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BIODIVERSITY AND AGRICULTURE

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

1. 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).

2. This decision established the AHTEG to provide biodiversity related information to the United Nations Framework Convention on Climate Change 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. The first meeting of this AHTEG took place in London, from 17 to 21 November 2008.

3. The draft findings of the first meeting of the AHTEG are being distributed by the Secretariat of the CBD on behalf of the AHTEG and in conjunction with statements made under agenda items 3 and 5 of the twenty-ninth session of the Subsidiary Body for Scientific and Technological Advice.

4. The following document has not been peer reviewed and, as such, presents an initial summary of the findings of the first meeting of the second AHTEG on biodiversity and climate change.

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DRAFT FINDINGS OF THE FIRST MEETING OF THE SECOND AD HOC TECHNICAL EXPERT GROUP ON BIODIVERSITY AND CLIMATE CHANGE **1/**

London, 17–21 November 2008

INTRODUCTION

5. 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 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, which includes:

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

(c) 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;

(d) 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;

(e) Identifying options to ensure that possible actions for reducing emissions from deforestation and forest degradation do not run counter to the objectives of the Convention on Biological Diversity but rather support the conservation and sustainable use of biodiversity.

1/ The following document has not been peer reviewed and, as such, presents an initial summary of the findings of the second ad hoc technical expert group on biodiversity and climate change.

I. EXECUTIVE SUMMARY

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, including 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.

C. 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 clearing and 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 by growing new carbon stocks (through reforestation, forest restoration and improved forest management) which, through the use of mixed native species, can yield multiple benefits for biodiversity;
- 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.

D. 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/

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

- 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; and
- 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.

II. 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, their significant carbon stocks and their contribution to adaptation. 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. Furthermore, in reference to Article 2, 3/ well-functioning ecosystems have greater resilience to climate change which will aid in their natural adaptation, and contribute to the assurance of long-term sustainable development under changing climatic conditions.

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 Convention on Biological Diversity 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 I. A list of possible win-win activities for the implementation of the UNFCCC and the CBD is provided in annex II.

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. A total of 312Gt carbon or 15.2 per cent of the global carbon stock is currently under some degree of protection (see table 1). The designation and effective management of new protected areas, 4/ and strengthening the management of the current protected area network, could contribute significantly to climate change mitigation efforts.

Table 1: 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

3/ 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."

4/ 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."

IUCN category I-VI	9.7	233	11
All Pas	**12.2**	**312**	**15.2**

The ecosystem approach 5/ 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.

In the absence of land use, land-use change and forestry (LULUCF) activities, including reduced deforestation and degradation, emission reductions will not be implemented within a time-frame sufficient to allow ecosystems to adapt naturally

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, 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.

The potential to reduce emissions and increase sequestration 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, and 2.3-6.4 $GtCO_2$-eq per year for agricultural activities for a price of US$ 100/tCO_2-eq by 2030.

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. Modified natural forests (i.e. those that have been logged or degraded) have lower carbon stocks, less biodiversity and less resilience than primary forests. 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 a higher biodiversity value 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 2 below.

Table 2: Different carbon 6/ and biodiversity benefits of main forest types

Forest type7/	Biomass Carbon stock8/	Carbon sequestration potential	Biodiversity value	Value of ecosystem services
Primary forest	+++	++(+)	+++	+++
Modified natural forest	++	++	++	++
Plantations (indigenous	+	+++ (depending on	+(+)	+

5/ 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.

6/ Referring to total ecosystem carbon.

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

8/ 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)		
Plantations (exotic species)	+	+++ (depending on 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 who 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 I) 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.

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 9/ in largely intact forested landscapes. Most of the biomass carbon in a primary forest is stored in older trees or the soil around and beneath them. 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. This creates a carbon debt which takes decades to centuries to recover, depending on initial conditions and the intensity of land use. Avoiding future emissions from existing carbon stocks in natural forests, especially primary 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 conservation and sustainable use.

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. Reforestation can involve the restoration of a permanent natural forest rather than a plantation forest, make use of remnant natural forests or use an appropriate mix of native species. Reforestation activities on long converted land can also supply sustainable wood products thereby relieving the pressure to extract them from more mature natural forests.

9/ "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.

Afforestation[10] **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.

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 better reflect natural processes. These tools include increasing rotation lengths, decreasing logging intensities, and reduced impact logging that minimizes collateral damage to living biomass and soil. 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 the biodiversity conservation value of 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 11**/ activities in areas of high carbon stocks and high biodiversity values 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 to potentially enhance positive benefits on biodiversity.

REDD methodologies based only on assessments of deforestation rates could have significant and often negative impacts on biodiversity conservation. In particular the question on whether gross deforestation or net deforestation 12/ 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 and their replacement *in situ* or elsewhere with areas of new forest. This could be accompanied by significant losses in biodiversity.

Addressing forest degradation is important because degradation leads to biodiversity loss, decreased forest resilience to fire and drought, and often leads to deforestation. Monitoring to detect levels of forest degradation is therefore a key issue which needs further development.

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

11/ 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.

12/ 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.

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 3 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 3: 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. 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. Recent studies have suggested that there are almost 100 GtC stored in North American Arctic soils alone. Furthermore, a recent global assessment of peat has estimated that peatlands store 550Gt of carbon. 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 are.

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 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. 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. 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. 13/

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. 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 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.

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.

I**n addition to direct impacts of mitigation activities (LULUCF, renewable energy technologies and geo-engineering) on biodiversity there may be significant indirect impacts which require further research.** There is also potential for new mitigation technologies to be developed with either positive, neutral or negative impacts on biodiversity.

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

III. BIODIVERSITY-RELATED IMPACTS OF ANTHROPOGENIC CLIMATE CHANGE

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. 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.

The rate of climate change has already exceeded the capacity of some species and ecosystems to adapt naturally, and is close to exceeding that of others

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 at which natural adaptation should have been able to take place. This is in contrast to the much more rapid rate of temperature change observed and projected today.

Given the rapid rate of projected change, some regions and ecosystems will be more vulnerable to extinction and degradation than others. The relative vulnerability of species and ecosystems is due to a combination of individual species traits that predispose them to risk, the degree of exposure of the environment to climate change, and their capacity to adapt, either genetically or behaviourally. For example, the very nature of small island developing States, as relatively isolated territories, low-lying and surrounded by an ocean or a sea, makes their biota extremely vulnerable to climate change and related sea level rise, prolonged droughts and increases in hurricane and storm surges frequency and strength.

During the course of this century the resilience of many ecosystems (their ability to adapt naturally) is likely to be exceeded by an unprecedented combination of change in climate, associated disturbances (e.g., flooding, drought, wildfire, insects, ocean acidification) and in other global change drivers (especially land-use change, pollution and over-exploitation of resources), if greenhouse gas emissions and other changes continue at or above current rates (high confidence). 14

Further climate change will have increasingly significant direct impacts on biodiversity. Increased rates of species extinctions are likely, with negative consequences for the provision of services 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 and species restricted to freshwater habitats.

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.

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 climatic 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" 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.

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

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 <5^0C 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) also 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. Temperature increases of 2°C above pre-industrial begin to put entire ecosystems at risk and the extinction rate is expected to rise accordingly.

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

The understanding of the characteristics that contribute to species' risks of decline or extinction has improved. Species with small ranges and tropical montane species are at particular risk as are those with naturally fragmented or isolated populations or limited dispersal ability. Areas of most concern are the arctic and Antarctic 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. 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 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 values 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. 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.

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 melts the glaciers that feed Asia's largest rivers in the dry season – 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 are expected to decrease agricultural productivity in tropical and subtropical areas. More frequent and more extreme droughts and floods will increase the likelihood of crop failure 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 could 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 particular 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.

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 plays similar roles in cultures elsewhere in the world.

Novel environments and novel ecosystems are likely to emerge with potentially unexpected behaviour. Climate change is already resulting in novel climates in some microclimates within existing protected areas. This shift may render existing conservation efforts less effective.

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. 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. 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 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 mangroves in 16 Pacific island States by the end of the century.

Enhancing natural adaptation by biodiversity can reduce negative impacts from climate change and contribute to climate change mitigation by preserving key functions such as carbon sequestration

Climate change will continue to alter the composition, physical and trophic structure, successional processes and community dynamics of many ecosystems, with cascading effects to the services these ecosystems provide, including carbon storage. Examples include the invasion of temperate grasslands by woody plants possibly facilitated by increasing CO_2 concentrations, and changes in the structure of reef ecosystems due to bleaching and ocean acidification. Regional modelling also projects increases in GPP for some regions as a result of longer growing seasons and higher CO_2 concentrations. However, where water balance is more important GPP is projected to either decline or to increase only slightly relative to present day conditions. Changes in productivity will result in changes in litterfall and nutrient cycling. Where litterfall increases, it may contribute to increasing respiration and loss of soil carbon.

Ecosystems are currently acting as a carbon sink to sequester 30% of anthropogenic emissions, but if no action is taken on mitigation, these sinks would slowly convert to carbon sources as temperatures rise, largely due to the increased soil respiration and regional drought. 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. In particular:

- Local conversion of forests from sinks to sources would be exacerbated by deforestation and degradation, which increases the vulnerability of forest to climate change and reduces local precipitation encouraging drying. Some models predict that the Amazon is particularly vulnerable to such processes. 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, especially in Eastern Amazonia, could shift the forest into a permanently drier climate, increasing the risk of fire and carbon release.
- Arctic ecosystems and tropical peatlands could also 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.
- Experimental evidence suggests that the warming climate will alter the plant species present in ecosystems that are currently based on peat soils, reducing the capacity of the peat to sequester carbon.

IV. ASSESSING THE RELIABILITY OF THE KNOWLEDGE ON THE IMPACTS OF CLIMATE CHANGE ON BIODIVERSITY AND IDENTIFYING KNOWLEDGE GAPS

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 in tropical and subtropical 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. 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. 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 at understanding where species are not (a critical factor in performing many bioclimatic models). 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. This is also an impediment to using models to separate the impacts of climate change from other human activities.

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 ecological processes

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 in 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 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 likely to not be gradual, but 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 events.

The difficulty in predicting thresholds makes the management of biodiversity and the diversity of ecosystems an important safeguard. Landscape-scale ecosystem heterogeneity may – to some extent – buffer against moderate changes in climate. In particular, the diversity of species and interactions amongst them, as well as landscape-scale habitat heterogeneity may provide a range of natural adaptive capacity in the face of a certain level of change.

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 heatwave).

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 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 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.

V. GUIDANCE ON THE APPLICATION OF ASSESSMENT TOOLS AND METHODOLOGIES RELATED TO THE IMPACTS OF CLIMATE CHANGE ON BIODIVERSITY AT A RANGE OF SCALES

Assessments of impacts of climate change on biodiversity using currently available tools is dependent on the integration of data on the distribution of species with spatially explicit climate data for a range of climate change scenarios

Despite their limitations, the use of bioclimatic modelling techniques allows a useful, and often accurate first cut assessment of spatial distribution of exposure and vulnerability in relation to conservation efforts. Where expert knowledge on species demography is available, techniques can be applied that include consideration of climate variability and require species abundance data, but this places a higher demand on the spatial and temporal resolution of future climate data. While the use of spatially downscaled future scenario data is ideal if achievable, for robust risk and impacts assessments it may be more useful to focus on a range of future climate scenarios even if they are not downscaled, and not only on a mean or median future scenario.

Good Practice Standards and Guidelines for bioclimatic models, associating observed changes with climate, and assessing vulnerability should be developed. This could include information on how to best use the climate data, report on the results and uncertainties and perform the associations and attributions of the event with climate change. Ideally, these guidelines should be developed through an international body such as IPCC.

Observed changes and climate variability can potentially be used to assess the sensitivity of bioclimatic models. There have been a number of reviews examining how species ranges and the timing of events (e.g., arrival dates, egg laying) have been observed to be consistent with regional climate changes. These changes have occurred with a relatively small amount of global temperature change. While the number of conjoined studies (examining observed changes linked to bioclimatic models) is still small, observed changes can be used to help assess the sensitivity of some bioclimatic models – are the changes observed in the direction projected by the bioclimatic models? Other ways of assessing whether species' ranges are associated with climate, and thus would potentially move with climate changes, is whether a species' range changes in association with climate variability.

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 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 biome type 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.

Tools for assessing the vulnerability of species and ecosystems to climate change are available. Models are not the only way of assessing the vulnerability of species and ecosystems to climate change. Expert based systems, coupled with data where available, can be used to assess the potential vulnerability of both species and ecosystems. Some of these techniques also examine other human impacts on species and ecosystems and allows a comparison of the relative contribution of climate change versus other drivers over time.

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.

The establishment of multi-purpose monitoring programs which 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

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.

Observations 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

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 into 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.

Tools and methodologies for 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.

(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.

Annex I

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 II

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 degradation15 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
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

15/ 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*
			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 agrochemicals) affecting aquatic biodiversity	Introduction of invasive and alien species Encroachment into native ecosystems	Promote agroforestry as part of a broader landscape level planning that includes conservation of remaining native ecosystems and restoration, as appropriate Consider traditional and local knowledge Provide capacity-building and information on appropriate agroforestry systems

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

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