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BIOLOGICAL DIVERSITY AND CLIMATE CHANGE, INCLUDING COOPERATION WITH THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE

Brief overview of the impact of climate change on forest biological diversity

Note by the Executive Secretary

Executive summary

At its fifth meeting, held in Nairobi in May 2000, the Conference of the Parties made reference to the interactions between climate change and the conservation and sustainable use of biological diversity in a number of thematic and cross-cutting areas, including forest biological diversity.

Specifically, in decision V/4, the Conference of the Parties requested the Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA) to consider the impact of climate change on forest biological diversity (para. 11) and to prepare scientific advice in order to integrate biological diversity considerations, including biological diversity conservation, into the implementation of the UNFCCC and its Kyoto Protocol (para. 18).

In order to assist the Subsidiary Body in its consideration of the matter, the Executive Secretary has prepared the present information document on the impact of climate change on forest biological diversity on the basis of an in-depth technical paper under preparation that will be considered by the Ad Hoc Technical Expert Group on Forest Biological Diversity. The present document supplements the note by the Executive Secretary on biological diversity and climate change that has also been submitted under this item (UNEP/CBD/SBSTTA/6/11).

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I. INTRODUCTION

1. The potential impact of climate change on forest biological diversity is overshadowed by the overwhelming effect of human-induced modifications of terrestrial ecosystems that are responsible for major losses in forest biological diversity. Therefore, it is necessary to discriminate between the more immediate and more obvious effects of forest-habitat modification by humans and the longer-term, more subtle effects of climate change. Despite varying opinion about the nature and extent of the impact of climate change on biological diversity, there is a general agreement that biological diversity will decline worldwide under most climate change scenarios. This consensus has evolved through an overall synthesis of trends in organism response to measured variation in paleoclimate, from experimental results in controlled environments including carbon-dioxide enrichment, and from intensive field-studies of impacts on biological diversity in intact and modified habitats along a series of existing environmental and climatic gradients worldwide.

2. Article 1 of the United Nations Framework Convention on Climate Change (UNFCCC) defines "climate change" as a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.

3. The same article describes "adverse effects of climate change" as changes in the physical environment or biota resulting from climate change which have significant deleterious effects on the composition, resilience or productivity of natural and managed ecosystems or on the operation of socio-economic systems or on human health and welfare.

4. In order to plan “to allow ecosystems to adapt naturally to climate change”, as stated in article 2 of the UNFCCC, and to mitigate climate impacts, there is a need to understand how organisms adapt to change. To forecast how a species will survive in a given climate scenario, it is therefore useful to characterize the individuals of different species according to their genetically determined functional or adaptive response to environmental change where this is known. Because such characterization is rarely reflected in a species name, recent developments in functional typology provide a useful complement to the more conventional description of biological diversity according to gene, species, ecosystem and biome. The impacts of climate change on forest biological diversity are therefore summarized under the following headings:

(a) Impact on genotypes;

(b) Impact on forest and forest-dependent species;

(c) Impact on forest ecosystems and biomes.

II. IMPACT OF CLIMATE CHANGE ON FOREST GENOTYPES, SPECIES, ECOSYSTEMS AND BIOMES

A. Impact on genotypes

5. There are few accounts of the impact of climate change on genotypes, although it is known that within-species variation seems lower at higher latitudes and *vice versa*, implying that for forested lands in temperate and boreal regions such variation is likely to increase with increasing carbon dioxide and rising temperatures. Such changes may induce parallel responses in equatorial, high montane and alpine genotypes. Climate warming could rapidly produce important genetic changes in some forest species such as birch trees (for example, reduced root/shoot ratio, reduced growth in alpine populations). On a longer time-scale, warming could also result in genetic changes as natural selection favours valley

genotypes in alpine sites where they are presently rare but will become less so as they expand their range. Forest fragmentation is likely to increase with global warming due to increasing seasonality, dessication and higher incidence of wildfire. This could lead initially to a collapse of obligate, perhumid forest species and thus to an initial loss in genetic variability, which may recover if and when fragments coalesce or as plant populations equilibrate. The collection of detailed information to evaluate these scenarios is time-consuming and costly. Without appropriate support to gather the right kinds of data, climate impact scenarios on genotypes are likely to remain difficult to forecast.

B. Impact on forest and forest-dependent species

Plants

6. *Species***.** Changes in atmospheric carbon dioxide may change the competitive balance between species that differ in rooting depth, photosynthetic pathway or woodiness, as well as in their associated below-ground organisms. While climate change in the form of land-use impact is likely to have the greatest effect on plant species, elevated carbon dioxide interaction with nitrogen deposition is likely to have the most notable effect on species metabolism and ultimately composition. Where there are conditions of extreme land-use change, further damage by other climate-change drivers may be inconsequential. Under climate change, the differential response of species will affect interaction and competition leading to changes in their spatial and temporal distribution. Most scenarios indicate that plant-breeding systems will be negatively affected by the loss of bird and insect pollinators resulting in loss in population viability and consequently species decline. A plant's ability to move under pressure from changing climate will vary according to species and functional type. Shoreline forest species and others capable of wide and rapid dispersal are likely to be less affected than poor dispersers in old growth forests. Relative migration rates are critical (see paragraph on ecosystems, below). Although there will be regional differences in the nature and extent of plant species response to climate change, a general consensus is that plant species diversity will decline overall.

7. *Plant functional types.** Shifts in species composition will be largely determined by the adaptive strategies defined in their functional make-up. For example, such features as the capacity to fix atmospheric nitrogen, to resist and tolerate dessication and low levels of nutrients, or to disperse rapidly will play a major role in vegetation response to climate change. Forest-canopy gaps may increase with seasonality, leading to the likelihood of a greater availability of ecological niches that may lead to a relative increase in the number of functional specialists to numbers of species. In a higher-light environment, the proportion of woody plant species with a capacity for green-stem photosynthesis and drought tolerance will increase. Many tropical humid forests contain drier, upper-storey, succulent plants, such as orchids and bromeliads and some cacti, which have photosynthetic pathways that are more typical of desert plants. With increased warming and rainfall seasonality, the incidence of these functional types may be expected to increase.

Invertebrates

8. Climate-change impact on insects is likely to differ markedly between temperate and tropical regions. In contrast to the temperate zone, most herbivory in the tropics (more than 70 per cent) occurs on ephemeral young leaves. As a consequence, plant/herbivore interaction in the tropics may be more susceptible to climate change, and insect outbreaks increase and herbivory rates rise two- to fourfold

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* "Functional types" are sets of organisms showing similar responses to environmental conditions and having similar effects on the dominant ecosystem processes. This is an extension of an earlier definition that used "plant functional types" to connote species or groups of species that have similar responses to a particular suite of environmental conditions. Functional types can be used to help reduce complex species groups to more manageable entities and to compare responses of individuals, for example, between geographically remote locations where environments and adaptive morphologies are similar but where species differ.

where increased carbon dioxide is combined with drying. The predicted increase in the number of herbivores may be primarily due to relaxed pressure from predators and parasitoids; under these circumstances, relative abundance of species could change and overall biological diversity decline. In a similar way, in countries like, for example, New Zealand, although the impacts of climate change will vary throughout the country, climate change is expected to increase the range of many insects and thus increase their pest status.

Birds

9. Several sources suggest that 12 per cent of birds may be at high risk of extinction, with the numbers increasing yearly, although this may vary from region to region. Bird-species richness appears to increase with terrestrial patchiness or intermediate levels of disturbance both in the tropics and in temperate zones. Where patchiness is reduced or damped under climate change leading to more homogeneous conditions with fewer plant species, there may be a reduction in overall avian biological diversity. For example, in south-eastern Australia, there are broad trends in bird-species distribution along gradients of elevation and soil moisture that are expected to result in shifts in bird populations with climate warming. With increased forest fragmentation, e.g. in Minas Gerais, Brazil, there has been a loss of 48 per cent of forest bird species, probably due to habitat loss resulting in very small sizes of forest fragments. There is therefore a need to preserve larger fragments in order to retain more specialized forest bird species

10. Impacts on birds may already be under way, with a trend detected in the movement of ranges towards higher latitudes in Antarctica, Australia and North America. Certain birds from high-elevation habitats and cloud forests are also expected to move where they can, towards higher latitudes as temperatures rise. In certain high island habitats, especially oceanic islands, endemic populations with limited flying range will be at increasing risk of extinction. Forest-dependent sea birds, for example the endemic Lord Howe Island Providence Petrel (*Pterodroma solandri*) with great flying range but highly specific forest habitat, could be at extreme risk. Increased forest fragmentation under global warming may lead to variable responses in bird-species richness depending on forest type and local climate. Migration patterns are almost certain to change for many species under a global warming scenario where increased land and sea temperatures significantly affect over-wintering resources en route to breeding habitats.

Amphibians and reptiles

11. Because many amphibians and reptiles are adapted to very cryptic, moist forest habitats, any change leading to a drying out of habitat, for example with increasing seasonality, is thus very likely to lead to a decline in species number. This is likely to affect both high mountain areas as well as lowland, humid forest habitats. While this may reflect the majority of cases, for example in the tropics, the converse may be equally true where warming is accompanied by increased moisture and reduced seasonality. Certain groups with dormancy strategies (e.g., some frogs) equipped to deal with increasing dessication may be expected to survive or possibly expand relative to others less well equipped. With an anticipated change in both these environmental determinants with global warming there are serious implications for these amphibian and reptile groups.

Mammals

12. As mammals ultimately depend largely on plants as a food and shelter resource, a significant change in the range distribution of a key plant species under climate change can have a critical impact on their distribution. With forest fragmentation already increasing under burgeoning land-management pressures, the range distribution of many forest-dwelling mammals has decreased dramatically. This process is almost certain to accelerate with global warming and accompanying human population

pressure. Many mammalian breeding strategies are closely constrained by temperature. With increasing temperature, certain mammals will be at a breeding disadvantage unless they are able to migrate to match the necessary conditions for survival. Food resources for a number of herbivorous mammals are in many cases restricted to certain plant species that may be under threat with climate change. The decline in abundance of these resources may have a domino effect on both herbivores and their top predators.

C. *Impact on forest ecosystems and biomes*

13. Earlier models that forecasted shifts in forest biomes or ecosystems as intact entities as a response to climate change are now no longer considered useful. The reason is due to the differential response of species and functional types to a changing environment in which biomes and ecosystems are likely to lose ecological integrity. For this reason, forest ecotones are likely to become blurred as the range distributions of species and functional types readjust to new environments. Migration rates between different plant and animal groups differ regionally with barriers to certain groups arising through increased habitat fragmentation. Most models suggest that increases in invasive weedy species, especially exotics, associated with regional shifts in pests of forest and agricultural crops may accompany biological diversity decline where the biogeochemical cycle is changed and where increased fragmentation favours expansion of more opportunistic weedy groups. Regional differences in ecosystem response restrict generalization about the invasive potential of species.

14. The most recent findings suggest that within the context of climate change, northern temperate forests are likely to experience the least impact because of the major land-use change that has already taken place. Impacts of biotic introductions are likely to be least in boreal and higher-latitude forests because of extreme conditions, although these may change depending on the level of climate warming. In the tropics, there will be relatively less impact in intact forest ecosystems because of their inherently high biological diversity and buffering against invasive impacts by alien species. However, depending on the region, this may change with shifts in seasonality and consequent canopy opening, leading to vulnerability to invasion by opportunistic, exotic and indigenous species. For many biomes, when all drivers of climate change are considered, climate change is second only to land-use change. Across biomes, the interaction of these factors, together with other important drivers, such as nitrogen deposition, carbon-dioxide enrichment and biotic exchange, renders it difficult to isolate the effect of climate change alone.

III. FORESTS AND THE KYOTO PROTOCOL

15. Articles 3, 6, 10 paragraph (a), and 17 of the Kyoto Protocol address the monitoring of greenhouse-gas removals and emissions from human-induced deforestation, afforestation and reforestation since 1990. Although there is a recognition of the need to redress the situation by slowing forest destruction and by tree planting, the Conference of the Parties to the UNFCCC may allow other, as yet unspecified, harvesting and management activities (see article 3, paragraphs 3 and 4, of the Protocol). Assessment of emissions and of climate impacts, especially on carbon sinks and sources, requires a clearer definition of forests and of afforestation, reforestation and deforestation (as proposed by the IPCC *Special Report on Land-Use, Land-Use Change and Forestry* (LULUCF)), and a reassessment of the fate of carbon in such systems. For example, recent studies show that, whereas in temperate and boreal forests, below-ground carbon is highly significant relative to above-ground carbon, this now appears less likely to be the case in many tropical forested lands, apart from freshwater and mangrove swamp forests on deep peats. It is also recognized that old-growth unmanaged forests have more carbon, as well as biological diversity, than do managed forests.

16. The Clean Development Mechanism (article 12 of the Kyoto Protocol) provides for industrialized countries to undertake emission-reduction projects in developing countries. However, the Mechanism does not specify what land-use change and forest projects will be allowed if any. A closer

study of potential impacts may therefore be needed in order to better define the ways in which the Mechanism is implemented. Although there is evidence that forests act as significant carbon sinks and that activities that enhance forest establishment through afforestation and reforestation could help mitigate the effects of climate change, it should also be kept in mind that afforestation may also adversely affect non-forest biological diversity. Conversely, deforestation will have an adverse effect on surface albedo while at the same time contributing to a relative increase in emissions through fire and a reduction in total carbon sinks.

IV. CONCLUSION

17. Although more and more forums, including the UNFCCC, clearly recognize and acknowledge the potential impact of climate change on forests and forested lands, many uncertainties remain about the nature and the extent of such impact. Few findings allow for a clear distinction to be made between the immediate and rather well known human-induced impacts on forest biological diversity and the more subtle effects of climate change. A key problem facing the UNFCCC, as well as the Convention on Biological Diversity and other related international bodies and processes, is the high level of uncertainty underlying the application of most of the models used in forecasting climate change. In particular, there is the problem of scaling up and down between surface to atmosphere that concerns, for example, many largely untested assumptions about the mechanisms involving transfer of water to and from soil and from leaf to canopy to atmosphere. Newer models that attempt to integrate many of these processes ("dynamic global vegetation models") and improved models of tree growth and soil hydrology will provide the UNFCCC and other forums with a better understanding of the role of forests with respect to the impact of climate change. Information of this kind will help provide a much-needed improved empirical basis for suggesting specific guidelines for sustainable management of forest biological diversity.
