Convention on Biological Diversity

DRAFT FINDINGS OF THE AD HOC TECHNICAL EXPERT GROUP ON BIODIVERSITY AND CLIMATE CHANGE[1]

[1] This document is un-edited. Editing will be done once the peer review comments have been considered and addressed by the AHTEG

PREFACE

1. Escalating biodiversity loss and climate change are putting international action to achieve the United Nations Millennium Development Goals (MDGs) at risk. In particular, poor people often depend heavily and directly on biodiversity to support their livelihoods. For example, in rural Zimbabwe, the poorest 20% of the community receive 40% of their total income from environmental products, whereas biodiversity only provides 29% of direct income for the richest 10%[1].

2. Biodiversity is also critical for the maintenance and enhancement of food security[2]. Conserving and maintaining healthy soil, clean water, a variety of genetic resources and ecological processes are essential ingredients to a sustainable and productive agricultural system and the subsequent eradication of hunger.

3. In addition, climate change is posing new challenges for development. Climate change is projected to reduce poor people's livelihood assets such as access to water, homes and infrastructure. Climate change is also expected to have a negative impact on traditional coping mechanisms thereby increasing the vulnerability of the world's poor to perturbations such as drought, flood and disease. Finally, the impacts of climate change on natural resources and labour productivity are likely to reduce economic growth, exacerbating poverty through reduced income opportunities.

4. Climate change is also projected to alter regional food security. Changes in rainfall patterns and extreme weather events are likely to diminish crop yields. Sea level rise, causing loss of coastal land and saline water intrusion, can also reduce agricultural productivity[3]. Coral bleaching and increased calcification of coral is likely to reduce fisheries, further threatening food security[4].

5. Biodiversity is being called on to contribute to development in an environment in which anthropogenic climate change is threatening the continued provision of ecosystem services by putting pressure on species and ecosystems to adapt or adjust to rapidly changing climate conditions. Hence the global community has issued an urgent call for additional research and action towards reducing the impacts of climate change on biodiversity.

6. In order to support additional work on the interlinkages between climate change and biodiversity, the second Ad Hoc Technical Expert Group (AHTEG) on Biodiversity and Climate Change was convened in response to paragraph 12 (b) of decision IX/16 B of the Conference of the Parties to the Convention on Biological Diversity (CBD). The first meeting of the second AHTEG took place in London, from 17 to 21 November 2008 and the second meeting took place in Helsinki from 18 to 22 April, 2009.

7. The AHTEG was established to provide biodiversity related information to the United Nations Framework Convention on Climate Change (UNFCCC) though 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 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.

INTRODUCTION

8. The fourth assessment report (AR4) of the Intergovernmental Panel on Climate Change (IPCC)[5] revealed a total temperature increase from 1850-1899 to 2001-2005 of 0.76°C with the warming trend escalating over the past 50 years. Furthermore, the average temperature of the oceans has increased to a depth of at least of 3000m since 1961.

9. Anthropogenic changes in climate and atmospheric Carbon Dioxide (CO2) 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 including reductions in species populations and disruptions to the provision of ecosystem service. Impacts are widespread even with the modest level of change observed thus far in comparison to some future projections. Observed signs of natural adaptation and negative impacts include changes in the:

- Geographic distributions of species;
- Timing of life cycles (phenology);
- Interactions between species;
- Rates of photosynthesis and respiration-decay (and thus carbon sequestration and storage) in response to altered temperate, climatic wetness, CO2 "fertilisation" and increased nitrogen deposition; and
- Changes in the taxonomic composition of ecological communities and vegetation structure of ecosystems.

10. In fact, the AR4 estimates that 20-30% of species assessed would be at risk of extinction if climate change leads to global average temperature rises greater that 1.5 -2.5°C[5]. Aside from well known arctic and high altitude case studies, there are many examples globally of individual species likely to be negatively impacted by climate change, especially through reduced geographic range sizes[6], including endemic species such as Mediterranean-climate South African Proteas, of which 30 to 40 percent are forecast ultimately to suffer extinction under plausible climate scenarios for this century. As another example, a projected sea-level rise of 88cm over the 21st century could lead to the loss of 13% of mangrove area in 16 pacific island countries or territories, with losses as high as 50% on some islands[6].

11. Such increased risks of extinction are also likely to impact and be impacted by ecosystem processes. There is ample evidence that warming will alter the patterns of plant, animal and human diseases. Numerous modelling studies project increases in economically important plant pathogens with warming, and experimental studies show similar patterns. There is also evidence that climate change may play a role in changing the distribution of diseases. For example, climate change has been listed as a contributing factor to increased instances of disease outbreaks among corals, sea turtles, sea urchins, molluscs and marine mammals[7].

12. In addition to affecting individual species and ecosystem health, the values and services provided to people by ecosystems, so called, ecosystem services, will also be impacted. These include provisioning services such as food and raw materials, which may improve in the short term in boreal regions and decline elsewhere; regulating services such as flood control and coastal protection which are expected to be particularly impacted by the degradation of coral reefs and wetlands; and cultural services including traditional livelihoods.

13. It is also important to note that climate change impacts on ecosystems can exert significant positive feedbacks to the climate system. It is generally agreed that one of the main feedbacks to the climate system will be through the increase in soil respiration under increased temperature, particularly in the arctic, with the potential to add 200ppm CO_2 to the atmosphere by 2100[8]. One area of research that has expanded since the 4AR is that of the projected Amazon drying and dieback. It has been suggested that climate change will cause increased seasonal water stress in the Eastern Amazon which could increase susceptibility to fire especially in areas near human settlements and agricultural lands. This increase in forest fire may contribute to increased greenhouse gas emissions[9].

14. At the same time that climate change is impacting biodiversity, biodiversity and associated ecosystem services have a recognized role in reducing climate change and its impacts.

15. Carbon is sequestered and stored by ecosystems, and the processes which constitute and sustain this ecosystem service are the result of biodiversity. An estimated 2,400 Gt carbon is stored in terrestrial ecosystems, compared to approximately 750Gt in the atmosphere. Furthermore, primary forests in all biomes – boreal, temperate and tropical – have also been shown to be, even at a very old age, continuing to function as carbon sinks[10]. Marine ecosystems also sequester large amounts of carbon through phytoplankton at the ocean surface, accounting for approximately 50% of the global ecosystem uptake of $CO_{2,}$, with a proportion of dead organic matter being deposited in the ocean floor sediment. Protecting the current stock of carbon in forests and other natural ecosystems such as wetlands is a necessary compliment to reducing fossil fuel emissions if total global anthropogenic emissions are to be reduced to a level that will avoid dangerous climate change[11].

16. Currently, however, only 312Gt carbon or 15.2 per cent of the global carbon stock is under some degree of protection within more than 100,000 protected areas. The conversion and degradation of natural ecosystems is therefore a significant contributing factor to climate change. For example, the conversion of peat swamp forests to oil palm causes a net release of approximately 650 Mg carbon-dioxide equivalents per hectare[12], while in tropical forests land use activities including logging have been shown to deplete carbon stocks and increase susceptibility to fire damage[13], in fact, some commercially managed temperate forests in the USA[14] have been found to be around 40% or more below natural carbon carrying capacity[15].

17. Given that, in the absence of mitigation policies, the AR4 projects that temperatures are likely to rise by 1.1ºC to 6.4ºC by the end of the 21st century relative to the 1980-1999 baseline, the role of ecosystems in storing and sequestering carbon is critically important. As such, the conservation and sustainable use of biodiversity has the potential to contribute significantly to the maintenance of carbon stocks while the rehabilitation (through natural or human-assisted means) of degraded ecosystems can increase sequestration. Both the protection of existing carbon stocks and the restoration of depleted carbon stocks will therefore help limit the required adaptations to the impacts of climate change.

18. Even with mitigation strategies in place, significant climate change is inevitable due to lagged responses in the Earth climate system, leading to the need for comprehensive and effective adaptation strategies. The recognition of the value of ecosystem services by the Millennium Ecosystem Assessment provided an opportunity to assess the potential economic impacts of the loss of such services in the face of increasing pressures.

19. Overall, 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)[16]. As one example, a study by the World Bank revealed that coral reef degradation attributable to climate change in Fiji is expected to cost between US$ 5 million and US$ 14 million a year by 2050[17]. There is therefore, an urgent need to include, within any adaptation plan, specific activities for the conservation and sustainable use of biodiversity and associated ecosystem service.

20. Adaptation focused on the conservation and sustainable use of biodiversity faces many challenges including the need to balance the natural adaptations of species and ecosystems with planned adaptation. For example, as species migrate in response to climate change, ranges and extent may shift beyond the borders of existing protected areas. As such, conservation strategies in the future will need to focus not only on conserving existing habitats but also restoring degraded habitats, better managing existing pressures such as invasive species, and enhancing connectivity in order to allow for natural adaptation.

21. The supporting role of biodiversity and associated ecosystem services should be integrated within broader adaptation planning and practices through the adoption of ecosystem-based adaptation, which may be further described as the use of sustainable ecosystem management activities to support societal adaptation. Such approaches can deliver multiple benefits for biodiversity and society

including improved flood control, enhanced carbon sequestration and storage, support for local livelihoods, etc.

22. Finally, as climate change mitigation and adaptation activities accelerate, it is important to ensure that such activities do not have negative impacts on biodiversity. For example, the impact of adaptation strategies on biodiversity has been shown to be negative in many circumstances, particularly in the case of 'hard defences' constructed to prevent coastal and inland flooding. This can result in mal-adaptation in the long term if it removes natural flood regulation properties of coastal and freshwater ecosystems, for example.

23. With regards to mitigation, activities involving land use change can have positive, negative or neutral impacts on biodiversity. The conversion of tropical forest and wetlands to palm oil plantations, for example, results in biodiversity loss and reduction in overall carbon storage capacities provided by these ecosystems. On the other hand, reducing emissions from deforestation and forest degradation, and careful reforestation, if well designed, has to potential to significantly contribute to global efforts towards the conservation and sustainable use of biodiversity.

KEY MESSAGES

A. Climate change and biodiversity interactions

- Maintaining natural ecosystems (including their genetic and species diversity) is essential to meet the ultimate objective of the UNFCCC because of their role in the global carbon cycle and because of the wide range of ecosystem services they provide that are essential for human well-being.

- Climate change is one of multiple interacting stresses on ecosystems, other stresses include habitat fragmentation through land-use change, over-exploitation, invasive alien species, and pollution.

- 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 potential, leading to increases in emissions of greenhouse gases and loss of biodiversity at the genetic, species and landscape level;
  - Hypothetically, if all tropical forests were completely deforested over the next 100 years, it would add as much as 400GtC to the atmosphere and increase the atmospheric concentration of carbon dioxide by about 100ppm, contributing to an increase in global mean surface temperatures of about $0.6\,^{0}$C;
  - Recent studies estimate that unmitigated climate change could lead to a thawing of Arctic permafrost releasing at least 100GtC into the atmosphere by 2100, thus amplifying global mean surface temperature changes.

B. Impacts of climate change on biodiversity

- Changes in the climate and in atmospheric carbon dioxide 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, which is modest compared to most future projected changes.

- Climate change is projected to increase species extinction rates, with approximately 10 per cent of the species assessed so far at an increasingly high risk of extinction for every 1^{0}C rise in global mean surface temperature within the range of future scenarios typically modelled in impacts assessments (usually $<5^{0}$C global temperature rise).

- Projections of the future impacts of climate change on biodiversity have identified wetlands, mangroves, coral reefs, Arctic ecosystems and cloud forests as being particularly vulnerable. In the absence of strong mitigation action, there is the possibility that some cloud forests and coral reefs would cease to function in their current forms within a few decades.

- Further climate change will have predominantly adverse impacts on many ecosystems and their services essential for human well-being, including the potential sequestration and storage of carbon, with significant adverse economic consequences, including the loss of natural capital.

- Enhancing natural adaptation of biodiversity through conservation and management strategies to maintain and enhance biodiversity can reduce some of the negative impacts from climate change and contribute to climate change mitigation by preserving carbon sequestration and other key functions; however there are levels of climate change for which natural adaptation will become increasingly difficult, especially where surrogate conditions may be absent or disconnected.

C. Adaptation to Reduce the Impacts of Climate Change on Biodiversity

- All adaptation activities should aim to maintain or enhance and take advantage of the natural adaptive capacity of species and ecosystems so as to increase the effectiveness of adaptation and reduce risks to biodiversity from climate change.

- To optimise their effectiveness as well as biodiversity co-benefits, adaptation activities can:
    - Maintain intact and interconnected ecosystems to increase resilience and allow for 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 or pollination to maintain ecosystem functions:
        - taking into account the adverse effects of climate change including impacts on disturbance regimes and extreme events, and
        - emphasizing restoration of functionality and habitat value rather than species composition since some pre-existing species may no longer be suited to changed environmental conditions.
    - Preserve and enhance protective ecosystem service values that help buffer human communities from floods, storms, erosion and other climate change hazards.
    - Ensure that the use of renewable natural resources will be sustainable under changed climatic conditions.
    - Collect, preserve and disseminate traditional and local knowledge, innovations and practices related to biodiversity conservation and sustainable use under climate change and variability.

- To increase the adaptive capacity of species and ecosystems to the stress of accelerated climate change, especially in light of tipping points and thresholds, it is further recommended that:
    - Non-climatic stresses, such as pollution, habitat loss and fragmentation and invasive species, are reduced or eliminated.
    - The resilience of ecosystems is improved or maintained by wider adoption of conservation and sustainable use practices.
    - Biodiversity values are recognized, maintained, and restored across land uses and tenures as suggested below.
    - Protected area networks are strengthened and enhanced because of their central role in maintaining biodiversity and enabling migration of species.
    - In some cases, relocation, captive breeding, and *ex-situ* storage of germplasm may be implemented when necessary to prevent a species becoming extinct, but such measures are often very expensive, less effective than *in situ* actions, are not applicable to all species, usually feasible only on small scales, and very rarely maintain ecosystem functions and services. In the case of relocation, potential effects on other species need to be considered.

- Risks to biodiversity from climate change and mal-adaptation can be assessed using available vulnerability and impact assessment guidelines with priority given to ecosystems and species of particular ecological, social, or economic importance.

- Planning and implementation of effective adaptation activities relies upon:
    - considering traditional knowledge, including the full involvement of local and indigenous communities;
    - defining measurable outcomes that are monitored and evaluated; and
    - building on a scientifically credible knowledge base concerning climate change impacts and evidence-based effective responses.

- Given ongoing development efforts, including through the Millennium Development Goals, identifying and reducing potential negative impacts of climate change on biodiversity is especially important in developing countries that are particularly vulnerable to the effects of climate change. As recognized by the UNFCCC this includes, especially, small island developing states and least developed countries, given their high levels of endemism, high exposure to risk, and limited capacity to adapt.

D. Ecosystem Based Adaptation

- Adaptation activities that make use of biodiversity and associated ecosystem services, when integrated into an overall adaptation strategy, may contribute to cost effective climate change adaptation and generate additional environmental and societal benefits.

- Ecosystem-based adaptation may be further described as the use of sustainable ecosystem management activities to support societal adaptation. Ecosystem-based adaptation:
    - Identifies and implements a range of strategies for the management, conservation and restoration of ecosystems to provide services that enable people to adapt to the impacts of climate change.
    - 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.

- Means of implementing ecosystem-based adaptation include activities such as sustainable water management where river basins provide water storage, flood regulation and coastal defences and the establishment and effective management of protected area systems that ensure both the representation and persistence of biodiversity to increasing resilience to climate change. The ecosystem approach and similar approaches provide useful guiding principles for designing and implementing ecosystem-based adaptation.

- There are many ecosystem-based adaptation approaches that deliver significant value for societal adaptation and an ability to provide additional benefits, including the use of coastal ecosystems to reduce risk of flooding from storm surges, and the maintenance of diverse agricultural landscapes to support productivity under changing climate conditions. Ecosystem-based adaptation, if designed, implemented and monitored appropriately, can:
    - 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 over others. 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. Impacts of Adaptation on Biodiversity

- Adaptation to the adverse impacts of climate change can have both positive and negative consequences for biodiversity and ecosystem services.

- 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 development of plantation forests including those with non-native species will result in novel ecosystems and may have impacts on the endemic species of the area. Additionally, the construction of hard infrastructure approaches in coastal areas (e.g., sea walls, dykes, etc.) often adversely impact natural ecosystems processes by altering tidal current flows, disrupting or disconnecting ecologically related coastal marine communities, and disrupting sediment or nutrition flows.

- In most cases there is the potential to reduce negative impacts and increase positive impacts to minimize trade-offs and the risk of maladaptation. Steps to achieve this include strategic environmental assessments (SEA), environmental impact assessments (EIA), and technology impact assessments, which facilitate the consideration of all adaptation options. Furthermore, an examination of case studies of maladaptation can provide important lessons learned.

F. Biodiversity and climate change mitigation through LULUCF activities including REDD

- Maintaining natural and restoring degraded ecosystems, and limiting human-induced climate change, result in multiple benefits for both the UNFCCC and CBD if mechanisms to do so are designed and managed appropriately, for example through protection of forest carbon stocks, or the avoided deforestation of intact natural forests and the use of mixed native forest species in reforestation activities.

- LULUCF activities, including reduced deforestation and degradation, that maintain, sequester and store carbon can, in concert with stringent reductions in fossil fuel emissions of greenhouse gases, play a necessary role in limiting increases in atmospheric greenhouse gas concentrations and human-induced climate change.

- Primary forests are generally more carbon dense, biologically diverse and resilient 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 emissions through loss of carbon stocks and continued sequestration, as well as for conserving biodiversity.

- In forest landscapes currently subject to harvesting, clearing and/or degradation, mitigation and biodiversity conservation can be best achieved by reducing deforestation, and reducing forest degradation through the sustainable management of forests and through forest restoration.

- 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 forest management which, through the use of mixed native species, can yield multiple benefits for biodiversity while sequestering carbon.

- Implementing REDD activities in identified areas of high carbon stocks and high biodiversity values can promote co-benefits for climate change mitigation and biodiversity conservation and complement the aims and objective of the UNFCCC and other international conventions, including the Convention on Biological Diversity.

- The specific design of potential REDD mechanisms (e.g., carbon accounting scheme, definition of reference scenarios, time frame, etc.) can have important impacts on biodiversity conservation;
    - Addressing forest degradation is important because degradation leads to loss of carbon and biodiversity, decreases forest resilience to fire and drought, and often leads to deforestation;
    - Both intra-national and inter-national displacement of emissions under REDD can have important consequences for both carbon and biodiversity, and therefore require consideration for achieving mutual benefits.

- While it is generally recognized that REDD holds potential benefits for forest-dwelling indigenous and local communities, a number of conditions would need to be met for these co-benefits to be achieved, e.g., indigenous peoples are unlikely to benefit from REDD where they do not own their lands; if there is no principle of free, prior and informed consent, and if their identities are not recognized or they have no space to participate in policy-making processes.

- The implementation of a range of appropriately designed land-management activities (e.g., conservation tillage and other means of sustainable cropland management, sustainable livestock management, agro-forestry systems, maintenance of natural water sources, and restoration of forests, peatlands and other wetlands) can result in the complementary objectives of the maintenance and potential increase of current carbon stocks and the conservation and sustainable use of biodiversity.

- Climate mitigation policies are needed to promote the conservation and enhanced sequestration of soil carbon, including in peatlands and wetlands, which is also beneficial for biodiversity.

- The potential to reduce emissions and increase the sequestration of carbon from LULUCF activities is dependent upon the price of carbon and is estimated to range from 1.3-4.2 $GtCO_2$-eq per year for forestry activities (REDD, sustainable forest management, restoration and reforestation), and 2.3-6.4 $GtCO_2$-eq per year for agricultural activities for a price of US$ 100/tCO_2-eq by 2030.

G. Biodiversity and climate change mitigation through renewable energy technologies and geo-engineering

- There is a range of renewable energy sources, including onshore and offshore wind, solar, tidal, wave, geothermal, biomass and hydropower and nuclear, which can displace fossil fuel energy, thus reducing greenhouse gas emissions, with a range of potential implications for biodiversity and ecosystem services.

- While bioenergy may contribute to energy security, rural development and avoiding climate change, there are concerns that, depending on the feedstock used and production schemes, many first generation biofuels (i.e., use of food crops for liquid fuels) are accelerating deforestation with adverse effects on biodiversity, and if the full life cycle is taken into account, may not currently be reducing greenhouse gas emissions. 2/

- Large-scale hydropower, which has substantial unexploited potential in many developing countries, can mitigate greenhouse gas emissions by displacing fossil fuel production of energy, but can often have significant adverse biodiversity and social effects.

- Artificial fertilization of nutrient limited oceans has been promoted as a technique to increase the uptake of atmospheric carbon dioxide, but it is increasingly thought to be of limited potential and the biodiversity consequences have been little explored.

H. Valuation and incentive measures

- Accounting for the value of biodiversity and the ecosystem it supports, is important for the decision making process, and for the provision of appropriate incentives for societal adaptation to climate change.

- Ecosystem services contribute to economic well-being and associated development goals (e.g. MDGs) in two major ways – through contributions to the generation of income and well-being (e.g., provisioning of food and fiber), and through the reduction of potentially costly impacts of

2/ The expert from Brazil disassociated himself from this statement.

climate change and other stresses on society (e.g., coral reefs and mangrove swamps protect coastal infrastructure).

- There are many methodologies which have been developed to estimate the economic value (including both market and non-market values) of ecosystem services and these should be applied in order to promote the full range of financial options when implementing ecosystem-based adaptation.

- Both economic and non-economic incentives could be used to implement ecosystem-based adaptation:
    - Economic measures include:
        - (i) removing perverse subsidies to sectors such as agriculture, fisheries, and energy;
        - (ii) introducing payments for ecosystem services;
        - (iii) implementing appropriate pricing policies for natural resources;
        - (v) establishing mechanisms to reduce nutrient releases and promote carbon uptake; and
        - (vi) applying fees, taxes, levees, and tariffs to discourage activities that degrade ecosystem services.

    - Policies should be assessed in all sectors to reduce or eliminate cross-sectoral impacts on ecosystem services.

    - Non-economic incentives and activities include improving or addressing:
        - (i) laws and regulations;
        - (ii) governance structures, nationally and internationally,
        - (iii) individual and community property or land rights;
        - (iv) access rights and restrictions;
        - (iv) information and education;
        - (v) policy, planning, and management of ecosystems; and
        - (vi) development and implementation of technologies relevant for biodiversity and climate change adaptation (e.g. technology that makes use of genetic resources and technology to manage natural disasters)

- In order to achieve intended adaptation objectives while avoiding market distortions, such as through tariff and non-tariff barriers, incentives for ecosystem-based adaptation should be carefully designed to consider social, economic and biophysical variables.

SECTION 1

BIODIVERSITY-RELATED IMPACTS OF ANTHROPOGENIC CLIMATE CHANGE

1.1 OBSERVED AND PROJECTED IMPACTS OF CLIMATE CHANGE ON BIODIVERSITY

Anthropogenic changes in climate and atmospheric CO2 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. Observed signs of natural adaptation and negative impacts include:

- **Geographic distributions:** Species' geographic ranges are shifting towards higher latitudes and elevations, where possible. While this can be interpreted as natural adaptation, caution is advised, as the ranges of some species are contracting from warm boundaries, but are not expanding elsewhere; there are also geographic limits to how far some species will be able to go. Range shifts have mostly been studied in temperate zones, 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.

- **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.

- **Interactions between species:** evidence of the disruption of biotic interactions is emerging. Changes in differential responses to 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 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 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.

- **Community and ecosystem changes:** observed structural and functional changes in ecosystems are resulting in substantial changes in species abundance and composition. 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 and recover 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 anthropogenic 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 (high confidence). [3]

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 – a rate

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

at which natural adaptation should have been able to take place (although the end of ice ages has been, historically, quite rapid[18]). This is in contrast to the much more rapid rate of temperature change observed and projected today[19].

Further climate change will have increasingly significant direct impacts on biodiversity. Increased rates of species extinctions are likely[20], with negative consequences for the provision of 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 mountain top species[21] and species restricted to freshwater habitats[22].

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 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 and in terrestrial systems that are not water-limited[23].

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 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 or “tipping points” that are not yet well understood.

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. However, shifts in distributions of native species as an adaptive response to climate change will force a reassessment of how we define what is meant by “invasive”. These pressures amplify climate change effects by causing fragmentation, degradation and drying of ecosystems, including increased incidence of fire, 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.

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[24]. 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[25]. In ecosystems accustomed 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 area, and only 25% of terrestrial areas retain unaffected (natural) fire regime conditions[26]. Moreover, effective biodiversity conservation requires that fire regimes are able play their role in maintaining ecosystem functioning, but at the same time 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 and interactions, 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.

Research shows 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, within the range of future scenarios modeled in impacts assessments (typically <5^{0}C global temperature rise). Given the observed temperature rise, this now places 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) places an additional 5-7% of species at increasingly high risk of extinction (based on single species studies and not including losses of entire ecosystems). A recent study of global bird distributions estimated that each degree of warming will yield a nonlinear increase in bird extinctions of about 100-500 species[27]. Temperature increases of 2°C above pre-industrial levels begin to put entire ecosystems at risk and the extinction rate is expected to rise accordingly.

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

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 depends on population characteristics as well as local conditions and may include large production losses. Climate change also affects the ability of ecosystems to regulate water flows, and cycle nutrients.

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 disease vectors[28]. 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 the tick-borne disease Theileriosis (East Coast fever) show increases in areas of suitability in Africa[29].

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 increased in mosquito-borne diseases such as malaria and dengue fever.

Climate change affects the ability of ecosystems to regulate water flows. Higher temperatures, changing insolation and cloud cover, and the degradation of ecosystem structure, impedes the ability of ecosystems to regulate water flow. In Asia, for example, water supplies are at risk because climate change is melting the glaciers that feed Asia's largest rivers in the dry season[30] – precisely the period when water is needed most to irrigate the crops on which hundreds of millions of people depend.

Climate change will have important impacts on agricultural biodiversity. Even slight changes in temperature, precipitation, etc. are expected to decrease agricultural productivity in tropical and subtropical areas. In regions that experience more frequent and more extreme droughts and floods, the likelihood of crop failure will increase and may result in negative livelihood impacts including forced sale of assets, out-migration and dependency on food relief. The wild relatives of crop plants – an important source of genetic diversity for crop improvement – are also potentially threatened by climate change.

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 Southeast Asia may be lost over the next 30 years. In addition, ocean acidification may cause pH to decrease by as much as 0.5 units by 2100 causing severe die-offs in shellfish[31].

Biodiversity loss and ecosystem service degradation resulting from climate change has a disproportionate impact on the poor and may increase human conflict. The areas of richest biodiversity and ecosystem services are in developing countries where billions of people directly rely on them to meet their basic needs. Competition for biodiversity resources and ecosystem services may lead to human conflict. Small Island Developing States and Least Developed Countries are particularly vulnerable to impacts such as projected sea level rise, ocean current oscillation changes and extreme weather events.

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.

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.

Many ecosystems are currently acting as carbon sinks, sequestering 30% of anthropogenic emissions, but if no action is taken on mitigation, some ecosystems in those regions which will experience a decrease in annual precipitation or an increasing in seasonality (and thus reduced rates of photosynthesis and biomass production) will slowly convert to carbon sources. The reason for this conversion from sink to source is linked to temperatures rises increasing soil respiration, thawing of peatlands, increasing wildfire, etc. Some studies suggest that this feedback could increase CO_2 concentrations by 20 to 200 ppm, and hence increase temperatures by 0.1 to 1.5ºC 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 2-4ºC above pre-industrial levels according to some models. 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 but if left undisturbed by anthropogenic disturbance could have sufficient natural resilience to buffer climate change impacts into the 22nd century[32]. On the other hand, 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, taiga peatlands, 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 100GtC 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[33].

- Reduced rainfall may change the equilibrium between vegetation, hydrology and soil in peatlands and mires. In areas where there will be insufficient precipitation peat formation will reduce or stop, and regression may take place.

Biodiversity can be important in ameliorating the negative impacts of some kinds of extreme climate events for human society; but certain types of extreme climate events which may be exacerbated by climate change will be damaging to biodiversity

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. During this period floods alone left more than 400 000 people homeless and caused many deaths[34]. In response to these events many countries adopted plans and programmes recognizing the need to maintain natural ecosystems.

The value of biodiversity 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 hectare[35]. Furthermore, the conservation and sustainable use of biodiversity has a significant role to play in response to drought providing important genetic diversity in livestock and crops.

The impacts of climate change on biodiversity will reduce the ability of some ecosystems to ameliorate the negative impacts of extreme events. Future predictions of the impacts of climate change on biodiversity have identified some of the ecosystems most critical for human security as being particularly vulnerable to the impacts of climate change. For example, climate change impacts are expected to result in a loss of over half the area of coastal protecting mangroves in 16 Pacific island States by the end of the century[36].

1.2 TOOLS FOR IMPACT, RISK[4] AND VULNERABILITY[5] ASSESSMENTS

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

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 (adaptive capacity) of many species is unknown, and may be a factor of exposure to past climates 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[37]. For example, one recent study found that limb length in one species is temperature dependent and thus would convey a potential adaptation potential to a range of climates[38]. One potential approach to estimating potential adaptive capacity would be to estimate potential exposure to past climate over evolutionary time in conjunction with dispersive capability. Research has shown that many species have shifted ranges with past climates (assuming rate of change matches 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 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 biodiversity in climate change as outlined in Box 1.

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4 *Risk* can be defined as a function of *hazard* and *vulnerability* (CBD 2009). From a climate change perspective, *hazard* can be defined as physical manifestations of climatic variability or change, such as droughts, floods, storms, episodes of heavy rainfall, long-term changes in the mean values of climatic variables, potential future shifts in climatic regimes (Brooks 2003).

5 *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.

The understanding of the characteristics that contribute to species' risks of decline or extinction has improved. Species with restricted distributions, those that occur at low density, and tropical montane species are at particular risk, as are those with limited dispersal ability. Areas of most concern are the arctic and Antarctic regions, alpine regions, 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 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[39]. 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.

The value of risk assessment lies in its ability to prioritize, for adaptation activities, species and ecosystems identified as being most vulnerable. Following the risk assessment, appropriate adaptation activities can be identified which reduce the risks to the identified species and ecosystems. These activities should include consideration of the necessary funding, stakeholders, monitoring and evaluation, and define time-bound, measurable outcomes. Furthermore, the risk assessment should involve two aspects: an assessment is required of the current and projected adverse impacts of climatic change to biodiversity based on consideration of the kinds of impacts expected to occur at a local, national or regional scale; and an assessment is also required of the vulnerability of selected species and ecosystems to the projected climatic change hazards [40]. Examples of good practices to assess and address risks to biodiversity from climate change are available in Annex 2.

Box 1: Guidelines for assessing risk to biodiversity values from climate change

1. **Assess the potential climatic change hazard using recommended 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).

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, economically important, culturally important, dominant, ecological keystone or, sources of crop, stock and medicinal genetic diversity, or those that are dependent on vulnerable ecosystems.

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.

There many techniques that have been used to analyze vulnerability (Table 1). These include Delphi models and expert systems frequently used for the analyses of vulnerability of endangered species to climate change. While quantitative in their use of scores, they are not quantitative models per se[41]. Table 1 does not included the wide range of studies and databases looking at observed changes over time (e.g., phenological networks). Observed changes over time, or changes 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 the regional climate changes.

Table 1: Tools and methodologies used to estimate impacts and/or vulnerability

Components of Vulnerability	**Scale of Biodiversity**		
	Genes	**Species**	**Communities & Ecosystems**
Exposure[42]	Projections of change (including CO_2 concentration; temperature, precipitation, extreme events, climate variability, sea levels, ocean acidification, sea surface temperature)	Projections of change (including CO_2 concentration; temperature, precipitation, extreme events, climate variability, sea levels, ocean acidification, sea surface temperature)	Projections of change (including CO_2 concentration; temperature, precipitation, extreme events, climate variability, sea levels, ocean acidification, sea surface temperature)
Sensitivity		Bioclimatic models (process and correlative)[43]; Demographic models[44]; Ecophysiological models[45]; Population viability models[46]; estimates of threatened status (e.g. Red List status)[47]; interactions and co-extinction models (e.g. pollination, predator-prey, competition, host-parasite)[48]; digital vegetation models; Species-specific energy-mass balance models[49]	Earth system models[50]; projections of productivity; Dynamic vegetation models (including plant functional types)[51]; biogeochemical cycle models[52]; Hydrological, soil and moisture balance, coastal flooding models[53]; estimates of ecosystem health[54]; fire models[55]; trophic relationships[56]; state-transition models
Adaptive capacity	Selection experiments[57]; experimental estimates of ecotypic variation of response[58]	Use of natural latitudinal or elevational gradients[59]; life history and species trait analysis[60]; estimates of resilience and non-climatic stresses[61]; GIS: analysis of spatial habitat availability, PAs, corridors, barriers, topography;	Estimates of resilience and role of non-climatic stresses[66]; GIS: analysis of spatial habitat availability, PAs, corridors, barriers, topography; state-transition models; responses to past climates

		Bioclimatic models; Experimental manipulations of CO_2, water, temperature etc[62]; translocation/transplant experiments[63]; responses to past or current climate variability[64]; responses to past climates[65]	

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

- *Climate Data* **-** Readily available downscaled probabilistic projections at appropriate spatial scales for regional and local management, including extreme events in addition to mean values.
- *Climate impact models need to be linked with other physical models* **–** Currently most models only link two items together (e.g., climate and species ranges, or climate and hydrological regime). Ideally, systems need to be developed that link bioclimatic models with other physical models (CIAS). For example, linking bioclimatic models with land-use models, fire models, hydrological models, vegetation change models, etc., preferably with the ability to look at feedbacks.
- *Climate impact models need to be linked with other biological models* – Ideally, systems need to be developed that link bioclimatic models with eco-physiological, demographic and viability models (e.g., using SCS (strategic cyclical scaling)). Furthermore, currently, most bioclimatic models look either at single species, or groups of species as one (e.g., plant functional types). Models need to be developed that take into account interactions between species and through trophic levels. What is further needed are more conjoined studies that simultaneously look at projections of changes to current climates over time using bioclimatic models, coupled with observed changes in the same species as a measure of a model's potential to capture future shifts in species range[67].
- *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 integrates biodiversity status, within a framework that includes threat status monitoring and the recording the effectiveness of adaptation measures is also recommended.

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

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 overwhelm climate change effects on biodiversity in the short to medium term. Alternative 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.

Readily available, easy to use, multiple impact stressor tools 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 GCMs. 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.

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 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.

1.3 CONFIDENCE LEVELS AND UNCERTAINTY

There is considerable confidence that climate models provide credible quantitative estimates of future 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.

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.

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[68]. 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.

Research needs and gaps remain. CBD Technical Series 10 outlined a number of research needs and gaps with regards to assessing the impacts of climate change and 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 underway (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, human land and water use patterns are available for many parts of the world, but are 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 temperature and uncertainties regarding key ecological processes, such as the rates of fire, photosynthesis and respiration

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.

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

- 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-fertilisation effect in the terrestrial biosphere and its components over time;
- the limitations of climate envelope models used to project responses of individual species to climate changes, and for deriving estimations of species extinction risks (see below);
- the synergistic role of invasive alien species on both biodiversity and ecosystem functioning;
- 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

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 likely to always be gradual, but instead may be stepwise, and changes may take place in the form of sudden shifts, whose timing and location is 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.

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[69]. 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 levels of change[70].

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 ecosystems and biodiversity (e.g., as observed following the 2003 European heat wave).

Investment in key areas that require scientific development would reduce uncertainty in assessments of the impacts of climate change on biodiversity and related impacts on human society

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-fertilisation effects, in mature forests in the Northern Hemisphere, seasonal tropical forests, and arid or semi-arid grassland and savannas.

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.

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-fertilisation and temperature/moisture-respiration responses have been quantified.

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.

Observations[71] from indigenous and local communities form an important component of impact assessments as long as they are conducted with prior informed consent and with the full participation of indigenous and local communities

Currently, remote sensing provides the only viable way to monitor changes at a global scale, which has serious limitations on developing a globally integrated picture of species level responses. 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.

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 wellbeing. 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.

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 it is suggested that further efforts are made to ensure that traditional 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.

Monitoring the impacts of climate change on biodiversity in partnership with indigenous and local communities can benefit from a range of practices. These include utilising the results of community-based monitoring linked to decision-making, especially because indigenous communities are able to provide data and monitoring information at a system rather than individual species level. Examples of supporting activities include:

(a) Promote documentation and validation of traditional knowledge, innovations and practices are limited. 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.

(b) 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.

(c) 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

Enhancing natural adaptation can reduce negative impacts from climate change and limit the scale and scope of damages and to ensure the continued provision of ecosystem services such as carbon sequestration

The components of biodiversity and their interactions and processes are subject to considerable impacts from climate change. As outlined in the previous section, these impacts increase the vulnerability of biodiversity to perturbations, destruction and extinction. There is, therefore, a need for adaptation strategies within the conservation sector, both to conserve biodiversity for its own sake and to maintain ecosystem services, which are critical for societal adaptation

Adaptation planning must consider the scope and extent of planned mitigation

The greater the reduction of greenhouse gas emissions through mitigation, the smaller the global and regional climate changes and associated impacts, and hence the less the challenge for adaptation. For example, stringent mitigation policy might induce emissions reductions that constrain global mean temperature rise to 2°C above pre-industrial levels; less stringent reductions might constrain it to 3°C; whilst modest reductions might constrain it to 4°C. The challenge that ecosystems and species face in adapting to a 3°C rise is very much greater than for a 2°C rise, as many ecosystems and species would be unable to adapt to a rise of 3°C[72].

An increasing number of hotspots for biodiversity are disrupted as temperatures increase from 2°C to 3°C. Examples include the Fynbos & Succulent Karoo botanical areas in Southern Africa, the mammalian diversity in the Kruger National Park, and the Cerrado botanical area in Brazil. Above 2°C many terrestrial species which try to move to higher latitudes or altitudes as temperatures rise, will exceed their limits for adaptation due to lack of availability of land. At 3°C widespread losses of species and severe ecosystem disruption are expected in cloud forests, in the Arctic, in alpine areas, and along coastlines as temperatures and sea levels rise, marine ecosystem disruption from ocean acidification may occur. Furthermore, at 3°C all coral reefs would be expected to convert to algal mats, whereas at 2°C coral reefs could persist in several areas. Finally at 3°C, or 2.5°C for forests, the sink service of the terrestrial biosphere begins to convert to a source, and together with increased fire frequency this will result in forest decline worldwide[73].

Were temperatures to reach 4°C above pre-industrial, few ecosystems would be expected to be able to adapt and 50% of nature reserves could no longer fulfil their conservation objective[74]. Hence stringent reductions of emissions of greenhouse gases can avoid many of the more severe and widespread impacts on ecosystems and dramatically reduce both extinction risks and the adaptation challenge that ecosystems and species face under climate change.

2.1 ADAPTATION FOR BIODIVERSITY AND ASSOCIATED ECOSYSTEM SERVICES

Experiences have yielded a number of principles of general applicability that can be used to guide adaptation activities for minimizing the risk to biodiversity values from climate change. Such adaptation activities may need to address not only wildlife conservation but also the replacement of lost ecological services. For example, it may be necessary to develop adaptations to losses to natural pest control, pollination and seed dispersal. While replacing providers of these services may sometimes be possible the alternatives may be costly. Finding a replacement for services such as contributions to nutrient cycling and ecosystem stability/biodiversity is likely to be more difficult. As such, the *ecosystem approach* as described in box 2, is recommended as an appropriate framework for applying these principles.

1. Principles for adaptation activity planning and implementation

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.

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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; and 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.

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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.

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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.

2. Principles regarding adaptation activity objectives and outcomes

Maintain intact and interconnected ecosystems to allow for 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; and (iv) maintaining key ecological attributes within natural ranges of variation. Ecosystem integrity can also be enhanced by abating other threats (e.g., habitat loss, invasive species). A comprehensive and adequate protected area system should be the backbone of land- and sea-scape wide approach to conservation management.

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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.

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.

Ensure that any use of renewable natural resources is sustainable given climate change impacts. The sustainable use of ecosystems may be effected by climate change if, among other things, the biological productivity declines. Management plans should be updated and harvest or use rates modified on the basis of such assessments to ensure sustainability.

Business as usual in biodiversity conservation may not be sufficient or desirable to protect species and ecosystems in the future

As ecosystems change as a result of natural adaptation, conservation strategies will also need to change. As such, adaptation for the conservation sector involves not only reducing the impacts of climate change on biodiversity but also assessing and, where necessary, adjusting traditional conservation practices in order to reflect rapidly changing conditions.

Ecosystems are not static entities. Through historical time, the structure and composition of ecosystems have changed with changing climates. Each species responds to the climate at its own rate and the composition of past ecosystems often have no analogue to present day ecosystems[75] . Palaeoecological data indicates the rates of change for many species were substantially slower than the current, and predicted future, rate of climate change. Further, recent research suggests that novel climates (for example, new combinations of temperature and precipitation) may arise in many continents[76]. The ecosystem services provided by these new assemblages may also be novel, in quantity and quality.

If emissions are reduced to 50% of 1990 values by 2050, so that temperatures are constrained to, but reach, 2°C warming above pre-industrial levels, recent work has shown that temperatures will not begin to decline for at least a century. Even if emissions peak in 2015, and then reduce at a rate that increases to 3%/yr there would be an estimated 20-50% (mean 30%) chance that temperatures will stay above 2°C for at least 100 years, depending on the rate of sulphate aerosol reduction, and a 20-25% chance that it stays above 2°C for 200 years. Less stringent policies would result in still longer periods exceeding 2°C. With higher emissions come higher temperatures with probabilities that ecosystems will need to adapt to 3° C, 4°C or even higher, for longer periods of time. Sea-level rise would then continue for a substantial period beyond this.

The aim of conservation strategies in the future should continue to be to maximise biodiversity (i.e. minimise loss) and to maintain ecosystem services. However, flexible conservation and adaptation strategies will be needed that will be robust in light of uncertainty concerning the magnitude, direction and rate of climate change. These strategies may need to *facilitate the autonomous transformation of ecosystems* in response to changing conditions so as to maximize biodiversity and maintain functionality.

Box 2: Application of the Ecosystem Approach to Adaptation

At its 5th Conference of the Parties in 2000 the CBD adopted the ecosystem approach as the primary framework for actions to help reach a balance of the three objectives 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 7th Conference of the Parties the CBD recognised “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. (Princip.les 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

Conservation strategies under changing climatic conditions must be based in solid science with full consideration of the possible negative impacts of changing conservation activities. Maintenance of current assemblages and services in their present form in their present location will, in many cases, be impossible. Accordingly, the four distinct but complementary strategies of 21st century conservation are described below.

1. Maintaining current ecosystems

The most fundamental biodiversity conservation strategy will be to continue to protect intact, functioning ecosystems wherever possible. This can be accomplished by:

- Reducing other threatening process and stresses on species and ecosystems. These processes include habitat loss and fragmentation as a result of unsustainable use, invasive alien species, damaging wildfire, pollution, and overharvesting. Minimization of these processes is necessary to maximise resistance of species and ecosystems to the new stress of rapid climate change.
- Increasing protected area systems and improving their connectivity to provide opportunities for species to adapt to climate change by migration. Increasing the size of protected areas will increase the probability of maintaining viable populations.
- 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. These refugia are most likely to provide refuges for species in surrounding ecosystems, not for the species for which they were refugia in the past.
- Identify existing locations that contain high levels of environmental heterogeneity (including latitudinal and elevational gradients) in which to focus conservation efforts. Regions of high heterogeneity (edaphic, moisture, and topographical conditions) will continue to provide the widest range of microhabitats, and therefore support the richest biodiversity in the future.
- Examine models to determine those areas with climatic suitability for an ecosystem now and at various times in the future as potential priorities for protection. Similar work has been performed for regions where coral reefs may be exposed to lower levels of temperature change and acidification.
- Many areas of high endemism have been relatively climatically stable for millions of years. These areas tend to have species with a high degree of specialization. Research needs to focus on the risk of climate change in these areas. As the communities have largely evolved *in situ*, the options for relocation may be minimal so intensive efforts to maintain these areas, or preserve their genetic diversity, may be crucial.
- In many cases, conservation of existing ecosystems will involve active management of disturbance events that will alter in both frequency and intensity in the future.
- There is increasing interest in eco-engineering and this interest requires consideration of the potential implications of such activities. Eco-engineering may allow for the maintenance of representative samples of some ecosystems however, such efforts are likely to be expensive, especially if they need to continue for long-periods of time and success cannot be assured. Examples of this would include making snow to better mimic current winter precipitation regimes in alpine areas (should this be a limiting factor), shading reefs or beaches to lower temperatures, etc.

2. Adapting restoration practices to climate change

Ecosystem restoration involves activities that transform a degraded ecosystem into an ecosystem that is less disturbed and better able to provide ecosystem goods and services. Restoration is considered to be successful once ecosystem resilience has been re-achieved[77]. Restoration of ecosystems can be of economic importance where those systems protect property, but also when areas are critically important to biodiversity and /or for people with biodiversity-based livelihoods. However, it is less expensive to conserve ecosystems than to restore them.

Just as general strategies of conservation need to adjust to take into account future rapid climate change, so too will restoration efforts need to take place in the context of a changing environment. Ecosystem restoration strategies in the future will need to consider:

- *The role of extreme events:* Climate change will not only alter mean climate (e.g. mean annual temperature and rainfall) but will also alter the intensity and frequency of extreme events. Understanding and anticipating the potential changes in disturbance regimes that influence successional processes will be a key to restoration of functioning ecosystems.
- *Restoration of function not species composition:* As the climate changes, many species will become increasingly unsuited to conditions within their present day geographic range. Successful restoration of ecosystems will therefore need to focus on restoring functionality and ecosystem services, rather than attempting to re-create the species composition that previously existed at a location. For example, a given area may continue to be predominated by oaks (*Quercus* spp.) or eucalyptus under a future climate but the particular species may differ. It is also necessary to restore redundancy in order to ensure resilience.
- *Genetic provenances used in re-establishment:* A long-held paradigm of restoration ecology is the desirability of re-establishing individuals of local provenance i.e. propagation material collected within a narrow radius of the restoration site that is thought to be best-adapted to local conditions. As the climate, and therefore local conditions change in the future, this strategy may reduce the potential for the restored community to be sustainable in the medium- to long-term. The use of a mixture of genetic provenances collected over a broad range of sites and climates will increase the probability of restoration success and may be an effective form of risk-spreading. Such an approach requires careful consideration, however, in order to ensure that introduced species don't have negative impacts on that native flora and fauna which is able to adapt *in situ* to the impacts of climate change.

Depending on the amount of climate change that may be locked into the Earth's systems, more extreme measures may be needed to preserve genetic, species and functional diversity. Many of these techniques are controversial, involve high uncertainty, will be difficult at best, and very expensive. Two examples of such extreme measures are presented below.

3. Relocate species (assisted migration)

In some cases it might be necessary to relocate species, or assist them to relocate in response to climate change and its impacts. There are three general types of relocation: auto-relocation, where species shift their own ranges to stay in equilibrium with the new climate; assisted-relocation, where movements between areas with suitable habitats must be facilitated by human intervention; and engineered-relocation, where before a species can be moved, habitat in the new area must first be created or modified to allow the species to survive. An alternative type of "engineering" relocation could potentially include modifying organisms (e.g., selective breeding or genetic modification) or selection of more temperature/drought/salt tolerant species to move into an area.

There are limitations, risks, uncertainty, and high costs involved in each of these techniques. For a species to be able to auto-relocate assumes the species has the capacity to disperse that matches or exceeds the rate of climate change. This is more likely for winged animals, plants with small, highly dispersible seeds, or aquatic species that disperse in ocean currents or watercourses. There must also be habitat suitable for the species' survival at the new location and no barriers to migration. These movements are not risk free. For example, as species A moves into habitat B it becomes an "introduced" species to that habitat. Other risks include disruptions of predator-prey interactions or symbiotic interactions, changes in parasitism rates and potential competition with existing species for limited resources. Further, the loss of species A from habitat A may lead to disruption of critical ecosystem processes, depending on the level of redundancy in the system. The more fragmented the landscape the greater the probability of needing assisted-relocation. In order to be successful it will 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 scientists understand the necessary functions of the components of a natural ecosystem necessary for species to survive and thrive. This involves very high costs, is only feasible at small scales, and would likely fail in most cases. At its most extreme it may require modifying an existing ecosystem to make it suitable for new species without destroying its usefulness for existing species, again a very high cost, high risk strategy. This may mean a 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[78].

4. Bank species

Given the links between climate change and extinction risks, it may be necessary to bank species or genotypes that are unable to survive under new conditions. Depending on the level of greenhouse gas stabilization achieved, and the maximum level of climate change attained, many species are likely to become extinct. In other cases there may be loss of genetic variability even if the species survives (e.g., loss of populations, loss of subspecies). Therefore, it may be necessary to "bank" species or genotypes to use in reintroductions once climatic conditions have returned to a suitable level for those species. There are many reasons for the loss of genetic resources and the need to "bank" species and genotypes. However, use of this technique in terms of climate change should be seen as a last-ditch effort, something better avoided by mitigation if at all possible. Furthermore, in view of the high proportion of species likely to be affected, banking species (other than seeds) or simple ecosystem components on this scale is infeasible and extremely expensive.

Society has a long history of maintaining species and genetic stock in zoos, aquaria and gene banks. Most recently, the Svalbard Global Seed Vault has started collecting and storing seeds in order to protect against loss of seeds currently held in gene banks or against large-scale crises. There have been various attempts to recreate and simple ecosystems in closed or semi-closed environments (e.g., Biosphere 2, the Eden Project). These have met with mixed success depending on the original purpose but do indicate the difficulty of trying to recreate and hold even simple functioning ecosystems.

Endangered wildlife populations have been protected through the use of captive breeding and translocations. These techniques have been suggested in the past as methods to deal with future population pressures caused by climate change[79]. However, captive breeding and translocation, while effective tools for the conservation of some species, may be appropriate for only a few species. Combined with habitat restoration, such efforts may be successful in preventing the extinction of small numbers of key selected taxa. However, climate change could result in large-scale modifications of environmental conditions, including the loss or significant alteration of existing habitat over some or all of a species' range. Captive breeding and translocation should therefore not be perceived as panaceas for the loss of biodiversity that might accompany dramatic climate change, especially given the current state of the environment.

One limitation to captive breeding is the lack of space available and the cost to hold wildlife for breeding purposes. 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 programs[80]. These programs are also expensive and reintroductions are technically difficult. For example, it costs $22,000 to raise a single golden lion tamarin in the United States and reintroduce it to its native Brazil[81].

2.2 ECOSYSTEM-BASED ADAPTATION

Ecosystem-based adaptation can, when integrated into an overall adaptation strategy, deliver a cost effective contribution to climate change adaptation and generate societal benefits.

Ecosystem-based adaptation is the use of ecosystem management activities to support societal adaptation. Ecosystem-based adaptation identifies and implements a range of strategies for the management, conservation, and restoration of ecosystems to provide services that enable people to adapt to the impacts of climate change. It aims to increase the resilience and reduce the vulnerability of ecosystems and people in the face of climate change. Ecosystem-based adaptation is most appropriately integrated into broader adaptation and development strategies.

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, coasts and their associated vegetation provide water storage, flood regulation and coastal defences;
- disaster risk reduction where restoration of coastal habitats such as mangroves can be a particularly cost-effective measure against storm-surges;
- sustainable agriculture where using indigenous knowledge of specific crop and livestock varieties, and conserving mosaic agricultural landscapes secures food provision in changing local climatic conditions; and
- the establishment and effective management of protected area systems that ensure both the representation and persistence of biodiversity to increasing resilience to climate change, and ensuring the continued delivery of ecosystem services.

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

Restoration of ecosystems can be a cost-effective ecosystem-based adaptation strategy. Restoration activities include limiting human activities such as grazing or logging to allow ecosystems to recover, or restoring ecological components such as connectivity or hydrological regimes, through activities such as re-flooding wetlands. For example, an alternative to constructing additional dams or reservoirs for increased flood water storage could be flood plain restoration, which would also improve riparian habitat.

Adaptation approaches that include ecosystem-based adaptation may often be cost-effective, and can provide significant social, economic and environmental co-benefits. 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 achieve adaptation benefits for many sectors through a single investment.

Ecosystem-based adaptation options are often more accessible to the rural poor than actions based on infrastructure and engineering. The poor are often the most directly dependent on ecosystem services and thus benefit from adaptation strategies that maintain 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.

Like all adaptation activities ecosystem-based adaptation is not without complexity, uncertainty, and risk. Ecosystem-based adaptation may require giving priority to particular ecosystem services at the expense of other services. For example, using wetlands for coastal protection may require emphasis on silt accumulation and stabilization possibly at the expense of wildlife values and recreation. Slope stabilisation 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. Thus, it is important that decisions to use ecosystem-based adaptation be subject to risk management procedures and cost effectiveness. In addition, the implementation of ecosystem-

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based adaption requires an adaptive management approach, which allows management adjustments in response to changes in external pressures, and uncertainty in ecosystem functioning.

In addition to adaptation benefits, ecosystem based adaptation strategies can have significant co-benefits

Ecosystem-based adaptation can generate significant social, cultural and economic co-benefits for local communities. 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).

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 ecosystems is an integral part of both adaptation and mitigation efforts. Ecosystem-based adaptation measures that conserve natural forests, for example, also provide significant climate change mitigation benefits by maintaining existing carbon stocks and sequestration capacity, and preventing future emissions from deforestation and degradation. Adaptation projects that prevent fires or restore wetlands on tropical forest peatlands will be particularly important for mitigation efforts, as these ecosystems have very high carbon stocks and release significant quantities of greenhouse gasses when degraded. Restoration of degraded forest ecosystems increases sequestration and enhances carbon stocks. Similarly, the conservation and restoration of other natural ecosystems (such as savannahs, grasslands and wetlands) can result in both adaptation and mitigation benefits.

Ecosystem-based adaptation, if designed and implemented appropriately, can also contribute to biodiversity conservation. Conserving, restoring and sustainably managing ecosystems, as part of an adaptation strategy to decrease human vulnerability to climate change, can also help conserve biodiversity by 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[82]. The creation or expansion of community conserved areas in dryland regions can not only provide additional fodder resources for pastoralists, but also conserve dryland biodiversity. 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: 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) and 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	Maintenance of water flow and prevention of land slides	Recreational and cultural opportunities	Potential generation of income through ecotourism and recreational activities	Conservation of habitat for forest plant and animal species	Conservation of carbon stocks and reduction of emissions from

					deforestation and degradation
Restoration of degraded wetlands	Maintenance of water flow and quality and protection against storm inundation	Provision of recreational and employment opportunities	Potential revenue from recreational activities	Conservation of wetland flora and fauna and maintenance of breeding grounds for migratory species	Reduced emissions from wetland draining
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 adaptation to climatic variability	Enhanced food security, diversification of food products, and conservation of local and traditional knowledge and practices	Possibility of crops in difficult environments.	Conservation of genetic plant diversity	N/A
Conservation of medicinal plants used by local and indigenous communities	Local medicines available for key diseases such as malaria, dengue resulting from habitat destruction and degradation	Local communities have a better and sustainable source of medicines Maintenance of local knowledge and traditions	Local markets, if assessed and tapped, could be a reasonable source of income for local people	Medicinal plant conservation efforts enhanced; local and traditional knowledge inputs recognized and protected.	N/A

In order to ensure ecosystem-based adaptation measures deliver significant additional social, cultural, economic and biodiversity benefits, it is important that these co-benefits be specifically considered in the planning, design, implementation, monitoring and evaluation of these measures. Adaptation measures are more likely to deliver significant co-benefits if social, economic and cultural aspects are explicitly considered in all phases of project development and implementation; if all tradeoffs 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 presented in the case studies below.

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., Climate, Community and Biodiversity Standards; CCBA) and these could potentially be adapted to guide ecosystem-based adaptation measures.

Case studies on ecosystem-based adaptation

1. Using ecosystems for coastal defence

Human-induced climate change is already causing sea level rise, and projected climate change is projected to increase it further while also increasing the frequency of extreme weather events. This, in turn, is contributing to an increase in storm surges and floods. One adaptation response is through ‘hard’ defences (sea walls, dykes and tidal barriers). 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[83]. 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[84]. The accretion of sediments also maintains shallow depths that decrease wave strength[85].

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[86]. It has been estimated, that the value of mangroves for coastal defence in Malaysia is US$ 300,000 per km based on the cost of hard engineering that would otherwise be required[87]. Nearly 12,000 hectares of mangroves planted in Vietnam at a cost of US$1.1 million, saved an estimated $7.3 million per year in dyke maintenance whilst providing protection against a typhoon that devastated neighbouring areas[88].

2. Designing resilient Marine Protected Areas

Climate Change represents a serious threat to tropical marine ecosystems of the world, 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 exposure, among fish and marine mammals, to disease and parasites.

Marine Protected Areas (MPAs) are defined as "any area of the intertidal or sub-tidal terrain, together with its overlying water and associated flora, fauna, historical, and cultural features, which has been reserved by law or other effective means to protect part or the entire enclosed environment."[89] An MPA network is a portfolio of biologically connected MPAs that is fully representative of the range of target ecosystems, species, and processes.

The Coral Triangle comprises less than 2% of the world's oceans yet it encompasses 53% of the world's coral reefs, 76% of coral species[90] and 50% of coral reef fish species. The area includes all or part of six countries in Melanesia and Southeast Asia, Papua New Guinea, Solomon Islands, Philippines, Indonesia, Malaysia (Sabah) and East Timor. Since these are all developing countries where many people live subsistence lifestyles, these reefs support livelihood of 126 million people and the protein needs of millions more.

In recent years, principles for designing and managing MPA networks that are resilient to the threat of climate change have been developed. They include:

- Spreading the risk through representation and replication
- Protecting special and unique sites
- incorporating patterns of connectivity
- Effective management

As one example[91], Kimbe Bay, located on the north coast of the island of New Britain in the Bismark Sea, Papua New Guinea is a platform site, where the aim is to establish 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)
- Develop a land use strategy, which will address the threat of runoff from poor land use practices.

3. Restoring and maintaining upland watersheds

Climate change is leading to increased inland flooding 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 the maintaining regular water supplies. Run-off from mountainous areas in small islands is often the major supply of water[92], and in countries such as the Philippines, watersheds form a critical part of the national economy[93]. Often these watersheds are degraded, and their rehabilitation is one adaptation option[94].

Watersheds can reduce flooding and sedimentation 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 bog in Sri Lanka that buffers floodwaters from rivers have an estimated annual value of more than $5 million[95]. In the Morogoro region 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[96]. Ecuador and Argentina have integrated forests and wetlands into their 'living with floods' strategies[97], and reforestation is recognised as an important option for adaptation in the watersheds of the Philippines[98]. Viet Nam includes measures such as integrated management of watersheds in its disaster reduction planning, along with forest management, and soil and water conservation[99]. 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 forest[100].

4. Flood plain restoration

Climate change is causing an increase in the scale of flooding in 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[101]. 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[102]. 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[103]. Riparian floodplains can also help to reduce the levels of water pollution following extreme events[104]. In Europe, the conservation or restoration of river floodplains has been included in a number of flood reduction strategies[105], although there are many new river management plans that do not include such measures[106].

5. Contribution of agro-biodiversity to crop diversification

Climate change increases the risk of reductions in crop yields. Within a given region, different crops are subject to different degrees of impacts from current and projected climate change[107]. In light of this, the adoption of specific crops or varieties in areas and farms where they were not previously grown are among the adaptation options available to farmers[108]. Further, the use of currently under-utilised crops can help to maintain diverse and more stable agro-ecosystems[109]. Conserving crop diversity in many cases helps maintain local knowledge concerning management and uses of the crops or varieties concerned.

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[110] and to ensure the continued survival of crop wild relatives[111]. 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.

6. Changes in agricultural practice

Changes in climate are expected to increase soil erosion, carbon loss from soil, and fluctuations in soil moisture in arable lands, causing decreased yields. Thus practices that enhance soil conservation and sustainable use and maintain favourable microclimates are important in adaptation in agriculture. These practices can include methods such as: terracing and stone bunding[112]; the use organic fertilizers, and changes to tillage practices[113]; crop rotation, contour tiling, minimum tillage and the use of vegetation buffer strips[114]; and maintaining cover through plantings or mulches[115]. 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[116]. Many of these measures reduce the need for nutrient inputs and use of heavy machinery. They also decrease vulnerability to extreme weather events.

Climate change is resulting in higher temperatures in Northeast China. As a consequence the replacement of soybean with rice, which is tolerant of a warmer climate, has become very popular in some former wetlands. Extending rice paddies can in some cases contribute to the restoration of wetland ecosystems, increase local food production, decrease the flood risk in some lowlands, and makes an overall contribution to sustainable development[117].

7. Agroforestry

Agroforestry is a promising option for increasing the resilience of rural communities to climate change. Agroforestry involves the integration of trees into food and animal production 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[118], 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[119]. They can also serve an important role in climate change mitigation by enhancing carbon stocks within the agricultural landscape[120] and, in some cases, reducing pressure on nearby forests, thereby reducing emissions from deforestation.

8. Ecological management in drylands

Drylands cover more than 40% of the global land surface and are inhabited by a significant proportion of the world's poor and marginalized people[121]. The intensity and frequency of extreme events, both droughts and floods, are predicted to increase 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 the production, diversity 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[122]. 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[123].

9. Increasing the resilience of managed forests

Evidence suggests that intact[124] forests, particularly primary forests, will be more resistant to climate change than second-growth forests and degraded forests[125]. 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 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, expansion of the protected areas network, the protection of climatic refuges, the reduction of fragmentation, and the maintenance of natural fire regimes[126].

10. Increasing the long term benefits of reforestation and afforestation

Increasing the extent of tree plantations has often been proposed as both mitigation and adaptation measures. Forest plantations for carbon storage, however, are generally established using genetically uniform stock with high growth rates, but low adaptive capacity, which will ultimately diminish their capacity in mitigation[127]. 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 Nino[128]. Increasing both genetic and species diversity in 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[129].

11. Adaptation in urban areas

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[130], 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[131].

Biodiversity can also play a role in urban planning through 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[132]. ‘Urban greening’ can improve the microclimate by modifying heat absorption[133], whereas paving over areas covered by vegetation and water reduces heat loss and increases vulnerability to flooding[134]. 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 land management to reduce threats to health

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[135]. Increasing CO_2 levels and mean temperatures are predicted to favour its development and pollen production[136], and facilitate its further range expansion[137]. 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[138]. While traditional control measures (chemicals) 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.

2.3 IMPACTS OF ADAPTATION ON BIODIVERSITY

Climate change adaptation may require tradeoffs, which should be fully considered at all stages of planning

Many strategies adopted for adaptation may have negative impacts on biodiversity while some strategies may have positive impacts. The impacts of adaptation strategies on biodiversity will vary across sectors and will depend on the way in which such strategies are implemented. In most cases there is the potential to minimize negative impacts and maximize negative effects through, for example, the application of the ecosystem approach and the adoption of strategic environmental assessments. As such, when deciding on measures to address a given climate change impact, e.g. that of drought on agriculture in a certain area, there is usually a range of available options, as illustrated by the table in Annex 3. 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.

Identifying and minimizing potential negative impacts on biodiversity is especially important for small island developing States and Least Developed Countries. Islands tend to be characterized by high endemic biodiversity, while both islands and least developed countries (LDCs) are socially and ecologically highly vulnerable to climate change. All adaptation activities identified for the other thematic areas might also be relevant for islands and LDCs but their implementation may need special considerations due to their limited size, which does not permit great retreat, and/or high reliance on biodiversity resources for livelihoods. Risks for maladaptation may be higher especially on small islands with catastrophic results (extinction). In particular, maladaptation can be defined as an activity which increases vulnerability to climate change impacts rather than reducing it. 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.

To guide adaptation decisions which maximize positive impacts and minimize negative impacts on biodiversity, the following principles are recommended:

- *The potential of ecosystem-based adaptation options as contrasted with technical solutions should be fully considered* as outlined in table 2 above.
- *Strategic Environmental Assessment and Environmental Impact Assessment should be applied* in order to include a full consideration of all available alternatives, i.e. not be restricted to different variants of the same technical option (as often happens).
- *Monitoring and adaptive management approaches 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.

Sector specific considerations would include:

<u>Agriculture</u>

The agricultural sector (including both cultivation and livestock production) will have to cope with the multiple stresses of higher temperatures, water stress, greater climate variability and extreme events, changing pest and disease prevalence and saline water intrusion into groundwater. Common responses to these projected impacts could include intensification, use of systems which require greater inputs, such as irrigation and increased fertilizers and other chemicals. However, these responses are frequently maladaptive, for example by increasing soil erosion in the face of extreme events, eutrophication of water courses or relocating to new areas.

Genetically modified (GM) technology may provide traits that aid the adaptation of crops and tree plantations to climate change. The use of GM organisms outside of containment should consider technical, legal, socio-economic and environmental aspects, including potential positive and negative impacts on biodiversity. 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[6].

In many cases, it may be possible to use ecosystem based approaches, or to mitigate effects by considering the long-term ecosystem effects of potentially maladaptive approaches. The application of agro-ecological approaches aimed at conserving soil moisture and nutrients, integrated pest management and diversification 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.

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6 Modern biotechnology, as defined in the Cartagena Protocol on Biosafety, may be exploited. However the use of this technology should apply the provisions and processes as laid down by the Cartagena Protocol (http://www.cbd.int/biosafety/).

Fresh water management

Major impacts of climate change that need to be addressed in water management include increasing flood risk and increasing risk of drought. 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, reduced services in floodplains downstream, reduced flows upstream, and changing sediment flows. Restoration of upland watersheds and floodplain restoration are ecologically viable alternatives that deserve attention.

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

There is no universally applicable measure for adapting 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 including 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 alien trees or the use of genetically modified tree stock. These latter techniques will result in novel ecosystems and may have impacts on the endemic species of the area.

The negative impacts of adaptation to climate change in forests can be reduced through an increased understanding and improved application of sustainable forest management[139][140]. Sustainable forest management (the ecosystem approach applied in forestry[141]) is the main ecosystem-based tool by which adaptation in forests to climate change should be accomplished. Keeping in mind that forest ecosystems take decades to grow, adaptation to climate change may include applying sustainable management principles based on future conditions to enable long-term resilience of forest systems. For example, reducing a projected increase in wildfires may necessitate occasional prescribed burning to eliminate accumulated fuels. At the same time, however, dead wood structures provide habitats for many species, so removals should be relative to understood threshold volumes of wood to maintain these species. At broader scales, protection of primary forests, reducing fragmentation, and increasing landscape connectivity should be important adaptations to maintain biodiversity.

The current failure to implement sustainable forest management, in many areas of the world, limits the capacity of forests and forest-dependent peoples to adapt to climate change[142]. To meet the challenges of adaptation, commitments to achieving the goals of sustainable forest management must 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.

Human settlement

Adaptation measures in human settlements will have to be implemented to address severe weather events, erosion, flooding, and increased heat. While many of these responses will require hard development, some ecosystem-based measures can be employed.

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 and by protective hard infrastructure (e.g., dams and dykes). Adaptation strategies to promote biodiversity that can be applied in the urban environment lie predominantly in creating new potential habitats (above all new water bodies, dry and wet polders) as refugia for native plants and animals.

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. Special adaptation measures to reduce stresses in settlements are required, for example, by enlarging the flood retention capacity (polders) and sustainable drainage and through the construction of small water bodies.

Marine and coastal

Like other sectors, marine and coastal areas are already adversely impacted by many stresses, which will be exacerbated by additional climatic change impacts (e.g., sea level rise). Coastal ecosystems ranging from polar regions to Small Island Developing States are essential to, and can enhance, our capacity to respond to projected climate change impacts. Societal efforts to adapt therefore requires a holistic approach, which should consider the need to reduce all sources of stresses (human and climatic) on the coastal region without adversely impacting on coastal biodiversity

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).

However, societal efforts to adapt require a holistic approach, which should consider the need to reduce all sources of impacts (human & climatic). Approaches to adaptation should also include measures that address needs for coastal area protection while limiting adverse impacts on coastal biodiversity. Ecosystem-based approaches to adapting to climate change offer huge potential for co-benefits in the context of building climate resilient coastal communities. Approaches to adaptation should include measures that address needs for coastal protection, while limiting adverse impacts on coastal biodiversity. Ecosystem-based approaches to adapting to climate change offer huge potential for co-benefits by meeting coastal protection objectives, securing climate resilience coastal communities, while ensuring provision of coastal ecosystem services However, this approach is often not considered in favour of engineering approaches which can be site specific in meeting the objective of coastal defense yet more extensive in disrupting ecological services.

SECTION 3

BIODIVERSITY AND CLIMATE CHANGE MITIGATION

Maintaining natural and restoring degraded ecosystems, and limiting human-induced climate change, represent multiple benefits for both the UNFCCC and CBD if mechanisms to do so are designed and managed appropriately

Well-functioning ecosystems are necessary to meet the objective of the UNFCCC owing to 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. An estimated 2,400 Gt C is stored in terrestrial ecosystems, compared to approximately 750Gt in the atmosphere[143]. Furthermore, in reference to Article 2, 7/ well-functioning ecosystems have greater resistance to climate change which will reduce the vulnerability of may carbon stocks.

Maintaining and restoring ecosystems represents an opportunity for win-win benefits for carbon sequestration and storage, and biodiversity conservation and sustainable use. Co-benefits are most likely to be achieved in situations where integrated and holistic approaches to biodiversity loss and climate change are implemented. Many activities that are undertaken with the primary aim of meeting the objectives of the CBD have significant potential to contribute to the mitigation of climate change. Likewise, many activities that are undertaken or being considered with the primary purpose of mitigating climate change could have significant impacts on biodiversity. In some cases these impacts are negative, and there are trade-offs to be considered. An overview of the relevance of different mitigation options is presented in Annex 4. A list of possible win-win activities for the implementation of the UNFCCC and the CBD is provided in Annex 5.

While protected areas are primarily designated for the purpose of biodiversity conservation, they have significant additional value in storing and sequestering carbon. There are now more than 100,000 protected sites worldwide covering about 12 per cent of the Earth's land surface[144]. A total of 312Gt carbon or 15.2 per cent of the global carbon stock is currently under some degree of protection[145] (see Table 3). The designation and effective management of new protected areas, 8/ and strengthening the management of the current protected area network, could contribute significantly to climate change mitigation efforts.

Table 3: Global terrestrial carbon storage in protected areas

Protected area category	% land cover protected	Total carbon stored (Gt)	% terrestrial carbon stock in protected Areas
IUCN category I-II	3.8	87	4.2
IUCN category I-IV	5.7	139	6.8
IUCN category I-VI	9.7	233	11
All PAs	**12.2**	**312**	**15.2**

7/ Article 2 of the UNFCCC: "The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of the Convention, stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner."

8/ The Programme of Work on Protected Areas of the CBD (decision VII/28) 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."

The ecosystem approach 9/ is a key tool for maximizing the synergies between implementation of the UNFCCC and the CBD. The ecosystem approach is a strategy for the integrated management of land, water and living resources that promotes the conservation and sustainable use of biodiversity in a fair and equitable manner. It can, therefore, be applied to all ecosystems in order to deliver multiple benefits for carbon sequestration and biodiversity conservation and sustainable use.

LULUCF activities, including reduced deforestation and degradation can, in concert with stringent reductions in fossil fuel emissions of greenhouse gases, limit climate change.

Given that forests contain almost half of all terrestrial carbon[146], preliminary studies show that continued deforestation at current rates would significant hamper mitigation efforts. In fact, if all tropical forests were completely deforested over the next 100 years, it would add about 400GtC to the atmosphere, and increase the atmospheric concentration of carbon dioxide by about 100ppm, contributing to an increase in global mean surface temperatures of about 0.6 ^{0}C[147].

The potential to reduce emissions and increase sequestration from LULUCF activities will be influenced by if and how ecosystems, especially forests, are valued by emissions trading schemes. The price of carbon is estimated to range from 1.3-4.2 $GtCO_2$-eq per year for forestry activities[148], and 2.3-6.4 $GtCO_2$-eq per year for agricultural activities for a price of US$ 100/tCO_2-eq by 2030[149].

Balancing mitigation with natural adaptation of ecosystems would benefit from the consideration of a wide range of different forest types. Intact primary forests contain the greatest carbon stocks as well as harbouring the highest biodiversity and have the highest resilience to climate change.[150]. Modified natural forests (i.e. those that have been logged or degraded through other land use activities) have lower carbon stocks[151], less biodiversity and less resilience than primary forests[152]. Plantation forests may store and sequester considerable amounts of carbon but are not as beneficial for biodiversity conservation as natural forests. Among plantations types, those which comprise diverse mixtures of native species have potential for maintaining more biodiversity than those comprising monocultures or exotic species. In order to maximize the contribution of existing mitigation policies to both climate change mitigation and biodiversity conservation and sustainable use, such differences between forest types should be taken into account as outlined in Table 4 below.

Table 4: Different carbon 10/ and biodiversity benefits of main forest types

Forest type11/	Biomass Carbon stock12/	Carbon sequestration potential	Biodiversity	Value of ecosystem services
Primary forest	+++	++(+)	+++	+++
Modified natural forest	++	++	++	++
Plantations (indigenous species)	+	+++ (depending on species used and management)	+(+)	+
Plantations (exotic	+	+++ (depending on	+	(+)

9/ The main principles of the ecosystem approach focus on capacity building; participation; information gathering and dissemination; research; comprehensive monitoring and evaluation; and governance. Advantages of the ecosystem approach include: stakeholder participation; consideration of both scientific and technical and traditional knowledge; and the achievement of balanced ecological, economic and social costs and benefits. A review of the application of the ecosystem approach conducted by the CBD revealed many opportunities to strengthen ongoing efforts including: developing standards for application; adopting simplified and improved marketing approaches; and capacity building at all levels.

10/ Referring to total ecosystem carbon.

11/ Forest definitions are a simplified version of FAO classification.

12/ 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.

species)		species used and management)		

Different forest landscapes require different LULUCF mitigation approaches. Three forest landscape contexts can be broadly identified: 1) largely intact forested landscapes; 2) landscapes where forests have already been largely cleared and degraded; and (3) forested landscapes subject to ongoing clearing and degradation. In general terms, mitigation in category (1) landscapes can be best achieved through avoiding emissions by protecting existing carbon stocks; in category (2) by growing new carbon stocks; and in category (3) by reducing emissions from deforestation, degradation and land-use change. Each type of LULUCF activity varies in its potential benefits and risks to biodiversity conservation (see Annex 4) although each activity can also be designed and implemented in ways that enhance the potential benefits to biodiversity and reduce potential negative impacts.

Reducing deforestation and forest degradation has the potential to contribute considerably to the objective of allowing ecosystems to adapt naturally to climate change. In order to enhance the contribution of reduced deforestation and forest degradation 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.[153]

The conservation of existing primary forests where there is currently little deforestation or degradation occurring, is critical both for protecting carbon stocks and preventing future greenhouse emissions, as well as for conserving biodiversity

Significant emissions can be avoided through initiatives that lead to conservation 13/ in largely intact forested landscapes. Most of the biomass carbon in a primary forest is stored in older trees or the soil[154]. Land-use activities that involve clearing and logging reduce the standing stock of living biomass carbon, cause collateral damage to soil and dead biomass carbon, and have also been shown to reduce biodiversity and thus ecosystem resilience[155]. This creates a carbon debt which takes decades to centuries to recover, depending on initial conditions and the intensity of land use[156]. Avoiding future emissions from existing carbon stocks in tropical and some temperate natural forests, especially primary tropical forests, can be achieved through a range of means including (a) designating protected areas, (b) conservation agreements, easements and concessions (c) establishing biological corridors that promote conservation in a coordinated way at large scales across land tenures, (d) establishing payments for ecosystem services including carbon sequestration and storage, (e) special financial incentives to compensate land owners, stewards and Indigenous peoples on their traditional lands, for opportunity costs associated with forgoing certain kinds of development, and (f) promoting forms of economic development that are compatible with the conservation and sustainable use of biodiversity.

In natural forest landscapes that have already been largely cleared and degraded, mitigation and biodiversity conservation can be enhanced by growing new carbon stocks which, through the use of mixed native species, can yield multiple benefits for biodiversity

Reforestation can make a significant contribution to enhancing forest carbon stocks and biodiversity within landscapes that have been largely deforested and degraded[157]. Reforestation can involve the restoration of a permanent, semi-natural forest rather than a plantation forest, make use of remnant natural forests or use an appropriate mix of native species[158]. Reforestation activities on long converted land can also supply sustainable wood products thereby relieving the pressure to extract them from more mature natural forests.

13/ "Conservation" is considered in terms of avoiding emissions from extant natural forest carbon stocks by preventing the introduction of land use activities that would cause emissions.

Afforestation14 can have positive or negative effects on biodiversity conservation, depending on the design and management. Afforestation that converts non-forested landscapes with high biodiversity values (e.g. heathlands, native grasslands, savannas) and/or valuable ecosystem services (e.g. wetlands), increase threats to endemic biodiversity through *inter alia* habitat loss, fragmentation and the introduction of alien invasive species. Afforestation activities can help to conserve biodiversity, if they: convert only degraded land or ecosystems largely composed of exotic species; include native tree species; consist of diverse, multi-strata plantations; have minimal disturbance, and are strategically located within the landscape to enhance connectivity. [159]

In forest landscapes subject to ongoing clearing and degradation, mitigation and biodiversity conservation can be best achieved by reducing deforestation and forest degradation through the sustainable management of forests and through forest restoration

In landscapes currently subject to unsustainable land use activities, sustainable forest management (SFM) can make an important contribution to reducing emissions and enhancing carbon stocks. 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 covers and soils. The application of internationally accepted principles of sustainable forest management that have been established can maximize the realization of multiple benefits outside of largely intact primary forest landscapes. Relative to conventional commercial logging, SFM can also improve biodiversity conservation in a forest, and better deliver other related ecosystem services. Given that many landscapes contain a mix of categories of use a combination of conservation (on largely intact forested land) and SFM (on land subject to deforestation and degradation) will be needed to maximise mitigation efforts.

Implementing REDD 15**/ activities in areas of high carbon stocks and high biodiversity can promote co-benefits for climate change mitigation and biodiversity conservation and sustainable use.** Several tools and methodologies to support biodiversity benefits are available or under development. The national gap analyses carried out by Parties under the Programme of Work on Protected Areas of the CBD can be a valuable tool for identifying areas for the implementation of REDD schemes, in particular regarding the identification of priority forest areas for REDD activities at national level.

The specific design of potential REDD mechanisms can have important impacts on biodiversity

In order to avoid conflict between the implementation of the CBD and the UNFCCC, biodiversity considerations could be taken into account in the development of the REDD methodology. Standards, indicative guidelines and criteria taking into account biodiversity conservation could be developed[160].

REDD methodologies based only on assessments of deforestation rates could have significant and often negative impacts on biodiversity conservation. In particular the question of whether gross deforestation or net deforestation 16/ is considered is important in this context. The use of net rates could hide 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.

Addressing forest degradation is important because degradation results in biodiversity loss, decreased forest resilience to disturbances, and often leads to deforestation[161]. Monitoring to

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14 Afforestation here means the conversion of land that has not had forest cover for a very long time, if ever.

15/ It is intended to use terms and definitions in this document consistently with UNFCCC decisions 2/CP.13 (REDD) and 1/CP.13 (Bali Action Plan). Suggestions are made without any attempt to pre-empt ongoing or forthcoming negotiations.

16/ 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.

detect the severity and extent of forest degradation is therefore a key issue which needs further development.

Both intra-national and inter-national displacement of emissions under REDD can have important consequences not only for carbon, but also for biodiversity. While it often matters little where deforestation or degradation occurs from a carbon perspective, defining REDD eligible areas without considering biodiversity could displace deforestation to higher biodiversity valued forests.

While it is generally recognized that REDD holds potential benefits for forest-dwelling indigenous and local communities, a number of conditions would need to be met for these benefits to be achieved

The implementation of the UN Declaration on the Rights of Indigenous Peoples is key to delivering benefits from REDD for Indigenous Peoples. While it is generally recognized that REDD holds potential benefits for the livelihoods of forest-dwelling indigenous and local communities (ILCs), a number of conditions would need to be met for these co-benefits to be achieved. Indigenous peoples are unlikely to benefit from REDD where they do not own their lands; if there is no principle of free, prior and informed consent concerning the use of their lands and resources; and if their identities are not recognised or they have no space to participate in policy making processes as outlined in Table 5 below.

There is a need for capacity building on indigenous issues and rights, both on the side of governments, as well as Indigenous people and local communities. This needs to include education and awareness raising. Indigenous to Indigenous transfer of knowledge and capacity building.

Table 5: Overview of key challenges and opportunities for indigenous and local communities

Issue	Biodiversity implications	Climate Change implications
Recognition of rights	Land tenure gives ILCs opportunities to manage and protect biodiversity on which they rely for their livelihoods and culture.	Security of land tenure avoids deforestation.
Governance and Equity	Free, prior and informed consent is key 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, poor forest management and avoids perverse incentives.	Mitigation strategies presently do not 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.
Policy	Policies 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 traditional knowledge can contribute to the global and national debate on the conservation and sustainable use of forest biodiversity.	Policies developed with the effective participation of ILCs are more likely to be supported by them. ILCs concept of land and forest management based on traditional knowledge can contribute to the global and national debate on REDD
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.

Other issues	Concessions for forestry and extractive industries may be avoided. Opportunity to refocus attention and policies on forest conservation gain support for land tenure and land titling processes. Law and policies and their implementation may be improved.

The implementation of a range of appropriately designed land-management activities can result in the complementary objectives of the maintenance and potential increase of current carbon stocks and the conservation and sustainable use of biodiversity

Sustainable land management activities, including the restoration of degraded lands can yield multiple benefits for carbon, biodiversity and livelihoods. Restoring degraded land and implementing activities to maintain existing productivity can be cost-effective mitigation options with potential to offset 5 to 15 per cent of the global fossil-fuel emissions per year[162]. In particular, restoration of degraded cropland soils may increase crop yield, while contributing to the conservation of agricultural biodiversity, including soil biodiversity. Key examples of activities that can deliver multiple benefits include conservation tillage and other means of sustainable cropland management, sustainable livestock management, agroforestry systems, restoration of peatlands and other wetlands, and maintenance of natural water sources and their flows (see annex 2 for further information). It should be noted that all of these activities integrated to some extent within the decisions of the Convention on Biological Diversity.

Climate mitigation policies are needed to promote the conservation and enhanced sequestration of soil carbon, including in peatlands and wetlands, which is also beneficial for biodiversity

Carbon stored in soil accounts for a high percentage of the carbon stored in terrestrial ecosystems. In fact, global soil organic carbon has a sequestration potential 0.6-1.2 GtC/yr[163]. Recent studies have suggested that there are almost 100 GtC stored in North American Arctic soils alone[164]. Furthermore, a recent global assessment of peat has estimated that peatlands store 550Gt of carbon[165]. However, this could be an underestimate as peat depth estimates are still uncertain. Furthermore, ecosystems have the potential to store significantly more carbon than they currently do, as many of their carbon stocks are depleted below their natural carbon carrying capacity due to land use history, especially in temperate zones

Climate mitigation efforts that promote the conservation and enhanced sequestration of soil carbon may be also beneficial for biodiversity. The loss of soil carbon is largely due to land conversion, changes in land use, and a warming climate. Conversion of native ecosystems, such as forests or grasslands, to agricultural systems almost always results in a loss of soil carbon stocks, as cultivated soils generally contain 50-75% less carbon than those in natural ecosystems, and native vegetation provides a greater source of organic carbon into soil forming processes. Furthermore, human disturbances such as drainage for agriculture or forestry have transformed many peatlands from being a sink of carbon to a source in large areas. It is also important to consider the impacts of other LULUCF activities on soil carbon. For example, afforestation can have both negative and positive impacts on soil carbon stores, depending on disturbance regime.

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

Renewable energy sources, including onshore and offshore wind, solar, tidal, wave, geothermal, biomass and hydropower and nuclear, can displace fossil fuel energy, thus reducing greenhouse gas emissions, with a range of potential implications for biodiversity and ecosystem services. The impacts on biodiversity and ecosystem services of solar, tidal, geothermal, wave and nuclear energy are dependent on site selection and management practices.

While bioenergy may contribute to energy security, rural development and avoiding climate change, there are concerns that, depending on the feedstock used and production schemes, many first generation biofuels (i.e., use of food crops for liquid fuels, i.e., bio-ethanol or bio-diesel) are contributing to rising food prices, accelerating deforestation with adverse effects on biodiversity, and may not be reducing greenhouse gas emissions. Biofuel production can have considerable adverse consequences on biodiversity (genetic, species and landscape levels) and ecosystem services when it results in direct conversion of natural ecosystems or the indirect displacement of agricultural land into natural ecosystems[166]. However, biofuels can contribute to greenhouse gas savings and avoid adverse impacts on biodiversity, soils and water resources by avoiding land-use changes, in particular on land designated as of high conservation and sustainable use value. Advanced generation technologies will only have significant potential to reduce greenhouse gas emissions without adversely affecting biodiversity if feedstock production avoids, directly and indirectly, loss of natural ecosystems, or uses native grasses and trees on degraded lands. Evaluation of the environmental and social sustainability of different sources of biofuels could be achieved through the development and implementation of robust, comprehensive and certifiable standards. 17/

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 often have adverse biodiversity and social effects[167]. Dam and reservoir design is critical to limiting: (i) the emissions of carbon dioxide and methane from decomposition 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, dependent 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 and small dams typically have fewer adverse environmental and social effects. Sectoral environmental assessments can assist in designing systems with minimum adverse consequences for ecological systems.

Artificial ocean fertilization has been promoted and exposed to early testing as a technique to increase the uptake of atmospheric carbon dioxide, but it is increasingly thought to be of limited potential[168] and may have adverse environmental consequences. 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[169]/[170].

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.

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[171]. 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.

In addition to direct impacts of mitigation activities (LULUCF, renewable energy technologies and geo-engineering) on biodiversity there may be significant indirect impacts which require

17/ The expert from Brazil disassociated himself from this section.

further research. There is also potential for new mitigation technologies to be developed with either positive, neutral or negative impacts on biodiversity.

SECTION 4

VALUATION AND INCENTIVE MEASURES

4.1 VALUING BIODIVERSITY AND ECOSYSTEM SERVICES

The valuation of ecosystem services should be seen within the broader context of an ecosystem approach to adapting to climate change. This section[18] describes methodologies 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 values of ecosystem services generated by biodiversity that benefit humans rather than biodiversity as such.

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, 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 and society, in turn, is suffering the consequences.

Valuation techniques are important to ensure that the true value of ecosystems and their services provided are taken into account when estimating the impact of human-induced climate change on ecosystems. Informed decisions should evaluate the implications of any decision on all ecosystem services and estimate the value of changes in the services that result.

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.

Given that the application of many valuation techniques is costly and time-consuming, and require considerable expertise, a cost/benefit criterion should be applied, as appropriate, to the valuation study itself: in principle, they should be applied when the anticipated incremental

[18] This text of this section is largely based on language used in the Defra report, An Introductory Guide to Valuing Ecosystem Services; and the approaches and philospophy promoted by the Millennium Ecosystem Assessment (MA), The Economics of Ecosystems of Biodiversity (TEEB), the CBD Technical Series 29; and decisions VI/15 and VIII/25 of CBD COP.

(including long-term) improvements in the decision are commensurate with the cost of undertaking the valuation study.

Economic techniques for valuing ecosystem services are typically applied a within cost-benefit analysis or a cost-effectiveness analysis, whose results would otherwise be incomplete whenever relevant external costs and/or benefits are present. Cost-benefit analysis 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 action, where-as cost effectiveness analysis assesses the costs of different actions to achieve a particular outcome, e.g., to protect a particular coastal region. These economic analyses should in turn be applied within broader decision-making frameworks which go beyond mere economic logic, such as environmental impact assessments (EIA), strategic environment assessments (SEA), life-cycle analysis (LCA), risk assessment, and multi-criteria analysis.

Accounting for the value of biodiversity and the ecosystem it supports, is important for the decision making process, and for the provision of appropriate incentives for societal adaptation to climate change. One issue that has engendered endless debate is the choice of discount rate. 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[19].

There are many methodologies available for estimating the economic valuation 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 Annex 6. The appropriateness of various methodologies is determined by 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 reflected in people's willingness to pay for changes in their level of use of a particular service or bundle of services.

Regardless of the methodology employed, the interim report of TEEB outlined nine key principles of best practices for ecosystem valuation including:

- 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 and may not be the last word.

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19 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.

Therefore the key steps in estimating the impact of different climate change adaptation or mitigation decisions are:

- Establish the ecosystem baseline;
- 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: 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

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 what ecosystem services are affected, 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.

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 working with the science and economics disciplines will be essential in implementing this approach in practice. The critical importance of the links to scientific analysis, which form the basis for valuing ecosystem services, needs to be recognised.

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 6 below. Benefits transfer, which applies economic values that have been generated in one context to another context for which values are required, is also discussed. This approach, when used cautiously, have the potential to alleviate the problem of deficient primary data sets as well as of limited funds and time often encountered in valuation, and are of particular interest in cases where the potential savings in time and costs outweigh a certain loss of accuracy (e.g., rapid assessments).

The valuation methodologies discussed are not new in themselves. The challenge is in their appropriate application to ecosystem services. The ecosystem services framework emphasises 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 if we are to arrive at any meaningful values.

Table 6: Valuation methods for different ecosystem services[172]

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	Market data readily available and robust	Limited to those ecosystem services for which a market exists
Cost-based	Direct and	Depends on the	Market data	Can potentially

approaches	indirect use	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.	readily available and robust	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

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 very much in development.

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).

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[20]:

- 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 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 CONSERVATION AND SUSTAINABLE USE AND CLIMATE CHANGE ADAPTATION

A: The economic value of protection from natural disasters

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, USA; or (ii) the protection and restoration of “green infrastructure” such as healthy coastal wetlands (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 Vietnam began planting mangroves in 1994. By 2002, 12,000 hectares had cost US$ 1.1 million, but saved annual levee maintenance costs of US$ 7.3million, shielded inland areas from typhoon Wukong in 2000, and restored livelihoods in planting and harvesting shellfish.
- 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.
- In the Maldives, the degradation of protective coral reefs around Malé required construction of artificial breakwaters at a cost of US$ 10 million per kilometer.

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20 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.

B. The economic value of biodiversity-based livelihoods

The World Bank's Strategic Framework for Development and Climate Change

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's 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 weather 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.

Additional examples include:

- In Kimbe Bay, Papua New Guinea, coral reef resilience principles were applied to design a network of marine protected areas that can withstand the impacts of a warming ocean and continue to provide food and other marine resources to local communities. This approach is already being implemented at several more sites in Indonesia and for the Meso-American reef.
- 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 interventions to protect plant, animal and marine biodiversity in order to help alleviate some of this projected lost income.

C. The economic value of ecosystem services provided by forestry

The value of forests in Britain

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.

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, stabilise riverbanks and reduce pollution in run-off.

D. The economic value of protected areas

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

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 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
This analysis is partial and does not use the TEV but focuses on the value of tourism, commercial fishing and recreational activities, net of tourism. The values are Aus$5107 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

Changes in the broader set of economic incentives governing human behaviour and decision-making, as well as non-financial incentives, are essential to implement ecosystem-based adaptation activities to climate change that can benefit biodiversity and ecosystem services and human well-being. Incentives for ecosystem-based adaptation should be carefully designed not to negatively affect ecosystem services and the conservation of biological diversity, including in other countries.

- Measures changing to the economic incentives to decision-making 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 those subsidies to agriculture, 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 appropriate pricing policies for natural resources, e.g., for fresh water; (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.
- Non-financial incentives and activities seeking to influence individual bwhavior: (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 environment-friendly technologies.

Financial incentives, such as the payment for ecosystem services and environmental funds, 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 their role as mitigation against climate change[173]. 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[174] services will ensure communities are better able to maintain a balance between ecosystem and their use of the resources. The World Bank together with other multilateral financial institutions and conservation NGOs provide a plethora of financial funds.

Internalizing the value of biodiversity and ecosystem services, other than carbon, in climate change-related activities can provide a strong economic incentive for conserving biodiversity. A range of financial instruments are available and can be effective in a specific manner in accordance with ecosystem type, project scale and projected period (see Table below)

Criteria and indicators which are specific, measurable, appropriately monitored, and adapted to local conditions, need to be developed to assure that the ecosystem services targeted by the incentive measures are not degraded 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 for the long-term benefits of UNFCCC and CBD. 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 thus help in achieving the objectives of UNFCCC and CBD.

Non-financial mechanisms can become indirect incentives to achieve multiple benefits of adaptations and can 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.

While there are a wide range of incentives available, choosing one or combination of those incentive measure one need to consider several factors of conditions and scales (see Table 7 below). Examples include: 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 on 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 7: Tools and incentives for implementing ecosystem-based adaptation.

Tools and incentives	Application to ecosystem-based adaptation
Financial	
• 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 Mechanism, 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)
• Certification and Labeling	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.
• 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[175]	Creation of new markets and expansion of existing markets for products and services that are environmentally friendly.
• Agri – Environmental programme	Subsidies to organic farming, preservation of rare breed, eg; land set aside schemes, stewardship payments, rural credit /loans
Environmental Prize/Award	Public recognition for good environmental stewardship.
• Eliminate Perverse Subsidies (eg; Fishing; Agriculture)	Eliminate subsidies that destroy, degrade or lead to the unsustainable use of ecosystems. 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
• Development, transfer, diffusion and	Develop soft and hard technologies and

deployment of environmentally sound technology	methodologies that could help in the implementation of ecosystem-based adaptation (e.g., software development, early warning systems, artificial reefs)

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Annex 2

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

1. *Gondwana Link*, Australia

Principle: 2b

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)

Principle 2b

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 multi-sector 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

Principle 2b

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)

Principles 1a, 1b

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

Principle 2a

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 Vietnam

Principle 2c

Objectives: Restore coastal mangrove forests along the coasts of Vietnam 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 Vietnam 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 Vietnam 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 Vietnam – The long and hard journey back to harmony. Commemorative lecture at Kyoto University, November 2nd, 2008

7. Restoring floodplains along the Danube River, in Eastern Europe

Principle 2c

Objective: Restore 2,236 km2 of floodplain to form a 9,000 km2 "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, Romania, Moldova 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:10.1088/1755-1307/6/0/402002[176]

Annex 3
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 to 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 all types (A). Where the forest adaptations apply primarily to a given forest biome it is specified under the action column. Ecosystem-based adaptations are noted with an *.

Issue	Adaptation action	Positive effects on biodiversity	Maximise positive effects	Negative effects on biodiversity	Minimise negative effects	Comments and case studies
Agriculture and Drylands						
Cumulative effects of reduced moisture, increased temperature, increased pests, salinity and extreme events	Shift to more heat, pest, drought, flood and salt tolerant varieties or species of crops and livestock	Possible diversification; Possible changing management regimes; People encouraged to value local biodiversity	Use rare or local species; Support (from NGOs, agricultural extension workers…); Community involvement and building on traditional knowledge and management techniques	Local varieties or species replaced	Cautious use of GMOs and potentially invasive species	Potentially low-cost if suitable varieties available; High cost if breeding necessary; Relevance of traditional knowledge; Maladaptation risk unless all properties of the species are considered; especially in mountain, grassland, temperate grasslands, and SIDS
	Seed banks	Conserves genetic diversity; Reduced	Support (from NGOs, agricultural			

	need to bring in non-native varieties when extreme events cause losses	extension workers…); Community involvement and 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 and windbreaks, bund construction) and 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 and 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 benefits and long-term benefits	Potentially low-cost; Builds social capital and supports traditional knowledge ; Potential for co-benefits e.g. reduction of erosion, reduction of eutrophication problems, C-sequestration
*Diversification: multi-cropping or mixed farming systems (e.g. agroforestry systems) to enhance ecosystem resilience to extreme events	Increasing structural and species diversity; Use of native species	Use rare or local species; Support (from NGOs, agricultural extension workers…); Community involvement and building on traditional knowledge and management	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 area requirements for

		techniques			agriculture, increasing water efficiency
*Restoration of degraded ecosystems, e.g. revegetation, reforestation, slope stabilization	Reduced degradation		Possible non-native species introduction; potential invasives or GMOs	Use endemics, limit GMO use and only after testing and controlled outplanting	Co-benefits of increasing vegetation cover e.g. reduced erosion and C-sequestration; Comparatively high cost; Long timeframe; High technical inputs required
Rainwater harvesting, storing and management, e.g. contour trenches and rain-fed drip irrigation	Less water required from other sources	Support (from NGOs, agricultural extension workers…)			Low cost and 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		
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; Maladaptation risk if traditional management regimes disrupted or alternative unsustainable livelihood options adopted
Supplementing		Support adequate	Increasing pressure		Maladaptation

livelihoods by increased harvesting of plants or animals from the wild		management system to allow for regeneration	on wild species		risk by reducing potential for other ecosystem services, especially in moumntains
Flood protection for cultivated areas and livestock	Reduced land degradation				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
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		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 and 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
SLR Food Security	Relocation/manmade crop sites e.g. concrete elevated taro patch	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	Saving otherwise lost species	Improve irrigation	Loss of habitats at new sites,	Diversify food crops	Drought resistance island crops to be identified/researc h
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 capacity of poor communities to meet infrastructure costs / 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
Land use management in watersheds to maintain or enhance water retention, e.g. by maintaining /increasing forest coverage, conserving peatlands or adapting agricultural practices to improve soil water capacity	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 Avoid afforestation 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 wetland, river, floodplain or lake habitats	Choose design with low biodiversity impact (e.g. lateral reservoirs rather than dams across rivers)	
	Desalination	May decrease pressure on freshwater resources, and hypersalinity of coastal areas			Pre-treat effluent or dispose in deeper water	Very resource-intensive, conflict with climate change mitigation
	Demand-side management, e.g. reducing losses in transfer or 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	Reducing need for upkeep of				High investment cost to individual

	aquatic transport, e.g. changing boat design	infrastructure				users
	Limit land use change to conserve soil	Maintain forest ecosystems				
Drought surface water	Increase extraction potable water	May provide for other ecosystems	Efficient water use	Downstream ecosystems affected	Limit extraction rate	Assess alternative sources
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	Protect otherwise affected biodiversity sites when eroded	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 including assisted migration	Create habitats	Applicable in certain sites / regions	Changes to coastal currents, sea-bottom habitats, coastal biological communities, pollution; novel communities	migrate endemic species where possible	Scale, size and design, Relatively cost-effective Potential of co-benefits with fisheries (see below)
Reduced resilience of polar systems	Reduce tourism	Protect species from excessive energy				

		expenditures, reduce disruptions to normal behaviour				
Forestry						
Over-arching management policies to reduce impacts of CC	*Increase adaptive management systems (A)	Increased 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	Carefully model, 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	Regional scale
	*Incorporate traditional knowledge about CC into forest planning to improve	Increase resilience and resistance	Foster learning and interaction at the local community level			National impact

	and inform management systems (A)					
	*Increase use/area of protected areas to maintain gene stocks, and as C sinks (N)	Maintain genes, species and migration corridors, protection of vulnerable ecosystems	Select locations wisely to maximize C sequestration potential in time, develop synergies with other landscape planning; local community involvement			National/international impact: eg, of vulnerable systems: tropical, boreal, mountain
	Maintain gene banks (N)	Maintain genes, 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 and food webs; water pollution	Use biological insecticides; selected areas; avoid over-spray	Possibility of effects on multiple kinds of systems
	Introduction of pest-resistant varieties or species; promotion of pest-resistant 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
	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
2B. tropical	*Reduce fragmentation	Increase forest area and habitats	Proper landscape planning			National scale, regional implementation
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 spp. 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	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	Maintain increased forest cover/habitat	Apply SFM techniques			Local effects

	(S,P)					
	Introduce species/ provenances/genomes resistant to water stress (S,P)	Increase resilience	Use native sp. where possible	replacement of native species; Use of non-native species that 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			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 fertilisation/ 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 spp. where possible or replace non-native spp. once system is stable			Local and regional effects
	N fertilization (P)	Improve forest health	Understand C/N ratios	Overfertilisation acidification	Understand C/N ratios	Local effects
	Improve forest C	Improve dead wood	Understand			Local effects

	management (S,P)	and soil habitats	biodiversity relationships and thresholds		
	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
	Under-plant with legumes (S,P)	Enhanced soil processes increase soil C	Use endemic species; use traditional knowledge to select species		Local effects
	Payment for environmental services (N)	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
	Encourage adoption SFM techniques (A)	Improved forest resilience, improved use of NTFPs			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					

CC (temp, SLR, extreme events) Coastal Fisheries	Creation/enhancing effective MPAs	Preserve ecosystems, protect coastal processes, improve water quality etc	Provide Alternative protein and income generating sources		Effective management, use local knowledge, locally owned,	MPAs connectivity
CC 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 for eliminate breeding sites of vector borne diseases like mosquitoes			Management of wetland breeding sites. Transform ecosystems/ introduced alien species	Introduce endemic fish into wetlands to control larvae.	
	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			Bio-larvicide did not eliminate non-targeted organisms. Not 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 settlement Extreme events (e.g mudslides, hurricanes, flash floods)						
Over-arching management policies to reduce impacts of CC	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
	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	Design and where is place the new location	Shift some pressures from one habitat/ecosystem to another	Can be expensive. High potential for land use conflicts	Scale, characteristics of habitats/ ecosystems concerned

Annex 4

RELEVANCE OF DIFFERENT MITIGATION OPTIONS TO DIFFERENT LANDSCAPE CONTEXTS

Mitigation options	**Landscapes where active deforestation and degradation are occurring**	**Landscapes where there is minimal or no deforestation and degradation**	**Landscapes which have largely been deforested**
Reducing deforestation and degradation	*X*	*(not applicable, since no deforestation ongoing)*	*(not applicable, since no forest is left)*
Forest Conservation	*X (of forests that have not yet been deforested)*	*X*	*(not applicable, since no forest is left)*
Sustainable forest management	*X (on degraded forest land)*	*(not applicable, since no forest management ongoing)*	*(potentially applicable to remnant forest patches in landscape)*
Afforestation, reforestation and forest restoration	*X (on already-deforested land)*	*(not applicable since minimal deforested land available for planting)*	*X*
Implementation of sustainable cropland management	*X (on deforested land)*	*(not applicable since minimal deforested land available)*	*X*
Implementation of sustainable livestock management practices	*X (on deforested land)*	*(not applicable since minimal deforested land available)*	*X*
Implementation of Agroforestry systems	*X (on deforested land)*	*(not applicable since minimal deforested land available)*	*X*
Conservation and restoration of peatlands and wetlands	*X*	*X*	*X*
Biofuels	*X (on deforested land)*	*(not applicable since little deforested land available)*	*X (on deforested land)*
Mangrove restoration	*X*	*X*	*X*
Renewable energy (solar, hydro, wind, etc.)	*X*	*X*	*X*

Note: renewable energy mitigation options are possible, regardless of the landscape context.

Annex 5

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 maximize benefits or reduce negative impacts on biodiversity***
Reducing emissions from deforestation and forest degradation	Reduced forest loss and reduced forest degradation21 Reduced fragmentation Maintenance of diverse gene pools and robust species populations	Leakage into areas of high biodiversity	Develop premiums within incentive measures for biodiversity co-benefits At national level, prioritizing REDD actions in areas of high biodiversity Improving forest governance Promote 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 processes and functions Enhanced integrity of the landscape and enhanced resilience of ecosystems to climate change		Prioritize conservation of forests with high biodiversity Conserve large areas of intact forest Maintain landscape connectivity Conserve a diversity of forest types, covering different microclimatic conditions and including altitudinal gradients Avoid unsustainable hunting

21/ 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 maximize benefits or reduce negative impacts on biodiversity*
Sustainable Management of Forests	Reduced degradation of forest (relative to conventional logging)	Use encroachment in intact forest, resulting in biodiversity loss	Prioritize sustainable management in areas that are of lower biodiversity value and already slated for management Minimize use in intact forests of high biodiversity value Apply best-practice guidelines for sustainable forest management including reduced impact logging
Afforestation and Reforestation (A/R)	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. Implement afforestation/reforestation on degraded lands (not intact forests) 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 services during decision making regarding land-use change (e.g. water cycling, flood protection, etc.) Develop premiums within incentive measures for biodiversity co-benefits

Mitigation activity	*Potential benefits for biodiversity*	*Potential risks to biodiversity*	*Possible actions to maximize benefits or reduce negative impacts on biodiversity*
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
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	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

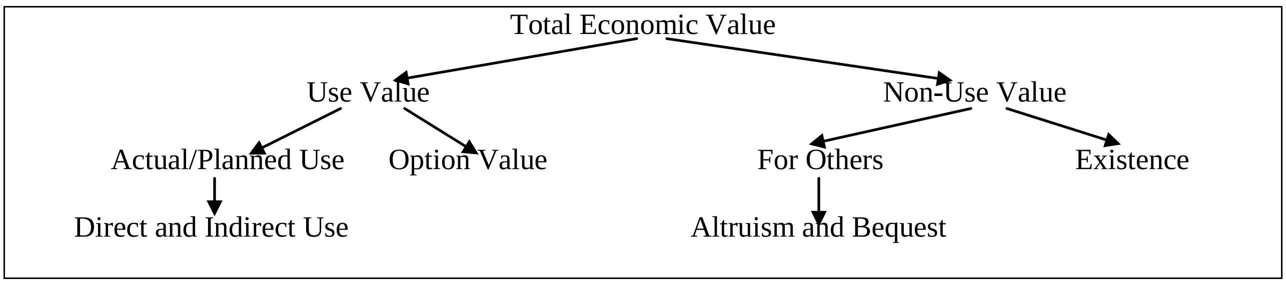
	agrochemicals) affecting aquatic biodiversity		
Conservation and restoration of peatlands and other wetlands including mangroves	Habitat conservation and restoration for both terrestrial and aquatic biodiversity Maintenance of ecological processes and functions, particularly those related to hydrology 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
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 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

Annex 6
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 and non-use 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.

Figure: Total Economic Value



Use values include direct use, indirect use and option value. Examples of *direct use* can be in the form of consumptive use, e.g., use of extracted resources such as food and timber (activities that can be traded in the market), or non-consumptive use, e.g., recreation (a non-marketable activity). Examples of *indirect use, which are not normally traded in the market,* are those where society benefits from services such as climate regulation, pollination, and soil maintenance. *Option value* is the value society places on the option to use a resource in the future, e.g., an individual may well be willing to pay for a national park even if they have no intention of using it in the near future, but want to keep the option open to visit in the future.

Non-use values include bequest, altruistic and existence values: *bequest value* where society attaches value to passing on the ecosystem services to future generations; *altruistic value* where individuals attach value to the availability of ecosystem services to others within the current generation; and *existence value* where an individual has no planned or actual use of an ecosystem service but is willing to pay for it to be maintained.

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 modeling); 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.

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