such as savannahs, grasslands and wetlands) can result in both adaptation and mitigation benefits.

103. **Ecosystem-based adaptation, if designed and implemented appropriately, contributes to biodiversity conservation and sustainable use.** Conserving, restoring and sustainably managing ecosystems, as part of an adaptation strategy can also help conserve biodiversity and a wider range of ecosystem services through providing important habitats and biological resources, and maintaining landscape connectivity. For example, the conservation or restoration of wetlands to ensure continued water flow in periods of drought also conserves plant and animal species that live or breed in these systems. The establishment of diverse agroforestry systems with native plant species as an adaptation measure can similarly help conserve biodiversity.[116] The creation or expansion of community conserved areas in dryland regions can not only provide additional fodder resources for pastoralists, but also provide habitat for native dryland species. Similarly, the establishment or creation of networks of marine protected areas can ensure the continued provision of ecosystem services for adaptation, as well as biodiversity conservation.

Table 2.3 ***Examples of ecosystem-based adaptation measures that provide co-benefits***

		Co-benefits			
Adaptation measure	**Adaptive function**	**Social and cultural**	**Economic**	**Biodiversity**	**Mitigation**
Mangrove conservation	Protection against storm surges, sea-level rise and coastal inundation	Provision of employment options (fisheries and prawn cultivation) Contribution to food security	Generation of income to local communities through marketing of mangrove products (fish, dyes, medicines)	Conservation of species that live or breed in mangroves	Conservation of carbon stocks, both above and below-ground
Forest conservation and sustainable forest management	Maintenance of nutrient and water flow Prevention of land slides	Opportunities for Recreation Culture protection of indigenous peoples and local communities	Potential generation of income through: Ecotourism, Recreation Sustainable logging	Conservation of habitat for forest plant and animal species	Conservation of carbon stocks Reduction of emissions from deforestation degradation

Adaptation measure	Adaptive function	Co-benefits			
		Social and cultural	Economic	Biodiversity	Mitigation
Restoration of degraded wetlands	Maintenance of nutrient and water flow, quality, storage and capacity Protection against floods or storm inundation	Sustained provision of: Livelihood Recreation Employment opportunities	Increased: Livelihood generation Potential revenue from recreational activities Sustainable use Sustainable logging of planted trees	Conservation of wetland flora and fauna through maintenance of breeding grounds and stop over sites for migratory species	Reduced emissions from soil carbon mineralization
Establishment of diverse agroforestry systems in agricultural land	Diversification of agricultural production to cope with changed climatic conditions	Contribution to food and fuel wood security.	Generation of income from sale of timber, firewood and other products	Conservation of biodiversity in agricultural landscape	Carbon storage in both above and below-ground biomass and soils
Conservation of agrobiodiversity	Provision of specific gene pools for crop and livestock adaptation to climatic variability	Enhanced food security Diversification of food products, Conservation of local and traditional knowledge and practices	Possibility of agricultural income in difficult environments Environmental services such as bees for pollination of cultivated crops	Conservation of genetic diversity of crop varieties and livestock breeds	
Conservation of medicinal plants used by local and indigenous communities	Local medicines available for health problems resulting from climate change or habitat degradation, e.g. malaria, diarrhea, cardiovascular problems.	Local communities have an independent and sustainable source of medicines Maintenance of local knowledge and traditions	Potential sources of income for local people	Enhanced medicinal plant conservation Local and traditional knowledge recognized and protected.	Environmental services such as bees for pollination of cultivated crops
Sustainable management of grassland	Protection against flood Storage of nutrients Maintenance of soil structure	Recreation and tourism	Generate income for local communities through products from grass (ex: broom)	Forage for grazing animals Provide diverse habitats for animals that are predators and prey	Maintenance of soil carbon storage of soil carbon

104. **In order to ensure that ecosystem-based adaptation activities deliver multiple social, economic, cultural, and biodiversity benefits, it is important that these co-benefits be specifically considered in the planning, design, implementation, monitoring and evaluation of these activities.** Adaptation activities are more likely to deliver significant co-benefits if social, economic, cultural and environmental aspects are explicitly considered in all phases of project development and implementation; if trade-offs and synergies are carefully identified and explored; and if all stakeholders are given a voice in deciding how adaptation measures are implemented. Examples of such considerations are provided in the case-studies below.

105. **Systems to monitor and evaluate co-benefits from ecosystem-based adaptation measures should be established to ensure the equitable distribution of benefits among stakeholders.** Guidelines already exist for ensuring the delivery of co-benefits in climate mitigation projects (e.g., the Climate, Community and Climate Change Alliance[117]) and these could potentially be adapted to guide ecosystem-based adaptation measures.

106. **Like all adaptation activities ecosystem-based adaptation is not without complexity, uncertainty, and risk.** Ecosystem-based adaptation may require managing ecosystems to provide particular services at the expense of others. For example, using wetlands for coastal protection may require emphasis on silt accumulation and stablilization possibly at the expense of wildlife values and recreation. Slope stabilization with dense shrubbery may expose the area to wildfire, especially in an increasing wet-dry alternation under a changing climate, and possibly a disastrous reversal of the adaptation goal. It is therefore important that decisions to implement ecosystem-based adaptation are subject to risk assessment, and scenario planning that recognise and incorporate these potential trade-offs. In addition, the implementation of ecosystem-based adaption requires an adaptive management approach, which allows management adjustments in response to changes in external pressures, and uncertainty in ecosystem functioning.

Case-studies on ecosystem-based adaptation

1. *Using ecosystems for coastal defence*

107. One adaptation response to observed and projected sea-level risk and increased frequency and intensity of extreme weather events is through "hard" defences (sea walls, dykes and tidal barriers). However, ecosystem-based adaptation can also play a role in a number of coastal defence strategies. These approaches include activities such as planting of marsh vegetation in the intertidal zone and wetland restoration.[118] Coastal wetlands can absorb wave energy and reduce erosion through increased drag on water motion, a reduction in the direct wind effect, and directly absorbing wave energy.[119] The accretion of sediments also maintains shallow depths that decrease wave strength.[120]

108. Mangroves, for example, can provide physical protection to coastal communities whilst providing provisioning ecosystem services such as productive fisheries; offering both physical protection and economic gain to the most vulnerable people[121] as well as sequestering carbon. As one example, nearly 12,000 hectares of mangroves were planted in Viet Nam at a cost of US$1.1 million. This investment saved an estimated $7.3 million per year in dyke maintenance whilst providing protection against a typhoon that devastated neighbouring areas.[122]

2. *Designing resilient marine protected area networks*

109. Climate change represents a serious threat to tropical marine ecosystems. For example, ocean acidification is reducing the ability of many marine organisms to produce shells while rising sea temperatures are increasing the instances and extent of coral bleaching and the exposure of fish and marine mammals to disease and parasites.

110. Marine protected areas (MPAs) are defined as "any defined area within or adjacent to the marine environment, together with its overlying waters and associated flora, fauna and historical and cultural features, which has been reserved by legislation or other effective means, including custom, with the effect that its marine and/or coastal biodiversity enjoys a higher level of protection that is surroundings".[123] An MPA network is a portfolio of biologically connected MPAs that is fully representative of the range of target ecosystems, species, and processes including in marine areas beyond national jurisdiction.

111. In recent years, principles for designing and managing MPA networks that are resilient to the adverse affects of climate change have been developed.[124] They include: spreading the risk through representation and replication; protecting special and unique sites; incorporating patterns of connectivity and effective management.

112. As one example,[125] Kimbe Bay, located on the north coast of the island of New Britain in the Bismarck Sea, Papua New Guinea, is a pilot site for establishing a resilient network of MPAs. The vision for Kimbe Bay is to "*Harness traditional and community values to protect and use land and sea resources in ways that maintain the exceptional natural and cultural heritage of the bay*". This will be achieved by working with local communities, governments and other stakeholders to: establish a resilient network of MPAs that is specifically designed to address the threat of climate change; develop a marine resource use strategy, which will address threats from overfishing destructive fishing and hunting of rare and threatened species (dugong and sea turtles) and develop a land use strategy, which will address the threat of runoff from poor land-use practices.

3. *Restoring and maintaining upland watersheds*

113. Climate change is leading to increased inland flooding in many regions through more variable rainfall events. Restoring and maintaining ecosystems in upland watersheds, including through the management of soils and vegetation, can contribute to reducing the risk of flooding and maintaining regular water supplies. Run-off from mountainous areas in small islands is often the major supply of water,[126], and in many countries, watersheds form a critical part of the national economy.[127] Often these watersheds are degraded, and their rehabilitation is one adaptation option.[128]

114. Wetland ecosystems in watersheds can reduce flooding and sediment deposition whilst improving water quality downstream. A study of upland forests in a watershed in Madagascar has estimated their flood protection value at $126,700, and peat bogs in Sri Lanka that buffer floodwaters from rivers have an estimated annual value of more than $5 million.[129] In the Morogoro region of the United Republic of Tanzania, reduced river flow and increased flooding has been attributed to deforestation in the mountains, and it has been suggested that effective management of soil, forests and water resources are needed as adaptation measures, along with improved social capacity.[130] Ecuador and Argentina have integrated forests and wetlands into their "living with floods" strategies,[131] and reforestation is recognised as an important option for adaptation in the watersheds of the Philippines.[132] Viet Nam includes measures such as integrated management of watersheds in its disaster reduction planning, along with

forest management, and soil and water conservation.[133] Large-scale afforestation projects in China have been carried out with the aim of reducing flooding and increasing water conservation, and countries of Central America are collaborating to protect watersheds and forests.[134]

4. *Flood plain restoration*

115. Climate change is causing an increase in the scale of flooding and dry periods in many flood plains. In some systems dams are no longer a viable adaptation strategy, and in some cases dams have had negative environmental and socio-economic impacts. In these circumstances ecosystem management is an effective adaptation strategy at the river basin scale and an alternative to the development of small-scale dams.[135]

116. In developed countries, cost-effective flood reduction strategies that allow re-growth of vegetation alongside rivers and establish vegetation buffers along streams, combined with the reduced development of infrastructure, are being promoted in some areas.[136] Some evidence that this can be an effective strategy has been provided in a modelling scenario exercise, which suggested that a combination of wetland restoration and hard defences provides optimal flood protection.[137]

117. Restoration of floodplain ecosystems can also help to reduce the levels of water pollution following extreme events.[138] In Europe, the conservation or restoration of river floodplains has been included in a number of flood reduction strategies,[139] although there are many new river-management plans that do not include such measures.[140]

5. Conserving agrobiodiversity as a basis for agricultural diversification

118. Climate change increases the risk of reductions in crop and livestock yields. Within a given region, different crops and livestock are subject to different degrees of impacts from current and projected climate change.[141] In light of this, the adoption of specific crops, livestock or varieties in areas and farms where they were not previously grown are among the adaptation options available to farmers.[142] Further, the use of currently under-utilized crops and livestock can help to maintain diverse and more stable agroecosystems.[143] Conserving crop and livestock diversity in many cases helps maintain local knowledge concerning management and use.

Bee and plum blossom, Canada
Photo courtesy of Dan Montagano

119. In order to develop climate-change-resistant crop and livestock varieties and genotypes, such as those resistant to drought, heat stress, disease, and saline conditions, it is critical to maintain agrobiodiversity[144] and to ensure the continued survival of crop wild relatives.[145] Developing new varieties may, in addition to meeting adaptation needs, generate co-benefits in the context of health and biodiversity conservation and sustainable use. For example, varieties resistant to crop diseases may contribute to the reduction of pesticide use. It is in light of this potential that the International Centre for Agricultural Research in Dry Areas (ICARDA) has developed a programme on climate change and drought management in Central Asia and China which seeks to enahnce food security and livelihood options through sustainable agricultural management and the development and dissemination of new genetic varieties.[146]

6. *Changes in agricultural practice*

120. Given the above-mentioned impacts of climate change on agricultural systems, practices that enhance soil conservation and sustainable use and maintain favourable microclimates are important for adaptation in agriculture.

121. These practices can include methods such as: terracing and stone-bunding,[147] the use of organic fertilizers, and changes to tillage practices,[148]; crop rotation and the use of vegetation buffer strips;[149] and maintaining cover through plantings or mulches.[150] In drylands, agricultural practices such as the use of shadow crops can enhance resilience by providing protection against extreme rainfall, and increasing infiltration into the soil.[151] Many of these measures reduce the need for nutrient inputs and use of heavy machinery. They also decrease vulnerability to extreme weather events. For example, in Thailand, the sustainable economy project is encouraging diversification within previous mono-cropping practices (largely rice paddies) with positive impacts on poverty alleviation, carbon sequestration and agricultural biodiversity.

7. *Agroforestry*

122. Agroforestry is a promising option for increasing the resilience of rural communities in the face of climate change. Agroforestry involves the integration of trees into crop and animal production areas and includes a diverse range of systems, such as silvopastoral systems, shade-grown perennial crops (e.g., coffee, cocoa, rubber), windbreaks, alley cropping, and improved fallows. Including trees within agricultural systems leads to increased soil conservation, microclimatic buffering and more efficient water use,[152] and thereby helps buffer the impacts of climate change. At the same time, agroforestry systems provide a wide array of products to smallholder farmers, diversifying their production and livelihood options. Agroforestry systems that are floristically and structurally diverse can also provide important biodiversity benefits to smallholder farmers.[153] They can also serve an important role in climate change mitigation by enhancing carbon stocks within the agricultural landscape[154] and, in some cases, reducing pressure on nearby forests, thereby reducing emissions from deforestation.

8. *Ecological management in drylands*

123. Drylands cover more than 40 per cent of the global land surface and are inhabited by a significant proportion of the world's poor and marginalized people.[155] The intensity and frequency of extreme events, both droughts and floods, are projected to increase in drylands under future climate change scenarios. Since widespread technological solutions may be unavailable across these often vast dryland systems, proper land tenure and ecosystem management policies can be particularly effective in helping dryland inhabitants adapt to climate change. For example, climate warming has been shown to decrease growth rates, the number of plant species found in a given area, and the delivery of key ecosystem services on the grasslands of the Tibetan Plateau. Ensuring that the amount and timing of grazing is appropriate to the seasonal availability of fodder resources can buffer the system from these negative warming effects.[156] More broadly, by reinforcing the traditional strategies pastoralists have developed to deal with climate variability (e.g. mobility, common land tenure, reciprocity, mixed species grazing), in addition to introducing newer techniques (e.g. grass banks, income diversification), the economic, social, and cultural well-being of societies dependent on dryland resources can be supported in the face of climate change.[157]

124. The dry forests of south-west Peru provide essential ecosystem services to a region supporting over 680,000 people however over time many areas have become degraded as a result of overuse. A restoration project of the Royal Botanic Gardens, Kew, and Peruvian national and international partners involves work with three agro-industrial operations involved in the production of asparagus, table grapes and avocado. The initiatives include establishment of a small biodiversity area within the large industrial plantations; establishment of native vegetation alongside stream beds through farmlands; and experimental irrigation with farm wastewater/sewage as a means of restoring forests. These measures reduce the need for additional irrigation in arid areas. In each case, the project aims to integrate biodiversity into production lands. The three different agro-industrial companies each supply supermarkets in the United Kingdom, where consumer demand for accredited biodiversity-friendly products is supporting the mainstreaming of biodiversity into the production sites.

9. *Increasing the resilience of managed forests*

125. Evidence suggests that intact[158] forests, particularly primary forests, will be more resistant to climate change than second-growth forests and degraded forests.[159] Management that is closer to natural forest dynamics is, therefore, likely to increase adaptive capacity. Maintaining or restoring species and genotypic diversity in these forests would increase their adaptive capacity when some species or genotypes will no longer be suited to the altered environment, and their resistance against spreading pests. In addition, maintaining structural diversity (presence of various successional stages instead of even-aged stands) would increase their resilience and resistance in the face of extreme events (wind-throw, ice/snow damage). At broader scales adaptation can include the maintenance of different forest types across environmental gradients, the expansion of national and, where appropriate, regional systems of protected areas, the protection of climatic refuges, the reduction of fragmentation, and the maintenance of natural fire regimes bearing in mind that as fire becomes a major threat to forests, risk assessment should be reviewed at regional level and an alert system should be developed.[160]

10. *Increasing the long term sustainability of reforestation and afforestation programmes*

126. Increasing the extent of tree plantations has often been proposed as both a mitigation and an adaptation measure. Forest plantations for carbon storage, however, are usually established using genetically uniform stock with high growth rates, but low adaptive capacity, which will ultimately diminish their performance in mitigation.[161] For example, the largest monoculture plantation in the American tropics suffered a large-scale tree mortality as a result of water stress during the 1997 El Niño event.[162] Increasing both genetic and species diversity in managed forest stands is likely to be important to increase forest resilience and resistance, and can be obtained through selecting a mix of species and range of age structures, including those that are likely to be adaptable to future climate conditions.[163]

11. *Adaptation in urban areas*

127. Just over half of the global population live in urban areas, and will be exposed to the impacts of climate change mainly through overheating (with higher temperatures expected in cities than in rural areas), flash floods, and extreme weather events,[164] in addition to the impacts of climate change on food and water supplies. "Structural" adaptation measures in the urban environment can include improved building design (for increased ventilation, shading etc), increased use of air conditioning, and improved drainage through more permeable surfaces.[165]

128. Biodiversity can also play a role in urban planning through, for example, expanses of green areas for cooling, improved use of natural areas for drainage and flood reduction, and urban tree-planting for structural integrity and removal of pollutants.[166] "Urban greening" can improve the microclimate by modifying heat absorption,[167] whereas paving over areas covered by vegetation and water reduces heat loss and increases vulnerability to flooding.[168] Increasing 'blue space' (e.g. lakes and canals) is also recommended for cooling and reduced risk of flooding. There is also a growing interest in using an understanding of ecosystem properties and functioning for the design of energy-efficient buildings and urban planning.

12. *Using sustainable land management to reduce threats to health from invasive alien species*

129. Climate change is expected to increase risks from invasive alien species. As one example, common ragweed (*Ambrosia artemisiifolia*) is the most important allergenic plant in North America. It is also an invasive alien species causing rapidly increasing health concerns in Europe and China.[169.] Increasing CO_2 levels and mean temperatures are predicted to favour its development and pollen production,[170] and facilitate its further range expansion.[171] The species spreads only to disturbed areas (it is a common cropland weed), and natural ecosystems are highly resistant to its invasion. Thus, land management has a major role in controlling its abundance.[172] While traditional control measures (chemicals or physical destruction) will remain necessary in intensive croplands, in other areas land-use that decreases disturbance levels and facilitates ecosystem recovery may effectively contribute to limiting ragweed abundance, pollen density, and, ultimately, to reducing negative impacts on human health.

SECTION 3: BIODIVERSITY AND CLIMATE CHANGE MITIGATION[xii]

130. This section examines the links between biodiversity and climate-change mitigation with a particular focus on land use management activities and reducing emissions from deforestation and forest degradation. The section explores the potential contribution of biodiversity conservation and sustainable use to mitigation efforts and suggests ways in which co-benefits can be enhanced. This section also examines the potential positive and negative impacts of mitigation activities on biodiversity while highlighting those mitigation approaches for which additional research is required.

3.1 ROLE OF ECOSYSTEMS IN CARBON STORAGE AND THE CARBON CYCLE

Conserving natural terrestrial and marine ecosystems and restoring degraded ecosystems can contribute to achieving several key objectives of both the UNFCCC and the Convention on Biological Diversity.

131. **Well-functioning ecosystems are necessary to meet the objective of the UNFCCC because of their role in the global carbon cycle and their significant carbon stocks.** Carbon is stored and sequestered by biological and biophysical processes in ecosystems, which are underpinned by biodiversity. About 2,500 Gt C is stored in terrestrial ecosystems, compared to approximately 750Gt in the atmosphere.[173] An additional ~ 38,000 Gt C is stored in the oceans (~37,000 Gt in deep oceans i.e. layers that will only feed back to atmospheric processes over very long time scales, ~ 1,000 Gt in the upper layer of oceans[174]) (table 3.1). A large amount of the terrestrial carbon is stored in forest (about 1,150 Gt C) with around 30-40% in vegetation and 60-70% in soil. However, significant carbon stocks, especially soil carbon, is found in other terrestrial ecosystems including wetlands and peat lands; e.g. peat soil has been estimated to contain nearly 30% of all global soil carbon whilst covering only 3% of the land surface.[175]

132. **Each year terrestrial ecosystems take up through photosynthesis and release through respiration, decay and burning approximately 60 Gt C so relatively small changes in the net exchange are important in the global carbon balance.** For example, during the 1990s it is estimated that while 6.4 ± 0.4 Gt C per year were emitted from combustion of fossil fuels, 0.5-2.7 Gt C per year were released by land-use activities (e.g. deforestation, land-use change and land degradation). However, another 0.9 to 4.3 Gt C per year was taken up by the residual land sink as a result of enhanced growth of terrestrial vegetation from CO_2 fertilization; additional nitrogen released by human activities and increased temperature. Marine ecosystems exchange even greater amounts of carbon with the atmosphere (about 90 Gt C per year) and on average store about 2.2 ± 0.4 Gt C per year.

Vietnam, Photo courtesy of Mathieu Rossier

xii The document largely uses the terms and definitions consistent with the UNFCCC decisions 1/CP.13 (Bali Action Plan and 2/CP.13 (REDD) without any attempt to pre-empt ongoing or forthcoming negotiations, or anticipate the outcome of these negotiations. The exception is when referring to terms that are defined differently under other international processes, or for which there is no general agreement of definition, in which case the use of the term is explained in the text.

The rate of storage is controlled by two "pumps", one biological and the other physical, that transport carbon into the ocean depths. Physical processes control the rate at which CO_2 dissolves in the oceans, and both physical and biological processes then determine how the dissolved inorganic carbon is transported within the oceans. These processes are also being affected by climate change.[176]

Table 3.1. *One estimate of global carbon stocks in terrestrial ecosystems*[177] (There remains uncertainty around estimates of carbon stocks due to differences in field data used to calculate carbon densities and methods for up-scaling these values.[178] There is also great variation within any biome, e.g. wet temperate forests can be 2-3 more carbon dense than the biome average.[179])

	Global Carbon Stocks (Gt C)		
Biome	**Vegetation**	**Soil**	**Total**
Tropical forests	212	216	428
Temperate forests	59	100	159
Boreal forests	88	471	559
Tropical savannas	66	264	330
Temperate grasslands	9	295	304
Deserts and semi deserts	8	191	199
Tundra	6	121	127
Wetlands	15	225	240
Croplands	3	128	131
Total	466	2 011	2 477

133. The widespread and accelerating degradation of ecosystems has been and remains a significant source of greenhouse gas emissions, and is reducing the potential of ecosystems to sequester carbon. Although the largest share of CO_2 emissions are as the result of the combustion of fossil fuels, in 2005 about 18% of annual global greenhouse gas emissions were attributable to deforestation and other land use change and an additional 5.1-6.1 Gt CO_2 eq., or 10-12% of global emissions, stemmed from agricultural land management practices (mostly through release of nitrous oxide (N_2O) and methane (CH_4)),[180] although there is still uncertainty around the range of estimates. Degradation of natural grasslands, for example, can be a large source of carbon loss since cultivated soils generally contain 50-70% less carbon than those in natural ecosystems. The continuing rapid loss and degradation of northern, temperate and tropical peatlands is also a major source of greenhouse gas emissions, with an estimated 3 Gt CO_2 eq. (or 10% of global emissions) released each year by the drainage and conversion of peatlands to agriculture or forestry, and peat fires.[181 182]

134. **Given that forests contain almost half of all terrestrial carbon,[183] continued deforestation and degradation at current rates would significantly hamper mitigation efforts.** An estimated 7 to 13 million ha of forests are cleared each year,[xiii] releasing about 1.5 Gt C (5.5 $GtCO_2$) into the atmosphere.[184]

xiii Estimates of the area of deforestation vary according to methodology, definitions of what constitutes a forest and due to natural variation from year to year.

In addition, 2 to 3 million hectares of tropical forests are degraded each year[185] by unsustainable management. Reducing these emissions would make a key contribution to climate mitigation and is critical for avoiding dangerous climate change.

135. **There is a wide range of different forest contexts: from primary forests to monoculture plantations and these differ in their carbon stock, carbon sequestration potential, biodiversity value and their resilience to climate change.** Primary forests are generally more carbon dense and biologically diverse than other forest ecosystems. Modified natural forests (i.e. those that have been logged or degraded through other land use activities) normally have lower carbon stocks[186] and less biodiversity than primary forests.[187] Plantation forests store and sequester carbon but, *inter alia*, stands are usually harvested at a young age[188] and therefore the time-averaged stock is relatively smaller than the natural forest they replace.[189 190] Also, they are less biologically diverse than the natural forests they replace.[191] Among plantation types, those with diverse mixtures of native species have potential for more positive consequences for biodiversity than those comprised of monocultures or exotic species.[192] Different forest areas could have similar carbon stocks and carbon uptake potential but differ in their biodiversity value (e.g. landscape situation, representativeness, degree of species endemism). Table 3.2 summarizes the contributions of different forest types to both mitigation of climate change and conservation and sustainable use of biodiversity.

Table 3.2. ***Total ecosystem carbon and biodiversity benefits of main forest contexts***[xiv.]

Forest context[15]	Carbon stock	Carbon sequestration potential	Biodiversity	Value of ecosystem goods and services
Primary forest[193]	+++[194]	+*[195]	+++	+++
Modified natural forest[196]	++	++	++	++
Plantations[2] (indigenous species)	+	+++ (depending on species used and management)	+(+)	+
Plantations (exotic species)[197]	+	+++ (depending on species used and management)	+	(+)

* Potential for additional sequestration depends on several elements.

136. **Given the importance of ecosystems in the global carbon cycle, a portfolio of land use management activities, including reduced deforestation and forest degradation, in addition to stringent reductions in fossil fuel emissions of greenhouse gases, can play an important role in limiting increases in atmospheric greenhouse-gas concentrations and human-induced climate change.** The potential to reduce emissions and increase the sequestration of carbon from land use management activities is estimated to range from 0.5-4 $GtCO_2$-eq per year for forestry activities (REDD, afforestation, forest management, agroforestry), and 1-6 $GtCO_2$-eq per year for agricultural activities.[xvii] Achieving

xiv This table provides a general overview. Actual situations may vary depending on forest types and biomes, e.g. between boreal and tropical forests

xv Forest definitions are a simplified version of FAO classification.

xvi Plantation forests store less carbon because stands are usually harvested at a relatively young age, and young trees store less carbon than older trees. Also, timber harvesting causes emissions from collateral damage to living and dead biomass and soil carbon. This is also why modified natural forests store less carbon than primary forests.

xvii These estimates include models that assume effective prices ranging from <US$20/tCO2e to US$100/tCO2e in 2030

this potential, however, will be dependent upon the design and mode of implementation of these activities, and the extent to which they are supported and enabled by technology, financing and capacity building

3.2. FORESTRY- RELATED CLIMATE CHANGE MITIGATION OPPORTUNITIES AND CONSIDERATIONS

Alaska
Photo courtesy of Toan Cung

137. **There is a wide range of forestry-related mitigation options that could potentially also provide important biodiversity conservation benefits, including reducing emissions from deforestation and forest degradation, forest conservation, sustainable management of forests and enhancement of forest carbon stocks.**[xviii] **Such activities can also could potentially also provide important biodiversity conservation benefits,** though the extent to which they deliver these benefits will depend on how and where these activities are implemented (annex IV). The effect of different climate change mitigation options are also time dependent. For instance, reducing emissions from deforestation and forest degradation has an immediate effect whereas the mitigation effect of afforestation and reforestation will build through time.

138. **Opportunities for implementing forest-related climate-change-mitigation options will vary across different landscape contexts, depending on the land-use history, current land use activities and socioeconomic conditions.** Three broad types of landscapes can be identified (table 3.3) and a mixture of forest-related and agricultural options may be applicable in each of these landscapes:

1) In forest landscapes subject to ongoing clearing and forest degradation, climate change mitigation and biodiversity conservation can be achieved by reducing deforestation and forest degradation and improving forest management;
2) In forest landscapes that currently have little deforestation or forest degradation occurring, the conservation of existing primary forests is critical both for protecting carbon stocks and preventing future greenhouse emissions, as well as for conserving biodiversity;
3) In forest landscapes that have already been largely cleared and degraded, climate change mitigation and biodiversity conservation can be achieved by enhancing carbon stocks through restoration and improved forest management, creating new carbon stocks (e.g., afforestation and reforestation), and improving agricultural management.

xviii The document uses the terms and definitions consistent with the UNFCCC decisions 1/CP.13 (Bali Action Plan and 2/CP.13 (REDD) without any attempt to pre-empt ongoing or forthcoming negotiations, or anticipate the outcome of these negotiations.

Table 3.3. ***Relevance of different climate change mitigation options to different landscape contexts***

Land use management and forestry-based climate change mitigation options	Landscape context		
	Landscapes where active deforestation and forest degradation are occurring	**2. Landscapes where there is minimal or no deforestation and forest degradation**	**3. Landscapes which have largely been deforested**
Reducing deforestation and forest degradation	*X*		
Forest conservation	*X*	*X*	
Sustainable management of forest carbon stocks	*X*		*X (potentially applicable to remnant forest patches in landscape)*
Afforestation, reforestation and forest restoration	*X (on already-deforested or degraded land)*		*X*
Implementation of sustainable cropland management	*X (on deforested land)*		*X*
Implementation of sustainable livestock management practices	*X (on deforested land)*		*X*
Implementation of agroforestry systems	*X (on deforested or degraded land)*		*X*
Conservation and restoration of peatlands, mangroves and other forested wetlands	*X*	*X*	*X*

139. The conservation of existing primary forests where there is currently little deforestation or forest degradation occurring, provides important opportunities for both protecting carbon stocks and preventing future greenhouse emissions, as well as for conserving biodiversity. Most of the biomass carbon in a primary forest is stored in older trees or the soil.[198] Land-use activities that involve clearing and logging reduce the standing stock of biomass carbon, cause collateral losses from soil, litter and deadwood and have also been shown to reduce biodiversity and thus ecosystem resilience.[199] This creates a carbon debt which can take decades to centuries to recover, depending on initial conditions and the intensity of land use.[200] Conserving forests threatened by deforestation and forest degradation and thus avoiding potential future emissions from land use change is therefore an important climate change mitigation opportunity for some countries.[201] Avoiding potential future emissions from existing carbon stocks in forests, especially primary forests, can be achieved through a range of means[202] including:

Mangroves, Quintana Roo, Mexico
Photo courtesy of Annie Cung

- Designating and expanding networks of protected areas,
- Establishing biological corridors that promote conservation in a coordinated way at large scales and across land tenures,
- Establishing payments for ecosystem services including carbon uptake and storage,
- Developing conservation agreements, easements and concessions,
- Providing incentives to compensate land owners, stewards and indigenous peoples on their traditional lands, for opportunity costs associated with forgoing certain kinds of development,
- Promoting forms of economic development that are compatible with conservation and sustainable use of biodiversity, and
- Adopting sound and effective technological and financial transfer mechanisms for conserving carbon stocks and biodiversity in those countries where forests still represent a significant asset.

140. **Addressing forest degradation is important because forest degradation leads to a loss of carbon and biodiversity, decreases forest resilience to fire and drought, and can lead to deforestation.** The definition of forest degradation is open to debate and can include unsustainable timber harvesting for commercial or subsistence use, in addition to other damaging processes such as fire and drought; all of which lead to reductions in carbon stocks[203] and negatively impact biodiversity. Estimates of the extent of forest degradation are still uncertain, due to differences in the way in which forest degradation is defined and limited data availability. However, in some regions of the world, the area of logged and degraded forest is comparable to that deforested.[204 205]. For example, it is estimated that forest damage from logging in the Amazon results in a 15 per cent reduction in carbon stocks,[206] and increased susceptibility to fire damage.[207 208] At the same time, forest degradation generally threatens biodiversity by reducing habitat and the provision of ecosystem services.

141. **While protected areas are primarily designated for the purpose of biodiversity conservation, they have significant additional value in storing and sequestering carbon and potentially preventing future deforestation.** There are now more than 100,000 protected sites worldwide covering about 12 per cent of the Earth's land surface.[209] Approximately 15 per cent of the terrestrial global carbon stock is currently under some degree of protection.[210] The designation and effective management of new protected areas,[xix] together with the improved management of the current protected-area network, could contribute significantly to climate-change-mitigation efforts. However, the extent to which protected areas are effective at conserving their carbon stocks depends on effective management, enforcement, and sustainable funding, especially in areas under anthropogenic pressure. The effectiveness of protected areas also depends on future climate change, due to their vulnerability.

142. **In forest landscapes currently subject to harvesting, clearing and/or degradation, climate change mitigation and biodiversity conservation and sustainable use can be best achieved by addressing the underlying drivers of deforestation and degradation, and improving the sustainable management of forests.** Sustainable forest management (SFM) refers to a tool kit of forest-management activities that emulate natural processes. These tools include planning for multiple values, planning at appropriate temporal and spatial scales, suitable rotation lengths, often decreasing logging intensities, and reduced impact logging that minimizes collateral damage to ground cover and soils. The application of internationally accepted principles of SFM in forests that are being degraded by current forestry practices can contribute to both climate change mitigation and biodiversity conservation and sustainable use goals, by enhancing carbon stocks and reducing greenhouse gas emissions. For example, a re-

xix The programme of work on protected areas under the Convention on Biological Diversity (decision VII/28, annex) encourages "the establishment of protected areas that benefit indigenous and local communities, including by respecting, preserving, and maintaining their traditional knowledge in accordance with Article 8(j) and related provisions."

cent study demonstrated that improved management of tropical forest through reduced impact logging can reduce carbon emission by approximately 30 per cent.[211] Globally, it is estimated that the sustainable management of forests could reduce emissions by a total of about 6.6 Gt C by 2030, which is approximately 3 per cent of current emissions.[212] However, especially in tropical forests, whilst such practices constitute a significant improvement on a "business as usual approach" they still result in depletion of *in situ* carbon stocks and increased emissions, along with reduced resilience and biodiversity loss, compared to an intact primary forest.[213] [214] [215] If SFM practices are applied to previously intact primary forests, this could lead to increased carbon emissions and biodiversity loss, depending on the specific practices and the forest type.[216]

143. **Reforestation can make a significant contribution to enhancing forest carbon stocks and biodiversity within landscapes that have been largely deforested and degraded, if the reforestation is designed and managed appropriately.**[217] While reforestation with fast-growing monocultures, often exotics, can yield high carbon sequestration rates and economic returns, this type of reforestation often has little value for biodiversity conservation. [218] [219] [220] However, reforestation can provide both biodiversity and climate change mitigation benefits if it uses an appropriate mix of native species, incorporates any natural forest remnants, and results in a permanent, semi-natural forest.[221] If appropriately designed and managed, reforestation activities on degraded lands can also relieve pressure on natural forests by supplying alternatives sources of sustainable wood products to local communities, thereby providing additional biodiversity and climate change mitigation benefits.

144. **Afforestation can have positive or negative effects on biodiversity, depending on the design and management.** Afforestation that converts non-forested landscapes with high biodiversity values (e.g. heath lands, native grasslands, savannas) and/or valuable ecosystem services (e.g. flood control) or increases threats to endemic biodiversity through habitat loss, fragmentation and the introduction of invasive alien species will have adverse impacts on biodiversity. However, afforestation activities can support biodiversity, if they convert only degraded land or ecosystems largely composed of invasive alien species; include native tree species; consist of diverse, multi-strata canopies; result in minimal disturbance, consider the invasiveness of non-native species, and are strategically located within the landscape to enhance connectivity.[222]

3.3 OTHER (NON-FOREST) LAND USE MANAGEMENT CLIMATE CHANGE MITIGATION OPTIONS

Agriculture and other land use management activities on non-forested land can also make an important contribution to climate change mitigation and biodiversity conservation

145. **In addition to forest-based climate-change-mitigation options, there is a wide variety of activities in the agricultural sector which can maintain and potentially increase carbon stocks, while also contributing to the conservation and sustainable use of biodiversity**. Key examples of agricultural activities that can deliver multiple benefits, include conservation tillage and other means of sustainable cropland management, sustainable livestock management, agroforestry systems, reduction of drainage systems in organic agricultural soils, improved management of fertilizers, and maintenance or restoration of natural water sources and their flows including peatlands and other wetlands (see annex IV for further information). The restoration of degraded cropland soils, for example, may increase soil carbon storage and crop yields, while contributing to the conservation of agricultural biodiversity, including soil biodiversity. The global sequestration potential through increasing soil organic carbon via improved agricultural practices is estimated to be 1-6 Gt C/yr.

146. **Policies that integrate and promote the conservation and enhanced sequestration of soil carbon, including in peatlands and wetlands, can contribute to climate change mitigation and be beneficial for biodiversity and ecosystem services.** Peatlands and wetlands have very high carbon stocks, particularly below ground, with an average carbon sequestration value of almost 1400t C/ha.[223] Globally, peat lands and wetlands harbour an estimated 550 Gt of carbon[224]. Human disturbances, such as drainage for agriculture and forestry production or the use of fire, have transformed large areas of peatlands from being a sink of carbon to a source. For example, tropical peat lands in South-east Asia emit 600 Mt CO_2 eq. per year (excluding peat fires).[225] There is significant and cost-effective potential to reduce emissions from degraded peat land by restoring drained peat lands and preventing further fires and drainage in intact peat lands.

3.4 ENHANCING THE CONTRIBUTION OF LAND-USE MANAGEMENT (INCLUDING REDD) TO BIODIVERSITY CONSERVATION

147. **Although forest and other land-use management climate-change-mitigation activities can contribute to both climate change mitigation and biodiversity conservation and sustainable use, if designed and managed appropriately, the extent to which they deliver these benefits will depend on how and where these activities are implemented.** Annex IV outlines the potential benefits and risks to biodiversity from different forest and other land-use management climate change mitigation activities, and highlights potential means of increasing biodiversity benefits or reducing negative impacts. Reducing deforestation and forest degradation, and conserving moist tropical forests will have the greatest and most immediate impact on biodiversity conservation, as tropical forests host more than 60 per cent of the world's known species.[226] However, all of these land-based climate-change-mitigation activities can have positive impacts on biodiversity if they result in additional conservation or restoration of diverse, natural ecosystems, promote the sustainable use of native species, and maintain landscape connectivity, and if they avoid displacement of deforestation, forest degradation or land use change into other ecosystems. In addition, if climate-change-mitigation strategies are implemented in areas of high biodiversity value (e.g., areas with high numbers of endemic or threatened species), the biodiversity benefits will likely be greater than if these activities are implemented in areas of lesser value.

148. **There may be some trade-offs between designing and managing activities for climate change mitigation and biodiversity conservation and sustainable use goals**. For example, the optimal age and species composition of plantation trees for wood supply may be different that that required to maximize biodiversity values or carbon storage.[227] Similarly, the forest areas that may provide the largest, most immediate emissions reductions will not necessarily be those of greatest conservation value. In particular, some regions that currently have high forest cover may be of critical importance for biodiversity conservation, but of lower immediate importance for emissions reductions due to current low deforestation rates (e.g., the so-called, high-forest/low-deforestation countries[228]).

3.5 POTENTIAL INTERACTIONS BETWEEN REDD AND BIODIVERSITY

149. **In general, reducing deforestation and forest degradation (REDD) can result in positive consequences for biodiversity by protecting important forest habitat and maintaining landscape connectivity.** Tropical forests have extremely high levels of biodiversity, including areas with a high density of endemic species. The Amazon rainforest alone hosts about a quarter of the world's terrestrial species.[229] However, if deforestation and forest degradation is simply displaced to other forest areas, or if it is shifted from an area of lower conservation value to one of higher conservation value, the biodiversity gains will be much reduced.[230] Similarly, if deforestation and forest degradation is displaced to other

native ecosystems- such as wetlands or savannahs, it could negatively impact the species native to these ecosystems.

150. **REDD also has the potential to contribute considerably to biodiversity conservation by allowing forest ecosystems to adapt naturally to climate change.** In order to enhance the contribution of REDD to adaptation, activities could be prioritized which minimize fragmentation, maximize resilience and aid in the maintenance of corridors and ecosystem services. This could be achieved in particular through maintaining connectivity of forest protected areas and other forests, at a landscape level.[231]

151. **The exact impact of REDD on biodiversity will depend on its design and implementation, including its scope, carbon accounting methodology, monitoring and verification, and what strategies are implemented to reduce deforestation and forest degradation and promote more sustainable land management practices**. There are several REDD design issues which will influence its potential to contribute to biodiversity conservation and sustainable use:

- REDD methodologies based on assessments of only net deforestation rates could have negative impacts on biodiversity. The use of net rather than gross deforestation rates[xx] could obscure the loss of mature (i.e. primary and modified natural) forests by their replacement in situ or elsewhere with areas of new forest growth. This could be accompanied by significant losses of biodiversity as well as unrecorded emissions.
- Addressing forest degradation is important because forest degradation may lead to the persistent loss of carbon and biodiversity, decreases forest resilience to fire and drought, and can lead to deforestation.[232] Monitoring to detect the severity and extent of forest degradation is therefore a key issue which needs further development.
- Both intra-national and international leakage under REDD can have important consequences for both carbon and biodiversity and therefore needs to be prevented or minimized.
- Implementing REDD in areas identified as having both high biodiversity value and dense carbon stocks can provide especially important co-benefits for biodiversity and climate-change mitigation. Several tools and methodologies are under development that could potentially be used to enhance the contribution of REDD to biodiversity. For example, existing information on critical forest areas for biodiversity conservation (e.g., critical bird areas, alliance for zero extinction sites, key biodiversity areas, and others) could be overlaid with information on deforestation rates and carbon stocks to determine which forests offer both the greatest climate change mitigation and biodiversity potential. The national gap analyses carried out by Parties under the Programme of Work on Protected Areas of the CBD could also be a valuable tool for identifying areas for the implementation of REDD schemes in forest areas that offer the greatest biodiversity co-benefits.

3.6 REDD AND OTHER LAND-USE MANAGEMENT ACTIVITIES, HUMAN LIVELIHOODS AND INDIGENOUS PEOPLES

While it is generally recognized that REDD and other land-use management activities could provide potential benefits, including critical ecosystem services , to forest-dwelling indigenous and local communities, a number of conditions are important for realizing these co-benefits

xx Net deforestation (net loss of forest area) is defined in the FAO Global Forest Resources Assessment 2005 as overall deforestation minus changes in forest area due to forest planting, landscape restoration and natural expansion of forests.

152. **The implementation of rights recognized in the United Nations Declaration on the Rights of Indigenous Peoples could be taken into account as a means of linking indigenous peoples' biodiversity-related practices to the potential benefits from REDD and other land management activities.** While it is generally recognized that REDD and other land use management activities could provide potential benefits, including critical ecosystem services, to forest-dwelling indigenous peoples and local communities (ILCs), a number of conditions are important for realizing these co-benefits. Indigenous peoples are likely to benefit from land use management climate change mitigation options where they own their lands, where there is the principle of free, prior and informed consent, and where their identities and cultural practices are recognized and they have space to participate in policy-making processes as outlined in table 3.5 below.

153. **There is a need for greater awareness and capacity building for indigenous peoples and local communities on biodiversity and climate change issues, so that these groups can take an active role in deciding how to engage in climate change mitigation activities.** It is also important that indigenous peoples can exchange their knowledge and practices of biodiversity conservation and sustainable management among themselves and have the opportunity to raise general awareness of such practices. At the same time, governments could benefit from indigenous peoples and local communities' traditional knowledge and practices related to biodiversity and forest conservation and management.

154. **Addressing the underlying drivers of deforestation and forest degradation will require a variety of approaches.** Possible approaches include improved forest governance, stricter enforcement of forest laws, land tenure reform, forest management planning, providing incentives for REDD, expansion of protected areas, improved forest management, adoption of agroforestry to ensure fuelwood and timber access, the establishment of alternative livelihood activities, and sourcing commercial wood supplies from reforestation/afforestation projects rather than primary forest, among others.[233] The selection of approaches to reduce deforestation and forest degradation depends on local, regional and national circumstances and include both economic and non-economic incentives and activities, including as the ones described in section 4.3 below.

155. **If REDD is to achieve significant and permanent emissions reductions, it will be important to provide alternative sustainable livelihood options (including employment, income and food security) for those people, especially the rural poor who are currently amongst the agents of deforestation and forest degradation.[234]** Specific livelihood options are most likely to be successful when they are tailored to specific social, economic and ecological contexts and consider sustainability under both current and projected future climate conditions.

Table 3.5. ***Overview of key issues for indigenous peoples and local communities (ILCs) related to biodiversity conservation and sustainable use and climate change mitigation***

Issue	Relevance to biodiversity conservation	Relevance to climate-change mitigation
Recognition of rights and generation of opportunities	Land tenure, access and benefit sharing, and participation in the decision-making process would give ILCs opportunities to manage and protect biodiversity on which they rely for their livelihoods and culture, and facilitates the distribution of benefits.	Promotion of alternative and sustainable production activities, which take into account local and indigenous knowledge and needs can reduce forest deforestation and forest degradation.
Awareness, capacity-building and dialogue	Need for awareness, capacity-building and knowledge exchange on biodiversity issues to ILCs. Governments could benefit from ILCs' traditional knowledge and practices related to biodiversity	Need for awareness, capacity=building and knowledge exchange on climate change issues to ILCs. Governments could benefit from ILC's traditional knowledge and practices related to climatic events (including adaptation).
Governance and equity	Free, prior and informed consent is important to the effective management of biodiversity by ILCs in so far as it facilitates decision making based on traditional structures, addresses the lack of law enforcement and poor forest management, and avoids perverse incentives.	Climate change mitigation strategies could take into account ILC processes or the possible negative impacts on ILCs. Free, prior and informed consent of ILCs could improve the effectiveness of REDD and other land management activities.
Policy and legislation	Policies and legislation developed with the effective participation of ILCs are more likely to be supported by them and contribute to biodiversity conservation. ILCs concept of forest management based on local and indigenous knowledge can contribute to the global and national debate on the conservation and sustainable use of forest biodiversity.	Policies and legislation developed with the effective participation of ILCs are more likely to be supported by them. ILCs concept of land and forest management based on local and indigenous knowledge can contribute to the global and national debate on REDD and other land management activities.
Gender	Women and elders hold valuable knowledge on forest biodiversity which should be safeguard and promoted with their prior informed consent.	Women and elders hold valuable knowledge on climate change impacts in forests and possible response activities which should be safeguarded and promoted with their prior informed consent.

3.7 THE IMPACTS OF OTHER CLIMATE CHANGE MITIGATION ACTIVITIES ON BIODIVERSITY

There is a range of renewable energy sources, which can displace fossil fuel energy, thus reducing greenhouse gas emissions, with potential implications for biodiversity and ecosystem services

156. **Renewable energy sources, including onshore and offshore wind, solar, tidal, wave, geothermal, biomass and hydropower, in addition to nuclear power, can displace fossil fuel energy, thus reducing greenhouse gas emissions, but have potential adverse implications for biodiversity and ecosystem services.** The impacts of wind, solar, tidal, geothermal, biomass, wave and nuclear energy on biodiversity and ecosystem services are dependent on site selection and management practices.

157. **While bioenergy can contribute to energy security, rural development and mitigating climate change, there are concerns that, depending on the diversity of production methods used and the diversity of agri-environmental contexts in which that production occurs, some first generation biofuels (i.e., use of food crops for liquid fuels, i.e., bio-ethanol or bio-diesel) are accelerating land use change, including deforestation, with adverse effects on biodiversity, and if a full life-cycle analysis is taken into account may not be currently be reducing greenhouse gas emissions.**[235] Biofuel production can have adverse consequences on biodiversity (genetic, species and ecosystem levels) and ecosystem services when it results in direct conversion of natural ecosystems into biofuel production, or the indirect conversion of natural ecosystems into agricultural land. For example, conversion of primary forest to biofuel production creates a carbon debt which must be first repaid. However, biofuels can contribute to greenhouse-gas savings and minimize the adverse impacts on biodiversity, soils and water resources by avoiding, directly and indirectly, the loss of natural ecosystems. Evaluation of the environmental and social sustainability of different sources of biofuels could be achieved through the development and implementation of certifiable standards, recognising the inherent complexity and difficulties involved in developing such standards and comparing their findings.[xxi]_

158. **Next-generation biofuels such as cellulosic ethanol and biomass-to-liquids technologies allow conversion into biofuels of more abundant and cheaper feedstocks than first generation.** These technologies have the potential to significantly reduce greenhouse gas emissions without adversely affecting food prices and biodiversity if feedstock production avoids, directly and indirectly, loss of natural ecosystems, or uses degraded lands. They could potentially reduce land requirements per unit of energy produced relative to first generation biofuels and improve life-cycle greenhouse-gas emissions, potentially mitigating the environmental pressures from first-generation biofuels. However, next-generation biofuel technologies are not yet commercially proven and their environmental and social effects still need to be examined. For example, the use of feedstock and farm residues can compete with the need to maintain organic matter in sustainable agro-ecosystems. Investment is needed in these technologies, although large-scale commercial viability is a number of years away.

159. **Bioelectricity and bioheat are important forms of renewable energy that are usually more efficient and produce less greenhouse-gas emissions than liquid biofuels and fossil fuels.** Digesters, gasifiers and direct combustion devices can be successfully employed in certain settings, e.g., off-grid areas. The impacts on biodiversity depend on the source of the biomass, e.g., use of agro-wastes for biogas should not threaten biodiversity. There is potential for expanding these applications but improved knowledge is needed to reduce costs and improve operational reliability. For all forms of bioenergy, decision makers should carefully weigh full social, environmental and economic costs against realistically achievable benefits and other sustainable energy options.

160. **The long-term stability of biochar in soils is, as yet, unknown and large-scale development could result in additional land use pressures.** The effectiveness and long-term stability of biochar in soils has not yet been established.[236] Furthermore, large-scale deployment of biochar may require significant amounts of biomass, creating the need for additional lands to grow biomass and thus creating additional land-use pressures.

161. **Hydropower, which has substantial unexploited potential in many developing countries, can potentially mitigate greenhouse gas emissions by displacing fossil fuel production of energy, but large scale hydropower systems, in particular, can have adverse biodiversity and social effects.** Dam and reservoir design is critical to limiting: (i) the emissions of carbon dioxide and methane from de-

xxi The expert from Brazil disassociated himself from this statement.

composition of underlying biomass, which can limit the effectiveness of mitigating climate change; and (ii) adverse environmental (e.g., loss of land and terrestrial biodiversity, disturbance of migratory pathways, disturbance of upstream and downstream aquatic ecosystems, and fish mortality in turbines) and social impacts (e.g., loss of livelihoods and involuntary displacement of local communities). The environmental and social impacts of hydropower projects vary widely, depending upon pre-dam conditions, the maintenance of upstream water flows and ecosystem integrity, the design and management of the dam (e.g., water-flow management) and the area, depth and length of the reservoir. Run of the river dams typically have fewer adverse environmental and social effects. Sectoral environmental assessments can assist in designing systems with minimum adverse consequences for ecological systems.

162. **The biological and chemical implications of deep-sea injection of carbon dioxide, associated with carbon capture and storage, are at present largely unknown, but could have significant adverse consequences for marine organisms and ecosystems in the deep sea.** Leakage from carbon storage on the sea bed could increase ocean acidification, which could have large-scale effects on marine ecosystems, including coral reefs.

A range of geo-engineering techniques has been proposed to offset human induced climate change, but their potential utility and their implications for biodiversity need further examination

163. There are a range of geo-engineering techniques suggested to mitigate climate change. They broadly fall into two categories: (i) large-scale manipulation of the radiative balance of the atmosphere through injecting sulphate aerosols into the troposphere or stratosphere; and (ii) changing the net flux of carbon dioxide between the atmosphere and the biosphere through techniques such as iron fertilization of the oceans.

- **Injecting sulphate aerosols into the troposphere or stratosphere can reduce the radiative flux reaching the Earth's surface, hence offsetting some of the greenhouse-gas induced surface warming,** however, they have not been adequately studied and hence their impact on ecosystems is unknown
- **Artificial fertilization of nutrient-limited oceans to increase the uptake of atmospheric carbon dioxide is increasingly thought to have limited potential**[237] with the greenhouse gas budget and impacts on biodiversity being uncertain. The potential of ocean fertilization to increase the sequestration of carbon dioxide with limiting nutrients such as iron or nitrogen, is highly uncertain and increasingly thought to be quite limited, and there are potential negative environmental effects including increased production of methane and nitrous oxide, de-oxygenation of intermediate waters and changes in phytoplankton community composition, which may lead to toxic algae blooms and/or promote further changes along the food chain.[238,239]

SECTION 4: VALUATION AND INCENTIVE MEASURES

164. This section provides information on techniques for valuing biodiversity highlighting that applying these techniques can quantify costs and benefits, opportunities and challenges and thus can improve decision making with regards to climate change related activities. The section further presents options on incentive measures that could be adopted so as to further elaborate the links between biodiversity and climate change related activities.

4.1 VALUING BIODIVERSITY AND ECOSYSTEM SERVICES

Consideration of the economic and non-economic values of biodiversity and ecosystem services is beneficial when implementing climate change related activities.

165. **Ecosystems provide humans with a vast diversity of benefits such as food, fibre, energy, clean water, healthy soils, pollinators, and many more**. Though our well-being is dependent upon the continued flow of these "ecosystem services" as outlined in box 3 below, many are public goods with no markets and no prices, so are typically not taken into account in current economic decision-making. As a result, biodiversity is declining, our ecosystems are being continuously degraded without an attached cost, and society, in turn, is suffering the consequences, which are partly irreversible.

166. **Ecosystem services contribute to economic well-being and associated development goals, such as the Millennium Development Goals**, in two major ways – through contributions to the generation of income and material goods (e.g., provisioning of food and fibre), and through the reduction of potential costs of adverse impacts of climate change (e.g., coral reefs and mangrove swamps protect coastal infrastructure).

167. **It is important to ensure that the economic (market and non-market) and non-economic values of biodiversity and ecosystem services are taken into account when planning and undertaking climate change related activities.** This can best be achieved by using a range of valuation techniques.

168. **The valuation of ecosystem services should generally be placed within an integrated approach to adapting to climate change.** Methodologies are available for analyzing the social, cultural and economic value of biodiversity and ecosystem services in supporting adaptation in communities and sectors vulnerable to climate change using the conceptual framework developed by the Millennium Ecosystem Assessment (MA), which links direct and indirect drivers of change to ecosystem services to elements of human well-being. In reality, valuation typically focuses on the economic (market and non-market) values of ecosystem services generated by biodiversity that benefit humans rather than biodiversity as such.

169. **Valuation techniques are important in accounting for ecosystems and their services when estimating the impact of human-induced climate change.** An evaluation of changes in services and their value is important for taking informed decisions relating to biodiversity and ecosystems. Application of these methods is more difficult when the quantity and quality of data islimited.

BOX 3: Ecosystem services

Definition: The MA developed a comprehensive categorization of ecosystem services, which include: (i) provisioning services, e.g., food, fibre, fuel, biochemicals, natural medicines and fresh water supply; (ii) regulating services, e.g., regulation of the climate, purification of air and water, flood protection, and natural hazard regulation: (iii) cultural services, e.g., cultural heritage, recreation, tourism and aesthetic values; and (iv) supporting services, e.g., soil formation and nutrient cycling.

Contribution to human well-being: Ecosystem services contribute directly and indirectly to human well-being by: (i) providing natural resources for basic survival, such as clean air and water; (ii) contributing to good physical and mental health, for example, through access to green spaces, both urban and rural, and genetic resources for medicines; (iii) providing fundamental natural processes, such as climate regulation and crop pollination; (iv) supporting a strong and healthy economy, through raw materials for industry and agriculture or through tourism and recreation; and (v) providing social, cultural and educational benefits, as well as well-being and inspiration from interaction with nature.

170. **Given that the application of many valuation techniques is costly and time-consuming, and require considerable expertise, an evaluation of the benefits versus costs of the valuation study itself should be assessed.** In principle, these techniques should be applied when the anticipated incremental (including long-term) improvements in the decision are commensurate with the cost of undertaking the valuation study.

171. **Economic techniques for valuing ecosystem services are typically applied within a cost-benefit analysis or a cost-effectiveness analysis, whose results would otherwise be incomplete.** Cost-benefit analysis (CBA) estimates the difference between the costs and benefits of a particular decision, e.g., the costs of a particular adaptation action compared to the benefits that would accrue from that action, whereas the cost-effectiveness analysis assesses the costs of different actions to achieve a particular outcome, e.g., to protect a particular coastal region. CBA often fails to take into account issues such as intergenerational equity, cumulative effects and risk. Qualitative assessments, provided they take into account the full range of values, may in some cases indicate which options are appropriate versus inappropriate, particularly in light of principles in previous sections. Further work may be needed on developing guidelines for decision making where full cost-benefit analysis would be too costly or time-consuming. These economic analyses should be applied within broader decision-making frameworks, such as environmental impact assessments (EIA), strategic environment assessments (SEA), life-cycle analysis (LCA), risk assessment, and multi-criteria analysis.

172. **Accounting for the value of biodiversity and the ecosystem services it supports, is important for the decision making process, and for the provision of appropriate incentives for adaptation to climate change**. One issue that has engendered much debate is the choice of discount rate. The key issue is the way in which conventional discounting, by virtue of the economic assumptions upon which it is based, "preferences" the benefits to the current generation over those of future generations, so is difficult to apply in the context of ecosystem services. Different choices of discount rate lead to very different estimates of the damage costs of climate change on biodiversity and ecosystems, and the relative costs and benefits of different strategies.[xxii]

173. **There are many methodologies available for estimating the economic value of ecosystem services. Methods for eliciting values should use a combination of economic and non-economic valuation methods as appropriate to the context of the decision** as outlined in box 4. The appropriateness

xxii Stern argued on ethical grounds that a low discount rate should be chosen to assess the damage costs of climate change. He considered how the application of appropriate discount rates, assumptions about the equity weighting attached to the valuation of impacts in poor countries, and estimates of the impacts on mortality and the environment (including on biodiversity) would increase the estimated economic costs of climate change.

of various methodologies is determined by stakeholders, including the biodiversity beneficiary (local versus global, private sector versus non-profit, etc) and the types of biodiversity benefits realized (direct versus indirect use values; use versus non-use values). A common feature of all methods of economic valuation of ecosystem services is that they are founded in the theoretical axioms and principles of welfare economics. These measures of change in well-being are correlated with people's willingness to pay for changes in their level of use of a particular service or bundle of services.

BOX 4: Basic principles for economic valuation and incentive measures

Methodologies available to value changes in ecosystem services: These values can be considered in a Total Economic Value (TEV) framework that takes into account both the use (direct use, indirect use and option value) and non-use (bequest, altruistic and existence) values individuals and society gain or lose from marginal changes in ecosystem services. TEV refers to the total change in well-being from a decision measured by the net sum of the willingness to pay (WTP) or willingness to accept (WTA). The value that we are trying to capture is the total value of a marginal change in the underlying ecosystem services. As many ecosystem services are not traded in markets, it is necessary to assess the relative economic worth of these goods or services using non-market valuation techniques. Typically, provisioning services have direct use and option values; regulating services have indirect use and option values; and cultural services have direct use, option and non-use values.

Economic valuation techniques include: (i) so-called revealed preference techniques, which are based on actual observed behavioural data (conventional and surrogate markets, based on for example market prices, hedonic pricing, travel cost method); (ii) so-called stated preference techniques, which are based on hypothetical rather than actual behaviour data, where people's responses to questions describing hypothetical markets or situations are used to infer value (hypothetical markets based on for example contingent valuation and choice modelling); and (iii) the so-called benefits transfer approach, which consists in the use of results obtained in one valuation study in a different, but very similar case.

Non-economic valuation: can be addressed through deliberative or participatory approaches. These approaches explore how opinions are formed or preferences expressed in units other than money.

Additional information: http://www.cbd.int/incentives/tools.shtml

174. **Regardless of the methodology employed, the interim report of the most recent relevant evaluation, *The Economics of Ecosystems and Biodiversity* (TEEB[240]), suggested nine key principles for ecosystem valuation that should be considered**:

- The focus of valuation should be on marginal changes rather than the "total" value of an ecosystem;
- Valuation of ecosystem services must be context specific, ecosystem-specific and relevant to the initial state of the ecosystem;
- Good practices in benefit transfers need to be adapted to biodiversity valuation, while more work is needed on how to aggregate the values of marginal changes;
- Values should be guided by the perception of the beneficiaries;
- Participatory approaches and ways of embedding the preferences of local communities may be used to help make valuation more accepted;
- Issues of irreversibility and resilience must be kept in mind;
- Substantiating bio-physical linkages helps the valuation exercise and contributes to its credibility;
- There are inevitable uncertainties in the valuation of ecosystem services, so a sensitivity analysis should be provided for decision makers; and;
- Valuation has the potential to shed light on conflicting goals and trade-offs but it should be presented in combination with other qualitative and quantitative information.

175. Therefore the key steps in estimating the impact of different climate change related decisions consistent with the TEEB interim report are (see also figure 4.1):

- Establish the ecosystem baseline for the full range of ecosystem services;
- Identify and provide qualitative assessment of the impacts of different decisions on ecosystem services;
- Quantify the impacts of different decisions on specific ecosystem services;
- Assess the effects on human welfare; and
- Value the changes in ecosystem services.

Figure 4.1: ***Overview of the impact pathway of a climate change decision***

Decision ⟶ Impact on Ecosystem ⟶ Changes in Ecosystem Services ⟶ Impacts on human welfare ⟶ Economic Value of Changes in Ecosystem services

176. **Following these steps can help to ensure a more systematic approach to accounting for the impacts of different decisions on ecosystems.** Even an initial screening of which ecosystem services are affected and how potentially significant these impacts could be and developing an understanding of the key uncertainties and gaps in evidence can be useful first steps towards integrating these considerations into decision-making so that appropriate actions can be taken.

177. **There is considerable complexity in understanding and assessing the causal links between a decision, its effects on ecosystems and related services and then valuing the effects in economic terms.** Integrated work among the science and economics disciplines will be essential in implementing this approach in practice. The links to scientific analysis, which form the basis for valuing ecosystem services, needs to be recognized.

178. **The type of valuation technique chosen will depend on the type of ecosystem service to be valued, as well as the quantity and quality of data available**. Some valuation methods may be more suited to capturing the values of particular ecosystem services than others as outlined in table 4.1 below. Benefits transfer applies economic values that have been generated in one context to another context for which values are required. This approach, when used cautiously, has the potential to alleviate the problem of deficient primary data sets as well as of limited funds and time often encountered in valuation, and is of particular interest in cases where the potential savings in time and costs outweigh a certain loss of accuracy (e.g., rapid assessments).

179. **The valuation methodologies discussed are not new in themselves.** The challenge is in their appropriate application to ecosystem services. The ecosystem services framework emphasizes the need to consider the ecosystem as a whole and stresses that changes or impacts on one part of an ecosystem have consequences for the whole system. Therefore, considering the scale and scope of the services to be valued is vital.

Table 4.1: ***Valuation methods for different ecosystem services***[241]

Valuation method	Element of TEV captured	Ecosystem service(s) valued	Benefits of approach	Limitations of approach
Market prices	Direct and indirect use	Those that contribute to marketed products e.g. crops, timber, fish, meat	Market data readily available and robust	Limited to those ecosystem services for which a market exists
Cost-based approaches	Direct and indirect use	Depends on the existence of relevant markets for the ecosystem service in question. Examples include man-made defences being used as proxy for wetlands storm protection; expenditure on water filtration as proxy for value of water pollution damages.	Market data readily available and robust	Can potentially overestimate actual value
Production function approach	Indirect use	Environmental services that serve as input to market products e.g. effects of air or water quality on agricultural production and forestry output	Market data readily available and robust	Data-intensive and data on changes in services and the impact on production often missing
Hedonic pricing	Direct and indirect use	Ecosystem services that contribute to air quality, visual amenity, landscape, quiet, i.e. attributes that can be appreciated by potential buyers	Based on market data, so relatively robust figures	Very data-intensive and limited mainly to services related to property
Travel cost	Direct and indirect use	All ecosystems services that contribute to recreational activities	Based on observed behaviour	Generally limited to recreational benefits. Difficulties arise when trips are made to multiple destinations.
Random utility	Direct and indirect use	All ecosystems services that contribute to recreational activities	Based on observed behaviour	Limited to use values
Contingent valuation	Use and non-use	All ecosystem services	Able to capture use and non-use values	Bias in responses, resource-intensive method, hypothetical nature of the market
Choice modelling	Use and non-use	All ecosystem services	Able to capture use and non-use values	Similar to contingent valuation above

180. **Key challenges in the valuation of ecosystem services relate to the underlying questions on how ecosystems provide services, and on how to deal with issues of irreversibility and high levels of uncertainty in ecosystem functioning.** Thus, while valuation is an important and valuable tool for good decision-making, it should be seen as only one of the inputs. Methodologies to deal with these challenges that account systematically for all the impacts on ecosystems and their services are being further developed.

181. **A number of studies have estimated the costs of climate change under different scenarios.** For a 2°C increase in global mean temperatures, for example, annual economic damages could reach US$ 8 trillion by 2100 (expressed in U.S. dollars at 2002 prices).

182. **There are few studies available, however, on the lost value associated with the impacts of climate change specifically on biodiversity in large part because of the difficulty in separating climate change impacts from other drivers of biodiversity loss.** Some case studies include:[xxiii]

- The World Bank estimated that coral reef degradation in Fiji attributable to climate change is expected to cost between US$ 5 million and US$ 14 million a year by 2050 due to the loss of value from fisheries, tourism and habitat.
- The loss in welfare associated with climate change in a mesic-Mediterranean landscape in Israel is estimated at US$ 51.5 million if conditions change to a Mediterranean climate, US$ 85.5 million if conditions change to a semi-arid landscape and US$ 107.6 million for conversion to an arid landscape based on loss grazing and willingness to pay.
- The lost value for protected areas associated with the projected impacts of climate change in Africa, based on willingness to pay, is estimated at US$ 74.5 million by 2100.
- The predicted negative impacts of climate change on coral reefs in the Bonaire National Marine Park in the Netherland Antilles, based on willingness to pay estimates by divers was US$ 45 per person per year if coral cover drops by from 35 per cent to 30 per cent and fish diversity drops from 300 species to 225 species and US$ 192 per person if coral cover drops from 35 per cent to 5 per cent and fish diversity drops from 300 species to 50 species.

4.2. CASE-STUDIES OF VALUE DERIVED FROM LINKING BIODIVERSITY AND CLIMATE-CHANGE ADAPTATION

183. The following case-studies demonstrate the economic value of a wide range of specific interventions. In conducting these studies, a number of assumptions and choices were made including: (i) discount rate; (ii) general circulation model; (iii) future greenhouse-gas scenarios.

A: The economic value of protection from natural disasters

184. Protecting and restoring ecosystems can be a cost-effective and affordable long-term strategy to help human communities defend against the effects of climate change induced natural disasters. Protection against storm surges or high winds associated with more intense cyclones can include: (i) hard infrastructures including seawalls and levees, which can be expensive, require ongoing maintenance, and can fail catastrophically under severe storm conditions, e.g., New Orleans in the United States of America; or (ii) the protection and restoration of "green infrastructure" such as healthy coastal wetlands

xxiii In conducting the studies, a number of assumptions had to be taken and choices made which could affect the outcomes including: (i) the discount rate; (ii) the General Circulation Model that the impacts are based upon; and (iii) future greenhouse gas scenarios.

(including mangrove forests) and coral reefs, which can be more cost-effective means for protecting large coastal areas, require less maintenance, and provide additional community benefits in terms of food, raw materials and livelihoods as well as benefiting biodiversity. Examples include:

- Red Cross of Viet Nam began planting mangroves in 1994. By 2002, 12,000 hectares had cost US$ 1.1 million, but saved annual levee maintenance costs of US$ 7.3 million, shielded inland areas from typhoon Wukong in 2000, and restored livelihoods in planting and harvesting shellfish.[242]
- In Malaysia, the value of existing mangroves for coastal protection is estimated at US$ 300,000 per km of coast based on the cost of installing artificial structures that would provide the same coastal protection.[243]
- In the Maldives, the degradation of protective coral reefs around Malé required construction of artificial breakwaters at a cost of US$ 10 million per kilometre.

B. The economic value of biodiversity-based livelihoods

The World Bank Strategic Framework for Development and Climate Change

185. From farming, ranching, timber and fishing, to water, fuel-wood, and subsistence resources, human welfare is inextricably tied to natural resources and the benefits that ecosystems provide. The World Bank Strategic Framework for Development and Climate Change warns that the disproportionate impacts of climate change on the poorest and most vulnerable communities could set back much of the development progress of the past decades and plunge communities back into poverty. By protecting and restoring healthy ecosystems that are more resilient to climate change impacts, ecosystem-based adaptation strategies can help to ensure continued availability and access to essential natural resources so that communities can cope with the conditions that are projected in a changing climate. Strategies that involve local governance and participation will also benefit from community experience with adapting to changing conditions, and may create greater commitment among communities for implementation.

186. Additional examples include:

- In southern Africa, the tourism industry has been valued at US$ 3.6 billion in 2000, however, the Intergovernmental Panel on Climate Change projects that between 25 and 40 per cent of mammals in national parks will become endangered as a result of climate change. As such, the National Climate Change Response Strategy of the Government of South Africa includes preventive interventions to protect plant, animal and marine biodiversity in order to preserve the biodiversity in order to maintain the tourism income.[244]

C. The economic value of ecosystem services provided by forestry

The value of forests in Britain

187. Well managed forests and woodlands deliver a range of ecosystem services with social and environmental benefits, including:

- Providing opportunities for open access outdoor recreation
- Supporting and enhancing biodiversity
- Contributing to the visual quality of the landscape
- Carbon sequestration.

188. A report by the Forestry Commission in 2003 estimated the total value of annual benefits to people in Britain to be around £1 billion. Annual benefits (£ million) include: (i) recreation £393 m; (ii) biodiversity £386 m; (iii) landscape £150 m; and (iv) carbon sequestration £94 m, for a total benefit of £1023 m. However, this analysis is only partial and did not take into account other social and environmental benefits, such as improving air quality and regulating water supply and water quality. For example, forests and woodlands "clean" the air as trees trap harmful dust particles and absorb gases such as sulphur dioxide and ozone, thus the improved air quality can be valued through the resulting improvements to human health. In addition, forests and woodlands can reduce soil erosion, stabilize riverbanks and reduce pollution in run-off.

D. The economic value of protected areas

189. The following two case-studies demonstrate the economic value of protected areas.

The value of the Okavango Delta in the economy of Botswana – a Ramsar site

190. The Okavango Delta generates an estimated P1.03 billion in terms of gross output, P380 million in terms of direct value added to gross national product (GNP) and P180 million in resource rent. The direct use values of the Okavango Delta are overwhelmingly dominated by the use of natural wetland assets for tourism activities in the central zone. Households in and around the delta earn a total of P225 million per year from natural resource use, sales, salaries and wages in the tourism industry, and rents and royalties in community-based natural resource management (CBNRM) arrangements. The total impact of the direct use of the resources of the Ramsar site is estimated to be P1.18 million in terms of contribution to GNP, of which P0.96 million is derived from use of the wetland itself. Thus the Ramsar site contributes 2.6% of the country's GNP, with the wetland contributing most of this (2.1%). The multiplier effect is greater for the formal sector than for the poorer components in society, because the former activities have greater backward linkages and households are primarily engaged in subsistence activities. The natural capital asset value of the Ramsar site is estimated to be about P3.9 billion, of which the Okavango Delta is worth P3.4 billion.

The economic value of the Great Barrier Reef to the Australian economy

191. This analysis is partial and does not use the total economic value (TEV) but focuses on the value of tourism, commercial fishing and recreational activities, net of tourism. The values are Aus$ 5,107 million, Aus$ 149 million, and Aus$ 610 million, respectively, for a total of Aus$ 5,866 million. Clearly the true economic value, when considering all the other non-use values, is considerably higher.

4.3 INCENTIVE MEASURES

192. **Economic and non-economic incentives influencing human behaviour and decision-making are essential to design and implement mitigation and adaptation activities that can benefit, and not adversely affect, biodiversity, ecosystem services and human well-being.** Incentives for climate change activities should be carefully designed and implemented not to negatively affect ecosystem services and the conservation of biological diversity, including leakage to other countries. Furthermore, in order for incentives to be successful - it is important for the incentives to be shared equitably with all relevant stakeholders – in accordance with the objectives of the Convention on Biological Diversity.

- Economic incentives should seek to ensure that the value of all ecosystem services, not just those bought and sold in the market, are taken into account when making decisions. Possible measures include: (i) remove subsidies (e.g., agricultural, fisheries and energy) that cause harm to people and the environment; (ii) introduce payments to landowners in return for managing their lands in ways that protect ecosystem services, such as water quality and carbon storage, that are of value to society; (iii) implement pricing policies for natural resources, e.g., for fresh water, that are appropriate at the national level and are sensitive to social needs; (iv) establish market mechanisms to reduce nutrient releases and promote carbon uptake in the most cost-effective way; and (v) apply fees, taxes, levees, and tariffs to discourage activities that degrade biodiversity and ecosystem services. The aforementioned mechanisms should be designed and implemented while ensuring conformity with provisions of the World Trade Organization and other international agreements

- Non-financial incentives and activities seeking to influence individual behaviour: (i) laws and regulations; (ii) new governance structures nationally and internationally that facilitate the integration of decision-making between different departments and sectors, (iii) promote individual and community property or land rights; (iv) improve access rights and restrictions; (iv) improve access to information and education to raise awareness about ecosystem-based adaptation; (v) improve policy, planning, and management of ecosystems by including sound management of ecosystem services in all planning decisions; and (vi) develop and use environmentally-sound technologies. With regards to non-financial incentives, it is important that such measures are consistent with the discussions under the CBD concerning the fair and equitable sharing of benefits arising from the use of genetic resources.

193. **Financial incentives, such as the payment for ecosystem services (singularly or an ensemble) and environmental funds, when treated as new and additional resources, could provide alternative sources of income/livelihoods for the poor that are heavily dependent on biodiversity and its components**. For example, a forest ecosystem provides a range of regulatory services besides its role in mitigating climate change.[245] It is these services that need to be maintained hence appropriate incentives such as the payment for ecosystem services and the use of environmental funds[246] services will ensure communities are better able to maintain a balance between ecosystem and their use of the resources. While the World Bank together with other multilateral financial institutions and conservation NGOs provide appreciable financial funds for the conservation and sustainable use of biodiversity, there is a recognized lack of financial resources to deal with the scale of the challenge. With regard to payments for ecosystem services, they should be made in accordance with WTO rules and international agreements.

194. **Internalizing the value of biodiversity and ecosystem services, in addition to carbon, in climate-change-related activities can provide a strong economic incentive for conserving biodiversity.** A range of financial and non-financial instruments are available to assist the effective implementation of climate-related activities in a specific manner in accordance with ecosystem type, project scale and projected period (see table 4.2 below).

195. **Criteria and indicators which are specific, measurable, adapted and monitored to local conditions, need to be developed to assure that the ecosystem services targeted by the incentive measures are maintained over time.** For instance, verification systems based on biological/ecosystem criteria and indicators can provide projects/countries with a financial incentive that ensures ecosystem-based adaptation. Properly designed criteria and indicators can become proxies for the intactness of ecosystems and adaptability, which can facilitate the evaluation of a measure, provide useful information in determining the need for corrective action, and can contribute to achieving the objectives of both the UNFCCC and the Convention on Biological Diversity.

196. **Non-financial instruments can become indirect incentives to harness multiple benefits of adaptation and to help build societal awareness and understanding of the important role of ecosystem-based adaptation to climate change.** Non-financial mechanisms include: the use of laws and regulations, property or land rights, access rights and restrictions, and valuation and education to raise

awareness about ecosystem-based adaptation. Enhancing food security and other ancillary benefits can be incentive to adopt ecosystem-based approach for the people who rely on such benefits for their livelihood. On a local scale, traditional codes have been a societal regulation to avoid the overuse of common ecosystem services. Incentives taking account for such societal codes can ensure the societal adaptability for climate change as well as biological conservation.

197. While there is a wide range of incentives available, choosing one or a combination of those incentive measures would be useful to be linked to factors such as conditions and scales (see table 4.2 below). Examples include: trade variables, the characteristics (physical, biological, social and economic) of the challenge, current and future financial and institutional arrangements, human resource and institutional capacities, gaps and obstacles, possibility of creating adverse impacts on other systems and sectors, opportunity for long-term sustainability and linkages with other programs. In particular, policies which create incentives without removing the underlying causes of biodiversity loss (including perverse incentives) are unlikely to succeed. The incentive measures adopted should also address issues of transparency, equity and should be regularly monitored and evaluated. CBD guidance such as the Proposals for the Design and Implementation of Incentive Measures, endorsed by the sixth meeting of the Conference of the Parties (http://www.cbd.int/doc/publications/inc-brochure-01-en.pdf), could be consulted for identifying further key elements to be considered when designing and implementing incentive measures, and for selecting appropriate and complementary measures.

Table 4.2: ***Instruments and incentives for implementing ecosystem-based adaptation***

Instruments and incentives	Application to ecosystem-based adaptation
Financial (variety of market and non-market sources)	
Payment for ecosystem services (not tradable)	Payment to reward the ecosystem services to those who maintain the service (e.g., payments for watershed management)
Carbon finance	Payment for carbon storage (e.g., Clean Development Mechanism, voluntary carbon market)
Incentives related to REDD	Positive incentive on issues relating to reducing emissions from deforestation and forest degradation in developing countries.
Biodiversity-based mechanisms, such as biodiversity banking, biodiversity offset	Payment based on proxy indicators or surrogate of biodiversity (e.g., area of intact forest)
Debt-for-nature swaps	Cancellation of debt in exchange for the conservation of natural ecosystems (e.g., creation of protected areas in Costa Rica in return for debt relief)
Conservation trust funds	Funds for improving the management of/and ensuring conservation of protected areas (e.g.; Conservation Covenant)

Instruments and incentives	Application to ecosystem-based adaptation
Certification and labelling	Certification of products and services which are produced with minimal impacts on ecosystems, verified using rigorous standards and indicators e.g. eco tourism, forest stewardship council (in a manner which avoids creating trade barriers).
Access/price premium to green markets	Adding value and increasing market access for sustainable products and services, e.g., niche market for organic products, organic coffee
Market development[247]	Creation of new markets and expansion of existing markets for products and services that are environmentally friendly.[xxiv]
Environmental prize/award	Public recognition for good environmental stewardship.
Eliminate perverse subsidies (e.g., fishing; agriculture, energy)	Eliminate subsidies that destroy, degrade or lead to the unsustainable use of ecosystems.
Taxes, fees, and charges	Taxation of activities that destroy, degrade or mismanage natural resources (e.g., taxation of pesticide use, unsustainable timber harvesting…)
Tradable quotas	Establishment of quotas for the extraction of goods (such as firewood, timber, fish harvest, harvest of wild species) from natural ecosystems, to ensure their sustainable management
Non-financial	
Definition of land tenure, and use planning and ownership and land use and management rights	Clarification of land tenure and rights, to enhance conservation, restoration and sustainable management of ecosystems
Public awareness and capacity building on ecosystem-based adaptation	Increased recognition of the value of ecosystem-based adaptation and its role in adaptation strategies, leading to increased implementation
Development, refinement and enforcement of legislation	Legislation that promotes the implementation of ecosystem-based adaptation and tools to ensure compliance; Legislation that promotes sustainable use of ecosystems or discourages mismanagement (e.g., protected area legislation, pesticide use regulations, water pollution laws)
Institutional strengthening and creation of partnerships	Provision of financial and human resources to relevant institutions and establishment of networks involving diverse stakeholders

xxiv Note that the definition of environmentally friendly goods and services is still under negotiation within the Negotiations Committee on Trade and Environment in Special Session of the WTO (paragraph 31. iii) of the Ministerial Declaration of November 2001).

Instruments and incentives	Application to ecosystem-based adaptation
Development, transfer, diffusion and deployment of environmentally sound technology	Develop soft and hard technologies and methodologies that could help in the implementation of ecosystem-based adaptation (e.g., software development, early warning systems, artificial reefs)

GLOSSARY

Adaptation: 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, autonomous and planned adaptation:

Anticipatory adaptation – Adaptation that takes place before impacts of climate change are observed (also referred to as proactive adaptation).

Autonomous adaptation – Adaptation that does not constitute a conscious response to climatic stimuli but is triggered by ecological changes in natural systems and by market or welfare changes in human systems (also referred to as spontaneous adaptation).

Planned adaptation – Adaptation that is the result of a deliberate policy decision, based on an awareness that conditions have changed or are about to change and that action is required to return to, maintain, or achieve a desired state.

Biochar : Biochar is a fine-grained, highly porous charcoal that helps soils retain nutrients and water.

Biodiversity: "Biological diversity" means 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.

Ecosystem approach: The ecosystem approach is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way.

Ecosystem services (also ecosystem goods and services): The benefits people obtain from ecosystems. These include provisioning services such as food, water, timber, and fibre; regulating services such as the regulation of climate, floods, disease, wastes, and water quality; cultural services such as recreation, aesthetic enjoyment, and spiritual fulfillment; and supporting services such as soil formation, photosynthesis, and nutrient cycling.

Mitigation: An anthropogenic intervention to reduce the anthropogenic forcing of the climate system; it includes strategies to reduce greenhouse gas sources and emissions and enhancing greenhouse gas sinks.

Maladaptation: Any changes in natural or human systems that inadvertently increase vulnerability to climatic stimuli; an adaptation that does not succeed in reducing vulnerability but increases it instead.

Annex I

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Annex II

CASE-STUDIES FOR BEST PRACTICES ON ADDRESSING CLIMATE-CHANGE-RELATED RISK TO BIODIVERSITY

1. GONDWANA LINK, AUSTRALIA

Objectives: The aim of the project is achieve "Reconnected country across south-western Australia… in which ecosystem function and biodiversity are restored and maintained". This region is a recognized global biodiversity hotspot, having been to broadscale clearing for intensive agriculture. The region is experiencing ongoing ecological degradation and threats from fragmentation, salinity and climate change.

Activities: Protecting and re-planting bushland over more than 1,000 km; purchasing bushland to protect and manage it; re-vegetating large areas of cleared land advocacy for stronger protection of public land; providing incentives for better land management; developing ecologically supportive industries such as commercial plantings of local species.

Participants: A consortium of local and national non-government organizations, universities, local councils, university research centres, government mediated networks and agencies, and business enterprises; including Bush Heritage Australia, Fitzgerald Biosphere Group, Friends of Fitzgerald River National Park, Greening Australia, Green Skills Ink, The Nature Conservancy, and The Wilderness Society Inc.

Adaptation outcomes: Gondwana Link will provide some protection against the worst ecological impacts of climate change by enabling gradual genetic and species interchange on a broad front. In previous (slower) periods of climate change, species and systems have predominantly "moved" along a south-west/north-east pathway; the direction Gondwana Link is spanning. The project is also consolidating north-south linkages, which may also be critical pathways for species impacted by climate change. The re-vegetation activities will also assist in stabilizing landscapes where clearing has led to large scale salinity, wind erosion and other degradation.

Reference: www.gondwanalink.org

2. COSTA RICA BIOLOGICAL CORRIDOR PROGRAM (PART OF THE MESOAMERICAN CONSERVATION CORRIDOR)

Objectives: Update a proposal for improving structural connectivity for the National System of Protected Areas.

Activities: (a) Designed an ecological conservation network in order to improve the connectivity between protected areas and key habitat remnants; (b) Designed latitudinal and altitudinal connectivity networks; (c) The National Biological Corridors Program, which aim is to provide technical and multisector coordination support to local management committees, and a national technical committee for advising biological corridor design and management were established.

Participants: National System of Conservation Areas (SINAC), The Nature Conservancy (TNC), Tropical Agronomic Research and Higher Education Center (CATIE), Conservation International, National Institute of Biodiversity (INBio).

Outcomes: (a) An ecological network that enhance ecosystem resilience to CC has been established; (b) local community committees for management the main biological corridors have been established; (c) Monitoring and systematic planning tools that include adaptation issues has been developed and implemented in order to provide input and feedback on their management.

Reference: Arias, E; Chacón, O; Herrera, B; Induni, G; Acevedo, H; Coto, M; Barborak; JR. 2008. Las redes de conectividad como base para la planificación de la conservación de la biodiversidad: propuesta para Costa Rica. Recursos Naturales y Ambiente no. 54:37-43.

3. NARIVA WETLAND RESTORATION PROJECT-TRINIDAD AND TOBAGO; WORLD BANK PROJECT

Objectives: The Nariva wetland (7,000 ha) is a biodiversity-rich environment with a mosaic of vegetation communities (tropical rain forest, palm forests, mangroves, and grass savannah/marshes). However, it was subject to hydrologic changes and land clearing by illegal rice farmers.

The objective of the project is the reforestation and restoration of the Nariva wetlands ecosystem.

Activities: (a) Restoration of hydrology - Water management plan to: (i) review the water budget of Nariva; (ii) identify land form composition of wetland area; (iii) develop criteria to select high priority restoration areas; and (iv) design and implement natural and engineered drainage options; (b) Reforestation program. 1,000 - 1,500 hectares being reforested; only native species used; (c) Fire Management Program - training for fire responders, fire response planning, and community environmental education; (d) Monitoring - Response of reforestation activities and biodiversity through key species.

Participants: Government, World Bank, NGOs, communities

Outcomes: Strengthening of buffer service for inland areas against anticipated changes climate and climate variability. The carbon sequestered and emission reductions effected will be sold and the proceeds from the sale will support community development and further adaptation actions as required.

Reference: www.worldbank.org

4. CONSERVATION MEASURES PARTNERSHIP (CMP)

Objectives: Establish standards, best practices and tools to support the design, management and monitoring of conservation projects at multiple scales.

Activities: The Conservation Measures Partnership compiled consistent, open standard guidelines for designing, managing, and measuring impacts of their conservation actions. They also developed a software tool based on these standards that helps users to prioritize threats, develop objectives and actions and select monitoring indicators to assess the effectiveness of strategies. This software is available at https://miradi.org. The software also supports development of work-plans, budgets and other project management tools.

Participants: Members of the Conservation Measures Partnership include: African Wildlife Foundation, The Nature Conservancy, Wildlife Conservation Society and World Wide Fund for Nature/World Wildlife Fund. Collaborator include: The Cambridge Conservation Forum, Conservation International, Enterprise Works Worldwide, Foundations of Success, The National Fish and Wildlife Foundation, Rare and the World Commission on Protected Areas/IUCN.

Outcomes: Consistent open standards have been established, and continue to be improved on the basis of experience by users.

Reference: www.conservationmeasures.org

5. MARINE PROTECTED AREAS IN KIMBE BAY, PNG

Objectives: Establish a network of marine protected areas that will conserve globally significant coral reefs and associated biodiversity, and sustain fisheries that local communities depend on for food and income.

Activities: Warming seas threaten to increase the frequency and extent of coral bleaching events in Kimbe Bay. When corals bleach, fish habitat and fisheries productivity are diminished. Systematic conservation planning methods were used to design a network of marine protected areas that (i) includes replicated examples of all coral and other coastal ecosystem types found in the bay, (ii) protects critical areas for fish spawning and reef sections that are more resistant to bleaching, and (iii) ensures connectivity across MPAs so that areas that might become depleted or degraded by coral bleaching can be repopulated. Local communities manage their own protected areas in the network so that they can best protect their fisheries and benefit from additional livelihood opportunities such as eco-tourism and sport fishing.

Participants: The Kimbe Bay MPA network was designed and implemented through a partnership between local communities and The Nature Conservancy.

Outcomes: The Kimbe Bay MPA network is expected to maintain the ecological integrity of the coral reefs and make them more resilient to bleaching.

Reference: Green, A., Lokani, P., Sheppard, S., Almany, J., Keu, S., Aitsi, J., Warku Karvon, J., Hamilton, R. and . Lipsett-Moore. 2007. Scientific Design of a Resilient Network of Marine Protected Areas. Kimbe Bay, West New Britain, Papua New Guinea. TNC Pacific Island Countries Report 2/07.

6. MANGROVE RESTORATION IN VIET NAM

Objectives: Restore coastal mangrove forests along the coasts of Viet Nam to provide coastal protection.

Activities: Waves and storm surges can erode shorelines, damage dykes, and flood communities, rice paddies, and aquaculture facilities. Such hazards are expected to increase because of sea level rise and changes in storm frequence and intensity associated with climate change. Mangroves have been replanted along coast of Viet Nam in order to improve protection of communities and coasts. Restored mangroves have been demonstrated to attenuate the height of waves hitting the shore, and to protect homes and people from damaging cyclones.

Participants: Mangrove restoration has been led by Vietnamese national and provincial governments, with support from the World Bank and various humanitarian NGOs such as the Red Cross.

Outcomes: Since 1975, more than 120,000 hectares of mangroves have been restored. They have provided community and levee protection during severe storm events in 2005 and 2006, and ongoing support for livelihoods associated with mangrove habitats such as replanting and tourism.

Reference: http://www.expo-cosmos.or.jp/album/2008/2008_slide_e.pdf Mangroves and Coastal Dwellers in Viet Nam – The long and hard journey back to harmony. Commemorative lecture at Kyoto University, 2 November 2008

7. RESTORING FLOODPLAINS ALONG THE DANUBE RIVER, IN EASTERN EUROPE

Objective: Restore 2,236 km^2 of floodplain to form a 9,000 km^2 "Lower Danube Green Corridor".

Activities: More frequent flooding is expected along the Danube River because of climate change. Floods in 2005 killed 34 people, displaced 2,000 people from their homes, and caused $625M in damages. Dykes along the Lower Danube River are being removed to reconnect historic floodplain areas to river channel. These areas are of only marginal value for other industrial activities. However, once restored, they are estimated to provide flood control and other ecosystem services valued at 500 Euros per hectare per year.

Participants: This restoration is being done by the World Wildlife Fund, working in conjunction with the Governments of Bulgaria, the Republic of Moldova, Romania, and Ukraine

Outcomes: Restored floodplains serve to retain and more slowly release floodwaters that might otherwise threaten to overtop or breach dykes.

Reference: Orieta Hulea, S Ebert, D Strobel. 2009. Floodplain restoration along the Lower Danube: a climate change adaptation case study. IOP Conf. Series: Earth and Environmental Science 6 (2009) doi:10.1088/1755-1307/6/0/402002248

8. CORAL TRIANGLE INITIATIVE ON CORAL REEFS, FISHERIES AND FOOD SECURITY (CTI-CFF): INDONESIA, MALAYSIA, PAPUA NEW GUINEA, THE PHILIPPINES, SOLOMON ISLANDS AND TIMOR LESTE.

Objectives: To conserve and sustainably manage coastal and marine resources within the Coral Triangle region, thus contributing to strengthened food security, increased resilience and adaptation to climate change.

Activities: The Coral Triangle region sustains the world's greatest diversity of marine life. The region's biological resources provide livelihood, income and food security for the 240 million coastal inhabitants of the six countries. Consequently, the marine and coastal ecosystems and resources are already under significant pressure from overfishing, destructive fishing practices and pollution, which increase the region's vulnerability to the threats of climate change. Climate change impacts threatening the Coral Triangle include ocean acidification, coral bleaching, and damage from increasing occurrence of extreme weather events, such as storm surges.

The Coral Triangle Initiative (CTI) is a new partnership which provides a unique platform for accelerated and collaborative actions to address issues such as climate change adaptation, marine conservation, food security and coastal poverty reduction. Underpinning the CTI collaboration is a firm conviction on the need to move beyond *incremental* actions, and to agree on and implement *transformational* actions that will be needed over the long-term to ensure the sustainable flow of benefits from marine and coastal resources for this and future generations. It fosters stewardship, builds capacity and flow on benefits associated with skill transfer, develops measures to control and mitigate existing and emerging pressures on marine biodiversity, resources and vulnerable marine systems, and promotes a better understanding of oceans and ocean processes.

The CTI regional plan of action and national plans call for an early response to the threats of climate change on oceans, including a "region-wide early action plan for climate change adaptation for the near-shore marine and coastal environment and small island ecosystems". This plan will serve as a major step toward implementing the climate change adaptation obligations of the Coral Triangle Governments under the United Nations Framework Convention on Climate Change. The plan will include regional collaborative actions, general actions to be taken in each country, and more specific actions covering a range of management scales and frameworks (e.g. transboundary seascape management plans; integrated coastal zone management plans; MPA network plans). Regional actions will include identifying the most important and immediate adaptation measures that should be taken across all Coral Triangle countries (based primarily on analyses using existing models); conducting capacity needs assessments and developing capacity-building programmes on climate-change adaptation measures.

Participants: Implementation of the CTI by the six Coral Triangle countries will be supported by invited partners: the Australian Government, the United States Government, the Global Environment Facility, the Asian Development Bank, The Nature Conservancy, Conservation International, WWF and others.

Outcomes: It is anticipated that the CTI will achieve tangible and measurable improvements in the health of the region's marine and coastal ecosystems, the status of fisheries, food security and the well-being of the communities which depend on the region's marine and coastal resources/ecosystems.

Reference: www.cti-secretariat.net

9. KEPPEL BAY RESILIENCE STRATEGIES

Objectives: To develop a collaborative, community and multi-agency based, resilience-focused management strategy for this shallow, inshore island and fringing coral-reef system.

Activities: The overarching multiple-use zoning already provides a range of habitat protection in this part of the Great Barrier Reef Marine Park; now the challenge is to expand the management toolbox to ensure that customized, non-regulatory responses can be implemented, based on the best available information.

Some of the strategy is responsive and some is proactive, elements include: a no-anchoring area pilot project to protect some coral habitats from anchor damage (sites selected via the resilience indicators developed by IUCN, in partnership with the local community); the general use of community-based monitoring programs – including the *Reef Health and Impact Survey* format and the *Bleachwatch* program to assess reef health; the *Climate Change Incident Response Framework* (used as the highest level of an integrated response planning approach to deal with significant events or emergencies e.g. mass coral bleaching) – under this sits the sectoral level response plans that determine how different community groups can customize a response transparently and appropriately to a climate change impact such as coral bleaching – the first examples of these are being trialled with a small commercial fishing sector in the Keppel Bay project. They include the *Coral Stress Response Plan* (a partnership across two levels of government and industry) and the *Stewardship Action Plan* (the industry plan to document best practice including community-based monitoring, supply of local knowledge and provision of voluntary actions and moratoriums under the framework to minimize the impact of collection on impacted areas).

Participants: The Great Barrier Reef Marine Park Authority; the Capricorn Coast Local Marine Advisory Committee ; the local community; Queensland Primary Industries and Fisheries; The Queensland Parks and Wildlife Service; ProVision Reef Inc (peak body for aquarium fishers in Queensland).

Outcomes: Trial of a toolbox of innovative techniques to assess reef health, respond to climate change impacts and implement long term resilience-based management at a regional scale.

References:

http://www.gbrmpa.gov.au/

http://www.gbrmpa.gov.au/corp_site/management/site_management/keppel_bay_and_islands_site_management_arrangements/keppel_bay_resilience_project_-_no_anchoring_areas

http://www.gbrmpa.gov.au/__data/assets/pdf_file/0010/24697/searead_news_20.pdf

http://www.cabinet.qld.gov.au/MMS/StatementDisplaySingle.aspx?id=64511

10. THE ROYAL BOTANIC GARDENS KEW'S MILLENNIUM SEED BANK PROJECT (MSBP)

Objectives: The MSBP is the world's largest ex situ conservation project which intends to store 25 per cent of the world's plant species by 2020. Seed banks provide an insurance policy against the extinction of plants in the wild and provide options for their future use. They complement *in situ* conservation methods, which conserve plants and animals directly in the wild.

Activities: The Millennium Seed Bank already holds seeds from species thought to be extinct in the wild. In addition, seed banks provide a controlled source of plant material for research, provide skills and knowledge that support wider plant conservation aims, and contribute to education and public awareness about plant conservation.

MSBP partners will have banked seed from 10 per cent of the world's wild plant species by the end of this decade. Seed collections are kept in the country of origin, in partner seed banks, and duplicates are brought to the Millennium Seed Bank in the United Kingdom. Each project is based on a legally binding contract, such as an access and benefit sharing agreement. In addition to the seed collecting activities, the MSBP partnerships include research and training and other capacity-building elements. Partnerships may focus their activities to support conservation or development objectives relevant to their country. In this way the partnerships are helping their countries to implement international objectives such as the Global Strategy for Plant Conservation and the United Nations Millennium Development Goals.

Participants: The Millennium Seed Bank Project is based on 27 long-term partnerships and collaborations with other organizations around the world. At the core of the main project are "partnership projects" in many different countries. These vary in their structure and scope but all aim to collect and conserve seeds (mainly from dryland plant species) and to strengthen in-country capacity for seed banking. Partners are a mixture of government, local and national non-governmental organizations, universities and conservation agencies.

Adaptation outcomes: Seeds from the Millennium Seed Bank and those held in partner countries are already being used to provide a wide range of benefits to mankind, ranging from food and building materials for rural communities to disease-resistant crops for agriculture. The collections held in the MSB, and the knowledge we are deriving from them, gives us almost infinite options for their conservation and use. With future climate-change scenarios and the ever-increasing impact of human activities, the MSBP intends to accelerate its activities to secure in safe storage 25 per cent of the world's plant species by 2020.

Reference: www.kew.org/msbp

Annex III
IMPACTS OF CLIMATE CHANGE ADAPTATION ON BIODIVERSITY

Examples of common societal adaptations that might be taken (or are already being used) to climate change or effects of climate change in agriculture and drylands, forests, coastal areas, fisheries, human health and settlements and some selected impacts on biodiversity (positive and negative) and suggested ways t[o] maximize or minimize these effects. No judgment is made about the efficacy of any of the selected adaptations. Most of these adaptations require environmental assessment to examine potential impacts and/or monitoring to improve results over the long term.

For forests, the majority of adaptations apply to managed forests; we use the FAO forest types, specifically natural (N), semi-natural (S), and plantation (P) or al[l] types of managed forests (A). Where the forest adaptations apply primarily to a given forest biome it is specified under the action column.

Issue	Adaptation action	Positive effects on biodiversity	Maximize positive effects	Negative effects on biodiversity	Minimize negative effects	Comments and case studies
Agriculture and Drylands						

Cumulative effects of:
• reduced moisture
• increased:
  ○ temperature
  ○ pest
  ○ salinity
  ○ extreme events
	Shift to varieties or species of crops and livestock more tolerant to:
	• heat
	• pests
	• drought
	• flood
	• salt
		Possible changing:
		• Diversification
		• Management regimes
		• People encouraged to value local biodiversity
			Use rare or local species;
			Support (from NGOs, agricultural extension worker);
			Community involvement
			Building on traditional knowledge and management techniques
				Local varieties or species replaced	Avoid incautious use of GMOs and potentially invasive species,
					Apply strict standards for testing, approval and monitoring
					Use of precautionary principle in relation to GMOs and potentially invasive species
						Potentially low-cost if suitable varieties available
						High cost if breeding necessary
						Relevance of traditional knowledge
						Maladaptaton risk unless all properties of the species are considered, especially in mountain, grassland, temperate grasslands, and SIDS

Issue	Adaptation action	Positive effects on biodiversity	Maximize positive effects	Negative effects on biodiversity	Minimize negative effects	Comments and case studies
	Seed banks	Conserves genetic diversity Reduced need to bring in non-native varieties when extreme events cause losses	Support (from NGOs, agricultural extension workers…) Community involvement Building on traditional knowledge			
	Application of agro-ecological approaches aimed at: • Conserving soil moisture and nutrients e.g. ◦ conservation tillage ◦ organic fertilizer use ◦ agroforestry ◦ mulching, ◦ shelterbelts ◦ windbreaks, ◦ bund construction) • Increasing productivity	More sustainable management regimes (e.g. less need for ('slash and burn'); Improved soil structure and composition; Increasing structural and species diversity	Use local species / agrobiodiversity Community involvement Building on traditional knowledge and management techniques Investment in heat, pest, drought, flood and salt resistant farming techniques Support (from NGOs, agricultural extension workers…)		Reduce chemical inputs Focus on short-term and long-term benefits	Potentially low-cost Builds social capital Supports traditional knowledge Potential for co-benefits e.g. reduction of: Erosion Eutrophication C-sequestration

Issue	Adaptation action	Positive effects on biodiversity	Maximize positive effects	Negative effects on biodiversity	Minimize negative effects	Comments and case studies
	Diversification: multi-cropping or mixed farming systems (e.g. agroforestry systems) to enhance ecosystem resilience to extreme events	• Increasing diversity: ◦ Structure ◦ Species • Use of native species	Use rare or local species Support (from NGOs, agricultural extension worker) Community involvement Building on traditional knowledge and management techniques	Non-native species introduction	Reduce chemical inputs	Potentially low-cost Builds social capital and supports traditional knowledge Potential for co-benefits e.g.: • reduction of erosion • decreasing agricultural area • increasing water efficiency
	Restoration of degraded ecosystems e.g. • Revegetation • Reforestation • Slope stabilization	Reduced degradation		Possible introduction of non-native species Potential invasives or GMOs	Use native species, Avoid incautious use of GMOs Apply strict standards for testing, approval and monitoring	Co-benefits of increasing vegetation cover e.g.: Reduced erosion C-sequestration Comparatively high cost Long timeframe High technical inputs required
	Rainwater harvesting, storing and management, e.g.: • Contour trenches • Rain-fed drip irrigation	Less water required from other sources	Support (from NGOs, agricultural extension workers)			Low cost Few technical inputs needed Co-benefits, e.g. groundwater supplies increase
	Less intensive farming or pastoral activities	Reduction of chemical inputs Increase of structural diversity		Need for alternative income may lead to other pressures		

Issue	Adaptation action	Positive effects on biodiversity	Maximize positive effects	Negative effects on biodiversity	Minimize negative effects	Comments and case studies
	Adapted grazing management regime	Degradation avoided/ reduced	Support local grazing management regimes	Pressure on biodiversity increases elsewhere	Careful management to avoid overgrazing	Potential for resource conflicts Maladaptaton risk if traditional management regimes disrupted Unsustainable livelihood options adopted
	Supplementing livelihoods by increased harvesting of plants or animals from the wild		Support adequate management system to allow for regeneration	Increasing pressure on wild species		Maladaptaton risk by reducing potential for other ecosystem services, especially in mountains
	Flood protection for cultivated areas and livestock	Reduced land degradation		Damage caused by protection infrastructure		High technical inputs and costly
	Intensification of irrigation and other farming techniques	Intensification in one area could reduce pressure elsewhere	Environmental education regarding increasing climate risks and vulnerability and risk of maladaptation	Could increase water scarcity in source ecosystems (marshes, lakes, deltas, rivers etc) Monocropping reduces biodiversity	Consider effects on entire watershed and all water users	Likely to be a common adaptation response High risk of maladaptation (monocropping increases vulnerability to extreme events) Conflict over resources
	Increased fertilizer use			Increasing eutrophication of nearby aquatic ecosystems	Careful management of fertilizer application	Risk of maladaptation

Issue	Adaptation action	Positive effects on biodiversity	Maximize positive effects	Negative effects on biodiversity	Minimize negative effects	Comments and case studies
	More pesticide / herbicide use in response to pest or disease increases			Impacts on non-target species such as pollinators Impacts on food webs Contamination of food or water resources	Careful management of pesticide / herbicide application	Risk of maladaptation
	Extension of agriculture or grazing into other areas			Replacement of other ecosystems	Use zoning to protect most vulnerable habitat	Potential for conflict over resources; especially alpine areas
	Abandonment of agriculture or grazing; migration	Reduction of chemical inputs Reversion to more natural state	Maximize use of afforestation	Possible colonization by non-native species Need for alternative income may lead to other pressures		High risk of conflict and maladaptation through over-exploitation of resources Loss of traditional knowledge Disruption of traditional management systems following migration
	Crop insurance	May decrease incentives for over-utilization		May increase incentives for over-utilization		Risk of promoting maladaptation
Sea level rise and Food Security	Relocation/manmade crop sites e.g. concrete elevated for taro production	Creation of new habitats Saving crop varieties	Use local materials	Impacts on new sites to be used	Minimize introduction of alien species Sitting	Limited areas in atolls to fully accommodate needed area
Drought Food security	Relocation to new sites e.g. wetland for taro	Conserving species	Improve irrigation	Loss of habitats at new sites,	Diversify food crops	Drought resistance island crops to be identified/ research

Issue	Adaptation action	Positive effects on biodiversity	Maximize positive effects	Negative effects on biodiversity	Minimize negative effects	Comments and case studies
Water resources						
Increasing flood risk	Construction and operation of dams	Creation of freshwater lake habitat		Floodplain habitat loss/damage Loss of natural inundation dynamics	Avoid construction in sensitive location	High relevance for protection of infrastructure and productive land High cost
	More resilient design of infrastructure	Reduces need for dams		May increase build-up	Avoid increasing the area taken up by infrastructure	Risk of maladaptation Financial constraint of poor communities to meet the cost of infra structure Standards exceeded
	Construction of dikes to prevent flooding			Floodplain habitat loss/damage Loss of natural inundation dynamics	Avoid construction in sensitive location	High relevance for protection of infrastructure and productive land High cost High maladaptation risk: Increasing danger of flooding downstream
	Re-zoning of flood plains, e.g., relocation of land use activities sensitive to flooding	Increase habitat for flood plain ecosystems	Manage using 'close to nature principles'			High potential for land use conflicts

Issue	Adaptation action	Positive effects on biodiversity	Maximize positive effects	Negative effects on biodiversity	Minimize negative effects	Comments and case studies
	Land-use management in watersheds to maintain or enhance water retention, e.g. • Maintaining / increasing forest coverage • Conserving peat lands • Adapting agricultural practices to improve efficiency of soil water uses	May contribute to conservation or restoration of forest, wetlands and agricultural biodiversity	Aim for natural or near-natural composition of forests and wetlands Use biodiversity-friendly agricultural techniques		Avoid afforestation: • in high biodiversity habitats • with non-native species or GMO Avoid agricultural soil management practices that increase need for herbicides	Need for effective incentives and clarification of land tenure issues Cost-benefit ratio depending on location and socio-economic setting, Potentially very good
Increasing low water periods in rivers and lakes	Shifting of water extraction to other sources, e.g. • Groundwater pumping, • Transfer through channels			Increasing water scarcity in other aquatic ecosystems	Avoid damage to high biodiversity habitats	High risk for delay of necessary adaptation by simply shifting the problem
	Construction and management of reservoirs	May provide additional habitat for wetland species	Optimise management, e.g. to imitate natural flooding dynamics	May have negative impact on existing habitats: • Wetland • River • Floodplain • Lake	Choose design with low biodiversity impact (e.g. lateral reservoirs rather than dams across rivers)	
	Desalination	May decrease pressure on freshwater resources Hypersalinity of coastal areas			Pre-treat effluent or dispose in deeper water	Very resource-intensive Conflict with climate change mitigation

Issue	Adaptation action	Positive effects on biodiversity	Maximize positive effects	Negative effects on biodiversity	Minimize negative effects	Comments and case studies
	Demand-side management, e.g. • Reducing losses in transfer • Increasing use efficiency • Use of grey water • etc.	Decreasing disturbance to natural water balance				Good long-term cost-benefit ratio
	Land use management in watersheds to maintain or enhance water retention, see above					
	Technical adaptations for aquatic transport infrastructure	May lead to loss of riverbed habitat Loss of natural shore structures			Choose design with low biodiversity impact	High cost Risk for maladaptation by changing sedimentation and currents
	Adapting means and management of aquatic transport, e.g. changing boat design	Reducing need for upkeep of infrastructure				High investment cost to individual users
	Limit land use change to conserve soil	Maintain forest ecosystems				
Drought & shortage of surface water	Increase extraction potable water	May available for other ecosystems	Efficient water use	Downstream ecosystems affected	Limit extraction rate	Assess alternative sources

Issue	Adaptation action	Positive effects on biodiversity	Maximize positive effects	Negative effects on biodiversity	Minimize negative effects	Comments and case studies
Coastal zone						
Sea-level rise/coastal erosion	Coastal Protection using hard infrastructure e.g. • Sea walls (types) • Dykes • Etc	Protect otherwise affected biodiversity sites when eroded	Proper design/location	Alter natural processes Habitat loss	Minimize other stresses	Sea walls are very site specific.
	Coastal Protection using soft structures, e.g. beach nourishment	Conserving: • Habitats • Biodiversity	Proper location of source/types of materials	Disturbance of intertidal or sea bottom habitats Primarily of source areas Relatively high cost High technological and information requirements		Sourcing of the material Scale Previous state of ecosystem
	Coastal protection using natural resources, e.g. mangrove, etc	Preserve current biodiversity	Replanting, Keep/improve other connected systems, e.g. freshwater flow	Keep systems healthy Decrease other stress		Inexpensive
	Creation of artificial reef Assisted migration	Create habitats	Applicable in certain sites / regions	Changes of: • Coastal currents • Sea-bottom habitats • Coastal communities • Pollution • Novel communities	Assist migration of endemic species	Consideration of scale, size and design, Relatively cost-effective Potential of co-benefits with fisheries (see below)

Issue	Adaptation action	Positive effects on biodiversity	Maximize positive effects	Negative effects on biodiversity	Minimize negative effects	Comments and case studies
Forestry						
Over-arching management policies to reduce impacts of CC	Increase adaptive management systems (A)	Where forests are currently subject to unsustainable land use activities, Increase use of sustainable forest management including regular monitoring and research on effects of management actions Increased recognition of biodiversity as a part of the managed forest; Increase forest ecosystem resilience Reduce over-harvesting	Increase practices to entire forest land base Increase application of community forestry Reduce illegal logging High mitigation benefit			National impact Best approach to ecosystem-based adaptation in forests. Case studies – successful application in various countries. Co-benefit of improved C-sequestration
	Reduce other stresses on forests, e.g., pollutants (A)	Increased forest vitality and resistance	Assess worst pollutants on a local and regional basis and mitigate			Local and regional scales
	Assisted migration (planting beyond current range of tree species) (A)	Maintain species in time and space Increase resilience	Using multiple models Test and select species	Possible incorrect selection based on dispersal capacity Anthropogenic novel ecosystem development Adaptive nature of genotypes leading to invasiveness	Improve models Select species in region Select individuals carefully based on criteria	Applicable on regional scale

Issue	Adaptation action	Positive effects on biodiversity	Maximize positive effects	Negative effects on biodiversity	Minimize negative effects	Comments and case studies
	Incorporate traditional knowledge about CC into forest planning to improve and inform management systems (A)	Increase resilience and resistance	Foster learning and interaction at the local community level			National impact
	Increasing protected areas Increasing uses of protected areas for: Maintain gene stocks C sinks (N)	Maintain: • Genes • Species • Migration corridors Protection of vulnerable ecosystems	Select locations carefully to maximize C sequestration potential in time Develop synergies with other landscape planning Local community involvement			National/international impact of vulnerable systems, e.g • Tropical • Boreal • Mountain
	Maintain gene banks (N)	Secure existing of genes and species				
Changes in severity of disturbances: 1.Increased pests	Increasing use of insecticides to combat pests (S,P)	Reduced loss of forest area		Impacts on: • Non-target species • Food webs • Water pollution	Use biological insecticides in selected areas Avoid over-spray	Possibility of effects on multiple kinds of systems
	Introduction and promotion of pest-resistant varieties or species (S,P)	Increase resistance		Possible invasiveness, competition with endemic species	Test thoroughly before release Release in isolated trial areas	Generally local and regional impact
	Promoting structurally rich mixed stands of native species (S,P)	Increasing habitat availability to native forest flora and fauna	Use native species and mixtures	Possible reduction in natural monocultures and associated flora and fauna	Maintain natural monocultures in some areas	Regional scale

Issue	Adaptation action	Positive effects on biodiversity	Maximize positive effects	Negative effects on biodiversity	Minimize negative effects	Comments and case studies
	Reduce rotation length to reduce favorable conditions to pests (S,P)			Reduction of old forest	Minimise area affected	Regional scale
	Develop and act on invasive species planning (A)	Protection of forest systems from invasion	Active monitoring and eradication research and programs	Alteration of systems by invasive species		National scale; see: Global Invasive Species Plan
2.A. Wildfire (boreal, temperate)	Controlled burning to reduce fuel loads (S,P)			Loss of dead wood habitats	Establish and maintain ecosystem-based thresholds	Stand scale
	Develop 'fire smart' landscapes (S,P)	Use of mixed wood forests	Use endemic fire-resistant species Consult traditional knowledge	Altered landscape structure vs. natural	Reduce total replacement of natural types	Landscape scale, regional effects
	Improve fire management to reduce fire (A)	Reduced mature forest loss	Increased training and investment			National scale Regional implementation
2.B. Tropical	Reduce fragmentation	Increase forest area and habitats	Proper landscape planning			National scale Regional implementation
	Thinning & harvesting dead biomass	Reduced disturbance on natural forests Reduce fuel load	Develop plans with local communities	Reduce below ground organic matter for establishment of seedling and habitats of soil fauna	Establish programme for appropriate thinning	Monitor effects Local and national scale

Issue	Adaptation action	Positive effects on biodiversity	Maximize positive effects	Negative effects on biodiversity	Minimize negative effects	Comments and case studies
3. Increased frequency/ intensity	Assist forest regeneration by increased planting after disturbances (also referred to as assisted natural regeneration) (S,P)	Increased resilience	Use native species where possible	Possible use of non-native species	Assess probability of invasiveness, plan to eliminate once stable system is achieved	Regional effects
	Incorporate risk management planning into FM (A)	Increased resilience	Improve models			Risk management is not generally a part of SFM
4. Non-native plant species invasion	Use of control means (A)	Maintain natural biodiversity	Reduce probability of invasibility early.	Effects of herbicides	Match timing of application to phenology	Invasive species planning required
Decreased moisture and increased temperature	Introduction or promotion of species with low water requirements (A)	Increased resilience	Use locally endemic species Research needed	Novel forest types	Use regional species pool	Local and regional scales
	Select species to increase resilience of stands (see above) (A)	Increasing habitat availability to native forest flora and fauna	Use locally endemic species		Use regional species pool	Local and regional scales
	Protect riparian areas and flood plain forests (S,P)	Maintain increased forest cover/habitat	Where forests are currently subject to unsustainable land use activities, apply SFM techniques			Local effects

Issue	Adaptation action	Positive effects on biodiversity	Maximize positive effects	Negative effects on biodiversity	Minimize negative effects	Comments and case studies
	Introduce species/ provenances/genomes resistant to water stress (S,P)	Increase resilience	Use native sp. where possible	Replacement of native species Non-native species may invade and displace endemics Novel systems	Monitor effects Test outplanting	Local effects Monitor effects Local impacts Method to enhance crop value
	In areas with risk of large-scale forest break-down: ensure sufficient area of forest is retained to avoid thresholds of regional or local hydrological cycles (A)	Retaining natural forest cover				Regional
	Adjust rate of cutting (S,P)	No forest loss over time	Improve models to predict G&Y (growth and yield)			Local effects
	Under-plant with suitable species (A)	No loss in forest over time		Use of non-native species	Improve models	Local effects
CO_2 fertilization/ altered N levels; alteration of forest sinks	Reduced deforestation and degradation (N,S)	Maintains forest habitats Maintain primary and intact forests Reduced fragmentation	Develop plans with local communities			Monitor effects Regional level
	Increased rotation period (S,P)	Increase old growth forests				Local and regional effects
	Afforestation/ reforestation of degraded lands (S,P)	Increase forest habitats Reduce fragmentation	Use native species. where possible Replace non-native spp. once system is stable			Local and regional effects

Issue	Adaptation action	Positive effects on biodiversity	Maximize positive effects	Negative effects on biodiversity	Minimize negative effects	Comments and case studies
	N fertilization (P)	Improve forest health	Understand C/N ratios	Overfertilization Acidification	Understand C/N ratios	Local effects
	Improve forest C management (S,P)	Improve dead wood and soil habitats	Understand biodiversity relationships and thresholds			Local effects
	Minimise soil disturbance in harvesting	Improve soil biota	Low impact harvesting			Local effects
	Prevent conversion of primary forests to plantations (N)	Maintain forest habitat Increase resilience (vs. resilience of plantations) Reduce fragmentation	Maintain large tracts Involve local communities			Local and regional effects
	Cover ground with legumes (S,P)	Enhanced soil processes increase soil C and N	Use endemic species Use traditional knowledge to select species			Local effects
	Payment for environmental services (A)	Maintain forest habitat Increase resilience (vs. resilience of plantations) Reduce fragmentation	Maintain large tracts Involve local communities			
Changing forest conditions for local and indigenous communities	Promote the use of traditional knowledge in forest planning (A)	Improved forest resilience				Local and regional effects

Issue	Adaptation action	Positive effects on biodiversity	Maximize positive effects	Negative effects on biodiversity	Minimize negative effects	Comments and case studies
	Encourage adoption of sustainable forest management techniques (A)	Improved forest resilience, improved use of non-timber forest products				Local and regional effects
	Increase size of protected areas where useful to protect communities (N,S)	Improved forest resilience Maintain gene banks				Local effects
Fisheries						
Climate change (temperature increase, sea level rise, extreme events) Coastal Fisheries	Creation/enhancing effective marine protected areas (MPAs)	Preserve ecosystems Protect coastal processes Improve water quality	Provide Alternative protein and income generating sources		Effective management Use local knowledge Locally owned	MPAs connectivity
Climate change ENSO pelagic fisheries open ocean	Sustainable harvesting of stock	Preserve ecosystems,	Reduce wasteful practices	create pressure on alternative recourses	Alter fishing methods e.g. net mesh size, use by-catch	Approach issue on regional basis
	Closure of critical fishing grounds	Allow stock to function	Good understanding of stock biology	Limited knowledge of stock Lack enforcement	Effective enforcement	Regional cooperation critical
Human health						
Increase and spread of vector borne diseases	Drainage of wetlands to eliminate breeding sites of disease-bearing vectors like mosquitoes			Transform ecosystems Introduced alien species	Management of wetland breeding sites.	

Issue	Adaptation action	Positive effects on biodiversity	Maximize positive effects	Negative effects on biodiversity	Minimize negative effects	Comments and case studies
	Management of wetland breeding sites (mosquitoes) Introducing fish to control larvae.	Preserve the ecosystem and the biodiversity.		Introduction of new species on the ecosystem	Introduce regional (local) fish species into wetlands to control larvae.	Alternative
	Chemical control of vector borne diseases like mosquitoes			Chemicals eliminate non-target organisms	.	Alternative
	Bio-larvicide control of vector borne diseases like mosquitoes	Neutral Bio-larvicides control population mosquitoes larvae	Research needed		Bio-larvicide did not eliminate non-targeted organisms. No chemical substances are liberated	Alternative
Wild game and food plants						
Reduced availability	Sustainable forest management	Protect natural sources				
	Assisted migration			Novel systems	Use regional species	
	Ex situ conservation	Conservation of genetic material				
	Wildlife ranching			Diseases Inbreeding	Use accepted techniques Monitor	
Human settlements Extreme events (e.g mudslides, hurricanes, flash floods)						

Issue	Adaptation action	Positive effects on biodiversity	Maximize positive effects	Negative effects on biodiversity	Minimize negative effects	Comments and case studies
Over-arching management policies to reduce impacts of climate change	Long-term strategic planning	Protection of green areas and their biodiversity in towns	To consult with local people and to derive benefit from them			National impact Best approach to sustainable life in settlements
	Spatial planning for flood management	Let some places without urban exploitation	To protect most valuable rests of semi-natural habitats	Disturb semi-natural habitats by wall and dyke construction	Make restoration of walls and dykes	Local impact
	Introduce adaptive management systems	Possibility to adapt measures damaging biodiversity	Increased and regular monitoring and research on effects of management actions			National impact
	Reduce other stresses in settlements, e.g. air-borne pollutants	Increased vitality and resistance of urban vegetation	Assess worst pollutants on a local and regional basis and mitigate			Local and regional scales
	Increase resilience of urban vegetation to extreme weather	Improved site conditions for more organisms	To realize wide extent of measures			Regional impact
Changes in severity of disturbances:	Reduce heat	Improving microclimate by use of green infrastructure (parks, trees, green roofs etc.)	Creating new potential habitat		Design (choice of regional species, management etc.)	Local to regional scales
	Construct new water bodies	Creating new potential habitats	Construct only small water bodies	Disturb semi-natural habitats		Local scale
	Construct new flood retention capacity (polders)	Creating new potential habitats	To select suitable water-adapted habitats	Disturb semi-natural habitats	Use regional species pool	Local scale

Issue	Adaptation action	Positive effects on biodiversity	Maximize positive effects	Negative effects on biodiversity	Minimize negative effects	Comments and case studies
	Habitat loss compensation	Creating new (mostly artificial) habitats as refugia for native plants and animals	Background from local species knowledge Use of natural materials (stone, wood)			Local scale
	Sustainable drainage	Maintenance of sustainable conditions for urban vegetation	Make plantations of regional species if necessary	Disturbance to soil organisms Change in water table level	Take into account local site conditions	Local and regional scales
	Construction of vegetated protection barriers	Create new niches for biodiversity	Use native species; design adequate	Shift some pressures from one habitat/ ecosystem to another	Lower costs Potential for land use conflicts	Alternative
	Relocation of hard infrastructure (building, etc.)	Leave free ancient urban space for new habitats	Developing design on new location	Shift some pressures from one habitat/ ecosystem to another	Can be expensive. High potential for land use conflicts	ScaleCharacteristics of habitats/ ecosystems concerned

Annex IV
OVERVIEW OF LINKAGES BETWEEN THE CONSERVATION AND SUSTAINABLE USE OF BIODIVERSITY AND CLIMATE-CHANGE MITIGATION

Mitigation activity	Potential benefits for biodiversity	Potential risks to biodiversity	Possible actions to enhance benefits or reduce negative impacts on biodiversity
Reducing emissions from deforestation and forest degradation[249]	Reduced forest loss and reduced forest degradation[xxv] Reduced fragmentation Maintenance of diverse gene pools and robust species populations	Leakage into areas of high biodiversity	At national level, prioritizing REDD actions in areas of high biodiversity Develop premiums within incentive measures for biodiversity co-benefits Improving forest governance Promote broad participation in the REDD mechanism, to minimize international leakage Involve forest-dwelling indigenous and local communities
Forest conservation	Conservation of intact forest habitat Reduced fragmentation Maintenance of diverse gene pools and robust species populations Maintenance of ecological and evolutionary processes and functions [250] Enhanced integrity of the landscape and enhanced resilience of ecosystems to climate change		Prioritize conservation of forests with high biodiversity Conserve large areas of primary intact forest Maintain landscape connectivity[251] Conserve a diversity of forest types, covering different microclimatic conditions and including altitudinal gradients Avoid unsustainable hunting
Sustainable management of forests	Reduced degradation of forest (relative to conventional logging)	Potential encroachment in intact forest, resulting in biodiversity loss	Prioritize sustainable management in areas that are already subject to intensive land use and are of high biodiversity values Minimize use in primary forests and intact forests of high biodiversity value Apply best-practice guidelines for sustainable forest management including reduced impact logging

xxv This could be achieved through: increased flow of financing to address deforestation and forest degradation; improved data on forests, facilitating decision-making; and capacity building on ways and means to address threats to forests and forest biodiversity.

Mitigation activity	Potential benefits for biodiversity	Potential risks to biodiversity	Possible actions to enhance benefits or reduce negative impacts on biodiversity
Afforestation and Reforestation (A/R)[252]	Habitat restoration of degraded landscapes (if native species and diverse plantings are used) Enhancement of landscape connectivity (depending on spatial arrangement) Protection of water resources, conserving aquatic biodiversity (depending on type of plantation)	Introduction of invasive and alien species Introduction of genetically modified trees Replacement of native grasslands, wetlands and other non-forest habitats by forest plantations Changes in water flow regimes, negatively affecting both aquatic and terrestrial biodiversity	Apply best practices for reforestation (e.g., native species, mixed plantations) Prevent replacement of intact forests, grasslands, wetlands, and other non-forest native ecosystems by forest plantations. Locate reforestation in such a way to enhance landscape connectivity and reduce edge effects on remaining forest patches Develop premiums within incentive measures for biodiversity co-benefits
Other land-use and land-use-change activities:			
Land-use change from low carbon to higher carbon land use (e.g., annual cropland to grassland; revegetation)	Restoration of native habitats	Introduction of invasive species Prioritization of high net carbon land uses over biodiversity considerations Conversion to non-native ecosystem types	Promote the use of native species when changing land use Restore native ecosystems Improve the assessment / valuation of biodiversity and ecosystem goods and services during decision making regarding land use change (e.g. water cycling, flood protection, etc.) Develop premiums within incentive measures for biodiversity co-benefits
Implementation of sustainable cropland management (including soil conservation, conservation tillage, fallows, etc)	Provision of habitats for agricultural biodiversity Reduced contamination of streams and other water bodies, affecting aquatic biodiversity	Expansion of cropland into native habitats Possible increased use of herbicides associated with conservation tillage	Promote sustainable crop management as part of a broader landscape level planning that includes conservation of remaining native ecosystems and restoration, as appropriate Consider traditional and local knowledge Provide capacity-building and information on appropriate sustainable cropland management

Mitigation activity	Potential benefits for biodiversity	Potential risks to biodiversity	Possible actions to enhance benefits or reduce negative impacts on biodiversity
Implementation of sustainable livestock management practices (including appropriate stocking density, grazing rotation systems, improved forage, etc.)	Provision of habitat for species present in pastoral systems Reduced contamination of streams and other water bodies, affecting aquatic biodiversity	Expansion of area used for livestock into native habitats	Promote sustainable livestock management as part of a broader landscape level planning that includes conservation of remaining native ecosystems and restoration, as appropriate Consider traditional and local knowledge Provide capacity-building and information on appropriate sustainable cropland management
Implementation of agroforestry systems on existing croplands or grazing lands	Provision of habitat for agricultural biodiversity Restoration of degraded landscapes Enhancement of landscape connectivity (depending on spatial arrangement) Protection of water resources, conserving aquatic biodiversity (depending on type of Agroforestry system) Reduced contamination of streams and other water bodies (due to reduced use of agrochemicals) affecting aquatic biodiversity	Introduction of invasive and alien species Encroachment into native ecosystems	Promote agroforestry as part of a broader landscape level planning that includes conservation of remaining native ecosystems and restoration, as appropriate Consider traditional and local knowledge Provide capacity-building and information on appropriate agroforestry systems Provide appropriate credit to apply best practices
Conservation and restoration of peatlands and other wetlands including mangroves	Habitat conservation and restoration for both terrestrial and aquatic biodiversity Maintenance of ecological processes and functions, particularly those related to hydrology Enhanced integrity of the landscape and enhanced resilience of ecosystems	Increased methane emissions if restoration is done inappropriately	Prioritize restoration of peatlands and wetlands of high biodiversity Maintain and restore entire hydrological catchments or at least the headwaters Restore and maintain landscape connectivity Maintain natural water flow regimes Encourage regeneration – or replant- native mangrove trees Involve indigenous and local communities

Mitigation activity	Potential benefits for biodiversity	Potential risks to biodiversity	Possible actions to enhance benefits or reduce negative impacts on biodiversity
Biofuels	Restoration of soils in degraded lands Enhanced connectivity between ecosystems Reduced air pollution Reduction in application of pesticides and fertilizers Reduction in water used for irrigation	Conversion and fragmentation of natural ecosystems, resulting in biodiversity loss Introduction of invasive species Intensification of pesticide and fertilizer use and irrigation Contamination of water reserves, affecting aquatic biodiversity Changes in water flow, affecting aquatic and terrestrial biodiversity	Prevent replacement of intact forests, grasslands, wetlands, and other native ecosystems by biofuel crops Minimize encroachment of biofuels into intact ecosystems of high biodiversity value Plant biofuel crops on already degraded lands Apply best practices and standards for biofuels Use native species where possible
Other large-scale renewable energy (including solar, hydro, wind, etc.)	Reduced air pollution	Habitat destruction Disruption of migration patterns of terrestrial and/or aquatic fauna Increased mortality of birds (wind turbines)	Identify areas for renewable energy projects that will have a lesser impact on biodiversity Conduct a comprehensive environmental impact assessment Apply best management practices

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