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FORESTS AND BIOLOGICAL DIVERSITY

Working document prepared for the meeting of the liaison group on forest biological diversity

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FORESTS AND BIOLOGICAL DIVERSITY

Note by the Secretariat

1. To facilitate the discussion and the identification of priorities of the liaison group on forest biological diversity, the Secretariat has prepared the attached document on forests and biological diversity.

2. The liaison group may wish to review and amend this document. The liaison group may wish to, specifically: identify specific issue-areas that need to be addressed; identify the knowledge base, including indigenous knowledge, and where relevant, state-of-the-art technologies and know-how in relation to the issue-area under review; identify the gaps in knowledge with respect to the issue-area.

3. Forests are the most biologically diverse terrestrial ecosystems. Forests are of major importance globally, occupying around a third of the world's ice-free land surface; they are diverse, reflecting the combined influences of evolution, biology, the physical environment, and people. The tropical rainforests are recognised as the most complex and species-rich terrestrial ecosystems, but even the simplest forest communities comprise genetically diverse populations of trees and a wealth of associated plants and animals.

4. Human societies have impacted greatly on forest biological diversity throughout history. Whilst the net effect of these impacts has been overwhelmingly negative, not all have been adverse - particularly in the case of forest-dwelling or -dependent peoples. The unprecedented scale and accelerating rate of recent human impacts on forests threaten forest biological diversity through the erosion and loss of ecosystems, of species within ecosystems, of populations within species, and of genetic diversity within populations.

5. Appreciation of forest biological diversity in the context of the objectives of the Convention on Biological Diversity requires a synopsis of forest biological diversity, the processes and forces that have shaped it, and those to which it is now subject.

1. Forest biological diversity: an overview

6. The biological diversity of forests is apparent at all levels of biological organisation. Forest biological diversity can be catalogued at each of these levels, in terms of ecosystem, species and genomic richness; but what is more important is the appreciation that - even in its poorly-known state - forest biological diversity is high relative to that of other terrestrial ecosystems. Contemporary forest biological diversity reflects the combined influence over evolutionary time of:

- the abiotic physical factors of climate, landform, lithological substrate and soil;
- diverse biotic factors, including competition and complementarity between coexisting organisms, host-pathogen interactions, and pollinators and predators;
- the reproductive biology of individual species, and their evolutionary history, and;
- human modifications of each of these factors.

7. The abiotic factors are constant at any one location, but they vary spatially. Each of the other factors also vary spatially as well as temporally. These dynamic, heterogeneous, interacting and variously interdependent factors characterise forest biological diversity in similar terms. Thus, no single parameter can adequately characterise forest biological diversity in all its manifestations, because:

- forest ecosystems are complex, in terms of composition, function and process;
- forests vary at all scales of organisation, from the molecular to that of landscape;
- the ecological and genetic processes which both maintain and change forests are dynamic, on time scales varying from minutes to millennia;
- populations of constituent species are similarly diverse and dynamic.

8. The resultant complexity of forest biological diversity defies simple description or measurement, and is more realistically represented in terms of the biological, spatial and temporal dimensions which jointly define this wealth of diversity, and the human influences which modify it. For practical purposes, though, we have to approximate such complexity with simpler frameworks that are both biologically meaningful and practically useful.

9. Such a framework comprises three principal foci, two of which are those of the forest community and its constituent populations of species. These two foci represent different but complementary perspectives on biological diversity, *viz.* those of ecology and genetics, respectively. An ecological perspective emphasises the role of environment and species biology in shaping forest communities; a genetic perspective emphasises the genetic forces that shape populations of a species. Thus, these perspectives inform different levels of biological organisation - with ecology most relevant to landscapes, ecosystems and habitats, and genetics to the species, population and genome levels. The third perspective essential to appreciating contemporary forest biological diversity and to considering its future is that of human history, emphasising how human societies have affected it over time, and are doing so now.

1.1 Scientific knowledge

1.1.1 Ecological perspectives

10. An ecosystem approach emphasises the complexity and interdependencies of biological communities and their dependencies on the abiotic site-specific (edaphic) factors. Furthermore, the concept introduces the importance of natural disturbance regimes and regeneration mechanisms as factors involved in maintenance of biological diversity over large landscapes. Finally, an ecological perspective notes the spatial organisation of communities and ecosystems as life-zones, formations, ecoregions, biogeographic zones/realms and biomes.

11. Ecosystems are necessarily defined loosely, and at a coarse rather than a fine scale, because forest communities are dynamic and spatially heterogeneous. The vegetation of any given area of forest is a point sample of a continuum of species assemblages grading into each other, reflecting the differential responses of constituent species to variation along environmental gradients, and to disturbance patterns and histories. These gradients may be subtle or strong, and perturbations widespread or very local, defining patterns of community variation on different spatial and temporal scales. As the composition and structure of the forest flora vary, so too do the habitats available for animals - and thus the forest community as a whole.

12. The spatial structure of landscapes determines processes, such as drainage and nutrient flows, with important ecological implications, and thus influences the spatial patterns of species distributions. Key landscape-level issues for the conservation of biological diversity are the maintenance of ecological processes, the space requirements of particular species, source-sink population structures, and metapopulation dynamics.

13. Maintenance of ecological processes and processes at the landscape scale is critical for the persistence of some species, and thus of the forest communities of which they are part. For example, the spatial configuration of habitat patches may affect the long-term viability of species susceptible to habitat fragmentation, as the case of the Northern Spotted Owl (*Strix occidentalis caurina*) in the forests of the Pacific Northwest of the USA demonstrates. Here, the persistence of owl populations is determined not just by the total reserved area of owl habitat - old growth forest - but by the spatial arrangement of these remnant patches. The isolation of patches by harvesting of intervening forests increased the mortality rate of dispersing juvenile animals sufficiently that the extinction of populations could be expected; an important corollary is that spatially isolated areas of suitable habitat may remain unoccupied. Such relationships, between the spatial arrangement of habitat patches and their rates of occupancy, are common.

14. Because animal species vary substantially in the space required to complete their life cycles, and because populations of some species cannot persist if they become isolated, many will be dependent on the maintenance of populations across forested landscapes. For example, many species exploit temporal environmental variation by migrating among different habitats, and others exploit spatial variation in natural disturbance regimes. Similarly, if, in some high quality habitats (sources), a species' rate of reproduction exceeds mortality, but in low quality habitats (sinks) its reproduction is less than mortality, net dispersal away from sources may sustain populations in sinks. Thus, the persistence of some components of forest biological diversity may require appropriate management of source areas; the conservation of metapopulations, *i.e.* sub-populations linked by dispersal, may be critical for the conservation of biological diversity at a landscape scale.

15. For these reasons, retention of small isolated populations is unlikely to be effective in the conservation of forest biological diversity; it is also likely to increase extinction risks associated with catastrophic events such as wildfire or disease. Hence, conserving species throughout their natural distributions is an important guiding principle for the conservation of forest biological diversity at the

landscape scale. Landscape-level conservation of biological diversity also will contribute to maintaining key ecological processes in forests, and thus sustain forest productivity.

16. The ecosystem approach on conservation and sustainable use of forest biological diversity is further based on integration of site specific biotic and abiotic conditions, natural forest regeneration regimes and considerations on the biogeographic status of the forests in question.

17. This approach may be illustrated by the case of Western Amazon tropical lowland forests. These forests are subjects to long-term fluvial dynamics resulting from the tectonic setting of the area. The alterating river system has caused an edaphic mosaic of forests which all have specific modes of regeneration after natural or man-made disturbance. The forests are comprised of young stands which grow on newly deposited alluvial soils, mature forests on abandoned floodplains and very old and diverse forests on weathered interfluvial surfaces. All these forests demand different approach with respect to conservation strategies and sustainable forestry. However, in many cases the modern conservation programs or management practices are based on an approach derived from principles of general tropical forest ecology or forestry practices. These practices fail to give operational guidance for management of the various forest classes which are present in the region.

18. The temperate and boreal forests have equally specific regeneration mechanisms. These mechanisms include, *inter alia*, regeneration by fire, windthrows, insect outbreaks and senescence of individual trees. Long-term management of biological diversity in these forests is highly dependent on the success in finding management and conservation practices which are based on the natural dynamics.

19. An ecological perspective thus emphasises the fundamental importance to forest biological diversity of self-regulating natural communities, with their complex co-adaptive balance. Our imperfect understanding of forest ecosystems suggests that the converse is also true: maintenance of plant and animal diversity is essential in sustaining structure and function of forest communities. An ecological perspective recognises that forest ecosystems are not merely serendipitous assemblages of independent species and individuals; rather, the diversity of ecosystems and the species which comprise them are shaped, maintained and changed by the complex interactions of organisms and their differential responses to both natural and human influences. In turn, the characteristics of organisms are an expression of their genes and of genetic processes, identifying the need for a genetic perspective.

20. To tie up the ecosystem based concept on management of forest biodiversity, an integrated approach is needed which is based on a wide set of tools, like:

- establishment of a network of protected areas which represent key elements of the landscape and regional continuum, as well as life-zones, formations, ecoregions, biogeographic zones/ realms and biomes;

- forest management practices which derive from natural regeneration mechanisms and disturbance regimes, site specific biotic and non-biotic interactions and metapopulation structure;

- indigenous and local peoples' knowledge of, and practices which impact on, forest biological diversity;

- development of data bases, including geographical information systems (GIS) and assessments on the status of endangered species.

21. In some situations, further research and development of economic incentives which may promote sustainable use of forest resources is needed, as well as site and region specific development of criteria and indicators for sustainable forestry.

1.1.2 Genetic perspectives

22. Within forest ecosystems, populations of individual species fluctuate according to landscape, ecosystem and genetic processes. Each plant species exists as a series of populations, genetically linked by varying degrees of gene flow. Although our knowledge for forest species is sparse and biased towards those of the temperate ecosystems, there is some consistency emerging from the recent proliferation of studies based on assaying variation in the enzymes or DNA of organisms. This information describes levels and patterns of genetic diversity, which together characterise the biological diversity within a species - that is, in more utilitarian terms, its genetic resources.

23. Tree species, the dominant life form of forest ecosystems, are much more genetically diverse than other plant species, a consequence of their mating systems, life histories, relatively extensive geographic distributions and typically limited history of domestication. In contrast to many non-woody plant species, and particularly those which have been domesticated as crops, tree populations maintain these high levels of genetic diversity through strongly outbreeding reproductive strategies, through extensive gene flow within and between sub-populations, and through the longevity and fecundity of individuals. Their reproductive biology also implies that geographically isolated trees in agroecosystems, and those in remnant forest fragments, may not be reproductively isolated, and indeed may play a critical role in maintaining gene flow within and between populations.

24. These mating system and life history differences also determine that the spatial patterns of genetic diversity in tree populations differ greatly from those of most non-woody plants. In general, most genes found in a tree species are present in most of the populations across a species' range, a testament to the effectiveness of gene flow between populations and the biological mechanisms which maintain genetic diversity within populations. Other forest plants with similar mating systems will exhibit similar patterns of genetic diversity, in marked contrast to those of inbreeding plants, for which there is strong genetic divergence between populations. Although the magnitude of genetic differences between populations of trees is small relative to that of inbreeding plant species, it is nevertheless responsible for variation of major consequence in traits of value to people and production systems.

25. Knowledge of the population biology of other forest species is variable but, overwhelmingly, limited. Whilst that of some forest animals and birds is relatively good, most species of forest invertebrates, fungi and micro-organisms are probably not yet known to science: there is no site on earth - even in the relatively simple and intensively-studied temperate forests - for which a full inventory of these forest species has been completed. Few generalisations are possible from those species of which we have some knowledge, in part because of the profound but particular influence on them of human activities.

26. A genetic perspective on forest biological diversity emphasises the fundamental role of the population, and of genetic processes at the population level. It describes the rich and diverse genetic resources of forests, and stresses the importance of maintaining viable populations of individual species. There is concordance with the ecological perspective on two fundamental points: firstly, because most forest species differ greatly in their genetic composition and population structure, generalisations are

helpful only at a coarse level; secondly, the genetic divergence evident between populations highlights the role of environmental variation in shaping and sustaining genetic diversity.

1.2 Traditional knowledge

27. Forest biological diversity is often paralleled by a diversity of indigenous societies, who have inhabited and manipulated forests - sometimes for millennia, sometimes only recently or transiently. The knowledge of these indigenous peoples includes a wealth of traditional ecological knowledge, relating to management and conservation of the environment; it includes systems of classification, sets of empirical observations about the local environment, and local management systems governing resource use. In the case of forest biological diversity, such traditional knowledge also describes that of rural communities with respect to the management and use of forest genetic resources - especially those of trees - in farming systems.

28. Traditional knowledge of forest biological diversity both contributes to and complements modern scientific knowledge. Indigenous knowledge of forest ecology and forest biological diversity is increasingly being used to define sustainable management regimes and identify genetic resources of value to other societies. An appreciation of the importance of traditional knowledge emphasises both the history and importance of human influences on forest biological diversity, and the potential role of indigenous and rural peoples in its conservation and sustainable use.

1.3 Human impacts on forest biological diversity

1.3.1 Human impacts throughout history

29. The history of humankind is one of modification of the forested environment: by the conversion and fragmentation of forest ecosystems; their alteration through the harvesting of forest products, use of fire, or more general environmental alteration; and the translocation and domestication of plant and animal species. These processes have exerted profound but poorly quantified impacts on forest biological diversity, demonstrated most spectacularly by examples of species extinction, but more commonly resulting in the erosion of biological diversity, *i.e.*, the impoverishment of ecosystems and gene pools. However, it is important to acknowledge also that not all human intervention has impacted adversely on forest biological diversity, with many traditional forest management and farming systems sustaining or enhancing diversity. Examples of such systems include the home and forest gardens of Asia, the forest patches of the Brazilian and Guinean savannah, and the *Leucaena* agroforestry systems of Mexico.

30. The conversion of forests to other land uses results in the loss of locally-adapted forest ecosystems and their constituent populations. The resultant fragmentation of ecosystems and populations is likely to reduce species richness within remaining forests, as fewer species are represented in fragments of smaller size than in those of larger area. Depending on the barriers that fragmentation imposes on migration between residual populations, and population size and structure within fragments, within-population genetic diversity may also be eroded. Consequently, fragmentation may also lead, ultimately, to the extinction of locally-adapted populations. Specific effects will depend on the scale and pattern of forest conversion, the dynamics of particular ecosystems, and the population structure and reproductive biology of particular species.

31. The effects of the harvesting of forest products will also vary with ecosystem, species and harvesting regime. Where harvesting of forest products is regulated effectively, either by the state or by communities, sustainable use regimes will be based on modern or traditional understanding of ecosystem

processes. Thus, for example, foresters will apply timber harvesting regimes which vary with ecosystem type and the species extracted; similarly, indigenous peoples' knowledge is manifested in management practices which, for example, favour the regeneration and development of particular species. The effects of harvesting on forest biological diversity are greatest where forest harvesting been little regulated according to scientific or traditional knowledge, and has been most rapid and extensive. Because such harvesting is likely to have major adverse impact on ecosystem function and process, or on the population size of particular species, forest biological diversity is likely to suffer at all levels of organisation, with consequences similar to those of fragmentation. Where the impacts of harvesting are below this poorly-defined threshold, there may still be effects on species genepools, though these may be transient and relatively ephemeral. However, our empirical knowledge of the genetic effects of ecologically-appropriate harvesting regimes remains poor, with inconsistent results from the few studies so far reported. What is apparent is the fundamental importance of management regimes which recognise the reproductive ecology of the species harvested, so that viable populations are maintained over time.

32. Fire regimes are among the most pervasive human influences on forest ecosystems, with major implications for ecosystem structure, composition, function and distribution. As well as being a natural phenomenon, fire is one of the technologically-simplest management tools, used with discrimination by almost all forest-dwelling and dependent peoples, and - sometimes less discriminately - by agriculturalists, foresters, and land managers. The modification of Australian and North American forest ecosystems by altered fire regimes following both Native and European occupation are two relatively well-documented examples. The consequences of forest fire for forest biological diversity are substantial but variable, with ecosystems and populations responding differentially according to their adaptation to particular fire regimes. Similarly general but imprecise conclusions apply to the consequences of more general environmental modification, such as those resulting from industrial pollution or climate change.

33. Another major impact of humans on forest biological diversity is that realised through the translocation to exotic environments of plants, animals and micro-organisms. Species introduced by humans may affect indigenous communities and populations by displacing native species and genotypes, or by becoming pests or pathogens of species with which they did not co-evolve. Within species groups, the anthropogenically-expanded range of economically important or useful species has both reduced genetic diversity by contamination of local gene pools and homogenisation of population structure, and expanded it through exposure to new environmental pressures and intra- and inter-specific hybridisation.

34. The processes of domestication, frequently but not invariably associated with translocation, typically reduce within-population genetic diversity, although total diversity within a species may be sustained through the maintenance of divergent populations. Although relatively few forest tree species have been domesticated for industrial use, indigenous communities have both domesticated and conserved species important in farming systems. The domesticated crop plants and animals of high-input agricultural systems illustrate the ultimate consequence of lengthy and intensive domestication, exhibiting low levels of genetic diversity; in contrast, most forest trees, even those most domesticated, still retain high levels of genetic diversity.

1.3.2 Contemporary human impacts

35. This century has seen enormous human impact on forest biological diversity, at a rate which continues to accelerate. For example, half the world's croplands were forested 90 years ago; in the tropics, change of this magnitude has been effected in only 50 years. Whilst the recent effects of humans on forest ecosystems have been greatest in the tropics, with rates of forest loss and degradation continuing to rise by between 4-9% annually, industrialised societies are also impacting adversely on

temperate and boreal forest ecosystems. Although the current rate of forest loss appears unprecedented in human history, its scale is reminiscent of that of European settlement on the forest ecosystems of the New World, and of earlier civilisations on the forests of Europe and the Middle East.

36. The major agents of the loss and erosion of forest biological diversity are relatively easily identified. The principal agents of ecosystem loss and fragmentation are those converting forests to agricultural systems, although developers of urban settlements, extractive industries, and associated infrastructure similarly affect forest ecosystems, albeit on a more localised scale. Individual agents of conversion and fragmentation range from large scale agricultural enterprises, including those establishing industrial plantation forests on forest sites, to the small-scale farmers whose individual impact may be trivial, but whose cumulative impact is not. Agriculturists and plantation foresters are also responsible for the majority of translocation and domestication of forest species. Those harvesting forest products - wood and wildlife, and plants or plant products of commercial or subsistence value - affect most directly the genepools and the viability of populations. The scale and purpose of harvesting activities vary from industrial to subsistence, and their impacts are similarly variable.

37. The underlying causes of the loss and erosion of forest ecosystems, populations and genepools are less easily generalised. They include:

- the distribution and allocation of resources in human societies, at scales varying from global to local;
- the operation of both market and subsistence economies, and the interactions between these systems;
- accounting mechanisms which do not accord appropriate value to natural capital, and the resultant misvaluation of both market and non-market goods and services;
- public policies which, perhaps as a consequence of the above, recognise little value in forest ecosystems or the biological diversity they represent;
- cultural mores and social attitudes;
- individual circumstances which constrain the sustainable use of forest resources;
- ignorance or disdain of the long-term consequences of our actions.

38. The causes of the loss and erosion of forest biological diversity emphasise that effective responses have ethical and political dimensions as well as those which are more technical and managerial.

1.3.2.1 New technologies

39. The new biotechnologies have been employed in forest science as in plant and animal science more generally. Those of most relevance to the conservation and sustainable use of forest biological diversity in the foreseeable future are molecular markers, genetic engineering, and technologies for *in vitro* storage and micropropagation. Their major impacts to date have been to inform us of genetic diversity at the molecular level, and to offer propagation options which themselves represent the gateway to the application of many biotechnologies. Genetic engineering of forest species remains at the early

experimental stage. With the exception of a very few advanced conservation or domestication programmes, the new biotechnologies have yet to impact substantially on either the conservation or sustainable use of forest biological diversity; the most profound impacts would arise from advances in genetic engineering and storage technologies.

1.4 Synthesis

40. Although we have quantitative data for only a trivial proportion of the complement of forest biological diversity, there is widespread agreement - based on our understanding of history, ecology and genetics - that the overall impact of human societies on biological diversity has been adverse, with rates of loss and erosion varying from rapid to slight, depending on circumstance. In the worst cases, the effects have been overwhelming and enduring, as the now depauperate state of many island flora and fauna demonstrate most strikingly. Although abundant biological diversity remains in forest ecosystems and their constituent populations, the accelerating rate and scale of human impacts demand urgent action if the objectives of the Convention on Biological Diversity are to be realised.

41. The complexity, heterogeneity and dynamism of forest biological diversity, and of the forces that have shaped and are changing it at a variety of spatial scales, define the context of the Convention on Biological Diversity in relation to forests. They require that we draw from our admittedly imperfect understanding of ecological, genetic and human perspectives on forest biological diversity to advance the objectives of the Convention on Biological Diversity.

2. Forest biological diversity in terms of the objectives of the Convention on Biological Diversity

42. The characteristics of forest biological diversity define the context in which the threefold objectives of the Convention on Biological Diversity relate to forests. Broadly, in the context of forest biological diversity:

- *conservation of biological diversity* implies that the communities represented by forest ecosystems, their constituent populations of species, and the genetic diversity of those species, be maintained at levels and in conditions sufficient to preclude their loss or erosion - whilst recognising the dynamic state of each of these levels of organisation;

- *sustainable use of the components of biological diversity* implies that harvesting regimes must operate within the constraints defined by conservation goals;

- *fair and equitable sharing of the benefits arising out of the utilisation of genetic resources* implies both recognition of the roles of people - individuals, communities and societies - in sustaining, shaping and harnessing forest biological diversity, and distribution of benefits consistent with such recognition. Benefit sharing regimes must acknowledge the spectrum of benefits and variety of roles which, together, conserve forest biological diversity and make its components available for use.

43. The interaction of ecological, genetic and anthropogenic forces which have shaped, and which will shape the future of, forest biological diversity determine that the conservation and sustainable use of biological diversity, and the fair and equitable sharing of benefits arising from its use, are not separable activities; rather, they represent complementary, interdependent and associated perspectives on the

spectrum of possible outcomes of human intervention in biological systems. This principle, of the mutually reinforcing roles of the Convention on Biological Diversity's objectives in relation to forest biological diversity, pervades the subsequent discussion.

3. Realising the objectives of the Convention on Biological Diversity for forest biological diversity

44. Our understanding of forest biological diversity, and of prevailing institutional structures and functions relevant to it, suggest issues and priorities relevant to realisation of the Convention on Biological Diversity's objectives for the particular case of forests. The following discussion considers such issues and priorities, and notes their correspondence with the provisions of the Convention.

3.1 Institutional structures and functions

45. The Articles of the Convention on Biological Diversity which restate the principle of sovereignty and responsibilities of nation states (Articles 3 & 4) reinforce the institutional framework long-established for the stewardship of forests. A brief synopsis of the history and scope of forest policies illustrates both this concordance and the limitations of traditional forest-related policy frameworks in terms of the objectives of the Convention on Biological Diversity.

3.1.1 A brief history of policies about forests

46. Most nations or their constituent administrative regions (*e.g.* states, provinces) have formally declared forest policies to express the principles by which the forests under their control - at least those in public ownership - should be managed. Such formal forest policies have a long history, originating in the 18th century in Europe and in the next century in India, and they have almost universally been founded on the dual principles of the sustainable harvesting of forest products and management for multiple products and benefits. Thus, whilst principles of conservation and sustainable use have formed the basis for forest policies since their inception, these objectives have usually been expressed in terms of a relatively limited range of forest products and services, typically with a focus on those with a direct or commercial value. More recent forest policy statements have recognised explicitly the broader range of forest values, including biological diversity, and some have recognised the principles of benefit sharing with local communities and of co-management. Correspondingly, forest policy formulation has acknowledged that many other public policies affect forests, and may be of more consequence for the conservation and sustainable use of forests than are forest policies *per se*.

47. The substantial - often overwhelming - influences of policies directed at non-forest issues - *e.g.*, those concerned with agriculture, regional or industrial development, or trade - have been long acknowledged as of fundamental importance to the success or otherwise of "forest" policies. However, public policy priorities which have favoured conversion rather than conservation of forests, and associated institutional constraints, have frequently restricted this acknowledgement to the level of rhetoric. As the rate of forest ecosystem loss and genetic erosion has accelerated over the past few decades, the obvious limitations of "forest policies" isolated from "policies about forests" are shifting the terms of discussion and action to the latter.

48. As the objectives of the Convention on Biological Diversity are broadly consistent with those already declared by governments for forests under their control, the Convention offers the prospect of a compatible integrating framework, within which hitherto disparate policies can be co-ordinated to better

realise the objectives of the Convention (Article 6). Two of the policy arenas for which closer integration with “forest policies” would be of immediate and enduring value to the achievement of the objectives of the Convention on Biological Diversity are those concerned with conservation through reserves, and those which affect the management of forests in private ownership. Other elements of public policy likely to be important in the formulation of national strategies effective in the sense of Article 6 are those identified in 1.3.2.

49. Policies directed at the conservation of forests through the establishment of strict reserve systems have usually been formulated and implemented by agencies other than those responsible for conserving and managing forests for production. Typically, conservation strategies have focused on establishment and maintenance of a reserve system to fulfil ecosystem, species or landscape conservation objectives. Allocation of forests to meet these conservation objectives has been competitive with, and often subsidiary to, allocation to other uses. In the absence of policies integrating conservation strategies across forests managed by different agencies, there has often been poor co-ordination in the realisation of conservation objectives within and without reserves, and consequent sub-optimal achievement of conservation objectives.

50. A limitation of major consequence to the scope of most public policies about forests is their restricted jurisdiction over forests under private ownership or control, with consequences for the conservation of forest biological diversity similar to those described above. Although a range of incentives and regulations may be employed to promote conservation and sustainable use, the effectiveness of these measures varies widely. Indeed, some have acted as perverse incentives for the conversion or unsustainable management of forests. National strategies which recognised that forest ecosystems and populations transcend tenurial boundaries would advance considerably the cause of the conservation of forest biological diversity. There are, however, encouraging examples of initiatives within the private sector, and of partnerships between the private, government and non-governmental sectors, which illustrate the potential of private ownership and enterprise to contribute to the conservation and sustainable use of forest biological diversity.

3.1.2 Institutional structures for co-operation in research, training, education and the exchange of information

51. The history of national (and sub-national) responsibility for forest management and forest genetic resources has fostered the development of various institutional structures to promote co-operation and information exchange between agencies and individuals, in support of national programmes. These structures comprise both institutions and co-operative mechanisms, which operate on bilateral and multilateral bases, within and without governments. Some are mandated with specific responsibilities in relation to forest biological diversity, whereas for others this role is more implicit within a broader charter.
An indicative but not exhaustive classification of these institutional structures for the case of forest biological diversity might be:

Mode of operation	**Examples**[1]

1 CIFOR - Center for International Forestry Research; CSIRO ATSC - CSIRO Australia, Australian Tree Seed Centre; FAO - Food and Agriculture Organisation of the United Nations; DANIDA TSC - Danish International Development Agency, Tree Seed Centre; ICRAF - Centre for International Research in Agroforestry; IPGRI - International Plant Genetic Resources Institute; IUCN - The World Conservation Union; IUFRO - International Union of Forest Research Organisations; ODA - Official Development Assistance; OFI - Oxford Forestry Institute; TNC - The Nature Conservancy (USA); WCMC - World Conservation Monitoring Centre; WWF - World Wide

Multilateral government	CIFOR, FAO, ICRAF, IPGRI
Multilateral non-government	IUCN, TNC, WWF
Multilateral informal	IUFRO
Bilateral government	National ODA agencies
Global centres	WCMC
National institutions with assumed international responsibilities	CSIRO ATSC, DANIDA TSC, OFI

52. These institutional structures already promote, facilitate and support co-operation in research, training, education and the exchange of information relevant to forest biological diversity (Articles 12, 13, 17, 18). However, the low status historically accorded forest genetic resources relative to that of crop plants has placed much of the onus for strategic development, co-ordination and action on those national institutions which have been able to assume international responsibilities, on informal collaborative structures, and more recently on non-governmental organisations. Few of these are well-resourced. It is not a lack of institutional structures, but of adequate and effective support for those which already exist, which most limits co-operation in research, training, education and the exchange of information relevant to the conservation and sustainable use of forest biological diversity.

3.2 The conservation of forest biological diversity

53. The conservation of forest biological diversity embraces conservation *in* and *ex situ* (Articles 8 and 9), demands effective identification and monitoring (Article 7), and is supported by both the sustainable use (3.3) and the fair and equitable sharing of benefits arising from the utilisation of forest genetic resources (3.4).

3.2.1 Conservation *in situ*

54. The complexity of forest ecosystems, the dominant role of tree species in them, the environmental and economic value of forests and trees, and the poor conservation status of most tree populations *ex situ*, has led to the characterisation of forest trees as a paradigm of *in situ* conservation. Effective *in situ* conservation (Article 8) demands that both ecosystem function and process, and intra-specific population genetic processes, are maintained in a network of sites which are comprehensive and representative in terms of all levels of genetic organisation.

55. Traditional conservation strategies have envisaged a reserve system of protected areas, the ultimate expression and focus of *in situ* conservation, buffered by land uses which operate in support of *in situ* conservation objectives. The identification of priority areas for protection is a critical element in any strategy for the conservation of forest biological diversity. The selection of these priority areas, which are then managed primarily for the protection of biological diversity, involves the development of management objectives, and the planning and implementation necessary to realise them. An array of sophisticated approaches have now been developed to aid the selection of priority areas; a prerequisite is data describing the distribution of selected biodiversity surrogates; sub-sets of species, species assemblages, environmental parameters, or combinations of these (3.2.2). The choice of surrogates will depend in part on the degree of urgency and the data that are already available, but should also be informed by new surveys designed explicitly to minimise spatial bias, and by local ecological knowledge. These new methods are based on the concept of complementarity, *i.e.* that protected areas should complement one another in terms of the biological diversity they represent; they should contribute

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different components of biological diversity so that the system of protected areas, taken as a whole, maximises representation.

56. The establishment of protected areas is a necessary but insufficient condition for the conservation of biodiversity. Reserve models based on population genetic principles, using various measures of population viability, suggest that very large areas may be required for the conservation *in situ* of many forest tree and animal species. For example, some tree species occur at densities of less than one per hectare, or have reproductive systems which promote mating between geographically disparate individuals, implying minimum area estimates for viable populations in the hundreds of hectares; estimates on the same basis for predatory forest animal species can be in the millions of hectares. These ideal reserve models pose three major problems for *in situ* conservation of forest biological diversity. The first relates to the location of reserves, the second to their size, and the third to risks associated with reliance on relatively few sites.

57. The history of establishment of protected areas - typically on sites less favoured for agriculture or production forestry - implies that national reserve systems almost invariably represent a biased sample of ecosystems and populations, with an over-representation of uplands and slopes, sites of lower fertility, and stands of lesser economic value, often isolated by their spatial distribution. Similarly, because few have been established or managed according to population genetic principles, they do not necessarily comprise viable populations of forest species; individual reserves are also susceptible to loss associated with catastrophic events, such as wildfire. While ideal reserve models emphasise the importance of large contiguous areas for *in situ* conservation, they also demonstrate the limits of the role of fully protected areas in the conservation of forest biological diversity. The mobility of many forest animal species, the scattered spatial arrangement of subpopulations within metapopulations, the extensive geographic distribution of most tree species, the reproductive biology of tree species and the high levels of gene flow between populations, and the large areas associated with minimum viable populations of many tree and animal species, emphasise the essential contribution of forests outside reserves to the conservation of populations within protected forest ecosystems. In reality, it is through the management of forests and trees outside reserves2 that most *in situ* conservation of forest biological diversity will be realised.

58. This conclusion highlights the roles of indigenous and local communities, and those of the managers of forests and trees outside reserves, in the conservation and sustainable use of forest biological diversity (Article 8j). It similarly emphasises the importance of the rehabilitation and restoration of degraded ecosystems (Article 8f) in the conservation of forest biological diversity, and suggests the use of metapopulation models of population structure and function to design and implement *in situ* conservation strategies. A metapopulation perspective on the demographic and genetic dynamics of individual species recognises that populations of a species wax and wane over time, within and across forest ecosystems or reserve boundaries; individuals and populations, variously linked by gene flow to form the overall metapopulation, play a dynamic role in the conservation of genetic diversity. Whilst the fate of specific populations depends on their particular population biology, the decline or demise of individual populations does not necessarily threaten the stability of metapopulation or conservation of its genepool, so long as other populations arise. A metapopulation perspective also emphasises the challenges inherent in the identification and monitoring of those components of forest biological diversity important for its conservation and sustainable use.

3.2.2 <u>Identification and monitoring</u>

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2 Sometimes defined as *circa situ*, to emphasise its distinction from conservation within reserves.

59. Given the complexity and dynamism of forest biological diversity, the identification of those components important for its conservation and sustainable use, and the monitoring of both these components and the effects of interventions (Article 7) - in terms which are both biologically meaningful and operationally feasible - are far from simple tasks. Because complete inventories of biological diversity are impractical, we are forced to approximate the totality of forest biological diversity with a series of surrogate measures, each of which has its own utility, but none of which is adequate in its own right.

- Genetic measures

At the level of variation within species and populations, various measures of allelic richness and evenness derived from assessment of the proteins or DNA of individuals inform us of levels and patterns of diversity. The different characteristics of these systems, and the different levels of technology, costs, and information associated with each, lends them to different purposes. For example, isozyme and RAPD markers are relatively simple and cheap to use, suggesting a primary role in extensive screening and characterisation of broad patterns of variation; the differential inheritance of organellar DNA, variation in which can be assessed using (currently) more laborious and expensive RFLP technology, suggest a role for this information in the identification of distinctive populations meriting priority for conservation.

- Non-genetic measures

At the landscape level, four categories of surrogate are feasible - a subset of species, ecological assemblages, environmental parameters, and combined surrogates:

- *Subsets of species*

Although some species or species groups appear to act, at some sites, as indicators or predictors of overall biological diversity, there is little evidence that any such subset can reasonably represent biological diversity *in toto* with any generality. Nevertheless, in ecosystems where many species are unknown or undescribed, as is the case for many tropical forest systems, the comparatively well-known and easily assessed tree flora may provide a first approximation to conservation priorities.

- *Ecological assemblages*

Ecological assemblages such as communities or habitat types are inevitably defined more loosely than is a species; they incorporate a level of ecological complexity which species cannot, but correspondingly mask finer-scale variation. Larger organisms such as vascular plants and vertebrates are most often used to define assemblages. In this case, and in that of environmental surrogates below, multivariate methods of characterisation are the most promising.

- *Environmental parameters*

Given the seminal influence of environmental variation in defining forest biological diversity, there is a strong theoretical basis for the use of environments as surrogates for biological diversity. Examples of classification systems which characterise variation in the physical environment at this landscape scale are the Australian “environmental domain analysis” and Canadian “ecological land classification”; each has been used as “coarse filter” to identify patterns on a broad (national and regional) scale. They have the advantage of drawing on environmental data - which tend to be more widely available and reliable - than biological data, but suffer similar limitations as do ecological assemblages with respect to fine-scale variation in forest biological diversity, and their value is - as yet - little tested.

- *Combined surrogates*

Consequently, various combinations of surrogates representing the different levels of biological organisation will be required to inform the conservation and sustainable use of forest biological diversity. The obvious limitations of our current knowledge should not restrain us from acting upon it, but do emphasise the importance of directing resources to the development of better measures for identification and monitoring of forest biological diversity. Support for the continuing development of technologies for the assessment of genetic diversity (*e.g.* molecular markers), the collection of more biological information using carefully designed stratified surveys, and the manipulation and interpretation of information (*e.g.* Geographical Information, Database, and Decision Support Systems) would promote realisation of Articles 7a-d. Similarly, further development of methodologies of population viability analyses, and of those for assessing levels of risk and uncertainty associated with both human interventions and conservation strategies, would contribute greatly to decision-making that is more informed in terms of Articles 7b&c. The direction of support for such work, in fulfilment of Articles 7a&b, to those institutions engaged in co-operative research and training (3.1.2) would be consistent with Articles 12, 16, 17 and 18.

60. Subject to the caveats above, we are already aware in general terms of the processes and categories of activities with significant adverse impacts on the conservation and sustainable use of forest biological diversity (1.3). The monitoring of these processes and activities (Article 7c) is simplest for those which impact at the landscape scale, *i.e.* conversion and fragmentation; national, regional and global data sets describing these impacts already exist from remotely sensed images, and are held by national conservation agencies and centres such as WCMC. Advances in information technology are increasing the accessibility and value of such data. Where impacts on ecosystems and populations are more specific, *e.g.* the effects of extractive use or of translocation, existing knowledge and technologies to acquire it in sufficient quantity are poorer. Here, we are likely to continue to rely on extrapolation from detailed studies; thus, resources should be used to support studies designed to provide generalisable results on issues of highest priority, for a range of ecosystems and interventions.

3.2.3 Conservation *ex situ*

61. The *ex situ* conservation status (Article 9) of forest species is generally correlated with the extent of their domestication, and is therefore either poor or non-existent for most. Only a trivial proportion of forest species (*e.g.* around 100 tree species) are conserved adequately *ex situ*. These species are almost exclusively those whose genetic resources have been assembled for domestication programmes, with which almost all substantive *ex situ* forest conservation activities are associated.

62. For the case of forest trees, national and sub-national seed centres or forestry agencies, and a few institutions with international mandate, hold the majority of forest genetic resources in store or in field trials; consistent with Article 9(e), support for these activities has focused increasingly on the country of origin of the genetic resources. The majority of *ex situ* resources, though, are represented by trees established in the forest or farm production systems. The majority of these trees represent a limited and poorly known sample of species gene pools, of limited value to *ex situ* conservation. For forest species, the value of *ex situ* seed storage is further limited by the relatively large number of species, many of economic importance, whose seed is not amenable to storage. Some progress has been made with other storage technologies, consequent to that with crop species, but none is currently operationally feasible for trees. Whilst research to develop these technologies has merit, their technical limitations and cost will continue to preclude their use in other than exceptional cases - emphasising the primary and overwhelming importance of conservation *in situ*.

63. Although crop plants of economic importance and a few animal species have been subject to more concerted *ex situ* conservation programmes than have most tree species, the general conclusions which apply to trees are also relevant to the vast majority of other forest species - the majority of which are not yet described by science.

3.2.4 Introductions of species and genetically-modified organisms

64. The potentially adverse consequences for forest biological diversity of introductions of exotic species have historically received little attention from those associated with their translocation. The risks associated with such introductions, and those potentially associated with the use or release of genetically modified organisms, have now generated sufficient concern to prompt the formulation of guidelines. In the case of species or germplasm introductions, though, these remain voluntary and untested. A strategy which addressed all aspects of the introduction and management of species, germplasm or modified organisms originating from or which could disrupt forest ecosystems, including protocols for testing and control, would support the conservation of forest biological diversity (Articles 8g&h).

3.2.5 Conclusions

65. *In situ* conservation will continue to play a pre-eminent role in the conservation of forest biological diversity, implying priority to those activities which support it. These may be classified into research issues and those measures which act as incentives for conservation. As most investigation of incentive structures has been conducted in the context of sustainable use, that issue is discussed subsequently (3.3).

66. In terms of research, our currently inadequate knowledge of forest metapopulation attributes and processes, and of associated issues - particularly the effects of ecosystem and population fragmentation - demand urgent attention. Without such information, the knowledge base necessary to integrate

conservation within and outside reserves will remain limiting. However, our current understanding of both forest metapopulations and surrogate approximations of forest biological diversity is sufficient for us to review the adequacy of existing reserve systems and, where feasible, enhance them.

67. A fuller appreciation of indigenous and local peoples' knowledge would complement that of metapopulation dynamics. It would better inform us of the consequences for forest biological diversity conservation of both traditional and modern forest and agro- ecosystem management practices, enabling more appropriate management for conservation both within and outside reserves. Research on both these fronts is underway, but remains on a trivial scale relative to both the apparent level of traditional knowledge, on the one hand, and the evident of limits of scientific knowledge, on the other. However, the limits of current knowledge do not preclude action now; because of the profound, pervasive and accelerating impacts of contemporary societies on forest biological diversity, the effective *in situ* conservation of forest biological diversity depends more fundamentally on political choices about resource use and benefit sharing than on the refinement of such knowledge as we do have.

3.3 Sustainable use of the components of forest biological diversity

68. As apparent from the preceding discussion, issues of the sustainable use of the components of forest biological diversity (Article 10) are embedded within, and inseparable from, those relevant to its conservation. Thus, the discussion here focuses on those issues which, whilst of importance to both objectives, are priorities for the sustainable use of the components of forest biological diversity - the products and services of forest ecosystems, and the genetic resources represented by forest populations and organisms.

3.3.1 Ecological perspectives on sustainable use

69. Both traditional and modern management regimes for forests have been based on the principle of sustainable use, manifested by regulation of the level of harvest to within the productive capacity of the forest. Whilst "scientific" forestry since the 18th century has focused principally on the "sustained yield" of wood products, traditional management regimes have applied to a much broader range of, primarily, non-timber forest products. More recently, modern forestry has acknowledged explicitly the importance of maintaining ecosystem function and process to maintaining productivity, and has sought to develop a more holistic approach to ecosystem management, a philosophy encapsulated by the so-called "new forestry". Ecological perspectives, and therefore ecological principles, have been dominant in the formulation of these management regimes, which recognise four elements of fundamental importance to the conservation of biological diversity in forests:

1. The maintenance of connectivity between protected areas. Connectivity benefits conservation, particularly of animal populations, by retaining the potential for exchange between subpopulations of a metapopulation, and for flow from source to sink areas. However, the effectiveness of retained corridors in achieving connectivity varies with species and the attributes of corridors and the landscape matrix in which they are embedded, emphasising the importance of defining their intended roles;

2. The maintenance of heterogeneity across the forest landscape. Key issues associated with landscape heterogeneity are the range of forest age classes represented, the size of forest patches of each, their spatial arrangement, and the impacts of both natural and human disturbance of these spatial patterns. As the size and spatial arrangement of habitat patches is of major

consequence for the persistence of some species, management regimes must account for the relationship between landscape heterogeneity and the spatial requirements of species;

3. The maintenance of structural complexity and floristic diversity within forest stands. Complexity and diversity at the stand level both reflect and provide the variety of niches which are manifested as biological diversity. Important elements of structural complexity in mature forests include hollow and senescent trees, mature live trees, logs on the forest floor, and understorey vegetation. Floristic diversity may be prejudiced by silvicultural regimes intended to favour a subset of commercial species;

4. Use of an array of management strategies implemented at different spatial scales. Different strategies for the conservation and sustainable use of forest biological diversity can be mutually supportive: for example, the value of protected areas is enhanced by linking them with corridors; the effectiveness of stand-level strategies, such as retention of habitat trees in harvested patches, will be enhanced where corridors facilitate recolonisation of harvested sites. Further, using an array of strategies minimises the risks associated with any one approach. Given the uncertainties of forest management regimes for the conservation and sustainable use of forest biological diversity, such risk-spreading seems prudent.

3.3.2 Genetic perspectives on sustainable use

70. Information on levels and patterns of genetic variation within species has been only sparsely available, and therefore little used to date in determining harvesting regimes. A major challenge to sustainable use of the components of forest biological diversity is the incorporation into ecologically-based management regimes of our emerging knowledge of the genetic structure and dynamics of forest populations. The experimental approach described above should incorporate genetic as well as ecological assessment; the first such comprehensive studies are already underway. The challenge of integrating information from different disciplines applies equally to the scope of methodologies used to assess the impacts of proposed projects on forest ecosystems (Article 14), for which the assessment of associated risk and uncertainty (3.2.2) is similarly relevant.

71. In the case of forests managed for both conservation and production, there are examples from Scandinavia, the Americas and Asia which demonstrate how forest managers have incorporated genetic criteria into forest management strategies and regimes. Experience with forest harvesting operations more generally suggests that, although some income may be foregone in the short term as a result of implementing conservation criteria, such opportunity costs are relatively small: in the short term, because they promote better planning and management of harvesting operations; in the longer term, because of the magnitude of benefits realised or maintained. The major technical obstacle to the more widespread application of conservation genetic principles to forest management is the difficulty of defining criteria and indicators for the conservation and sustainable use of forest biological diversity which satisfy the dual criteria of conservation genetic merit and operational feasibility. This conclusion emphasises the importance and urgency of advancing our knowledge of those components of forest biological diversity important for its conservation and sustainable use (Article 7), *i.e.*, those surrogate measures which will act as criteria for and indicators of forest biological diversity *in toto*.

72. In the interim, a precautionary approach based on current knowledge of forest ecology and forest genetics favours harvesting regimes whose impact at both landscape and local scales is the minimum consistent with the reproductive ecology of the species. This implies that appropriate harvesting regimes will vary with both the ecosystem and the species harvested; for many of these, a precautionary approach

is likely to imply harvesting operations more conservative of ecosystem structure than those to which large-scale industrial forestry has become accustomed.

73. Our embryonic knowledge of the metapopulation structure and dynamics of forest species also suggests that we accord priority to gaining a better understanding of how farmers and other land managers practices affect the genetic resources of forest species. Their practices of forest and tree retention, establishment, management and regeneration - including the processes by which they acquire and distribute germplasm of forest species - will impact on the sustainability of use of those components of forest biological diversity represented in agroecosystems. Such information will allow us to realise sustainable use by embedding production within a conservation context.

3.3.3 Institutional perspectives on sustainable use

74. Improving the knowledge base of forest population dynamics, and of the consequences of traditional and modern farming and forest management practices, will promote the development of sustainable use regimes. However, their implementation will depend more on the economic, political and cultural regimes which determine the balance between the conservation and conversion of forest ecosystems, reservation and production within retained forests, and forest and farm management practices within production systems. The forest policy literature is rich in both theory and example of regulatory frameworks, incentive mechanisms and institutional structures intended to promote the conservation and sustainable use of forests (Article 11). Synthesis of this literature, and of contemporary political thought, suggest an increasing emphasis on market-mediated and innovative institutional mechanisms acting as incentives for sustainable use, partly in response to the obvious limitations and perceived failures of approaches based on the regulatory mechanisms and institutional structures which have typified forest management and conservation agencies in the past.

75. For forest products entering the market place, the prospect of independent certification of the quality of management of the forests from which they originate has emerged as a promising incentive mechanism. Such certification relies upon the definition and implementation of forest management standards consistent with the conservation and sustainable use of forest biological diversity. This prospect reinforces the critical importance of identifying criteria for and indicators of sustainable forest management consistent with both ecological and genetic principles.

76. The advantages of institutional structures which recognise traditional resource rights, and which accommodate and promote participatory modes of forest management, emerge from theory and experience as a second principle of management likely to sustain the benefits and values of forests. Participatory processes are as diverse as the societies and environments in which they have been developed, though emphasis on local knowledge, custom and benefits is a common theme to those which have achieved some measure of success. Resource allocation mechanisms which acknowledge local as well as more distant demands, and direct benefits accordingly, and which recognise the long time horizons inherent in the management of forest ecosystems, are a third principle of policies which foster the sustainable use of forests and, with appropriate management in ecological and genetic terms, that of the components of forest biological diversity. The promotion of policies which incorporate and build from these principles is a priority in advancing the objective of sustainable use of the components of forest biological diversity.

3.4 Fair and equitable sharing of the benefits arising out of the utilisation of genetic resources

77. The genetic resources of forests are rich and diverse, comprising the genes and gene complexes of forest trees, plants and animals. Historically, we have exploited these genetic resources at the level of populations or individual organisms; new biotechnologies have the potential to make these resources available at the level of the gene or gene complex. The benefits arising from the utilisation of forest genetic resources accrue variously to individuals, communities, enterprises and societies both *in* and *ex situ*, but there are as yet few mechanisms which capture or direct these benefits to those who have conserved or developed forest biological diversity.

3.4.1 Access to and benefit-sharing from forest genetic resources

78. Typically, forest genetic resources have been sampled and tested for research and development purposes without restriction, and at nominal or no charge to the collector (Article 15). Where forest genetic resources have been assembled on a large scale, for example the collection of tree seed for operational establishment or of plant material for pharmaceutical screening, some market price reflecting primarily short-run supply and demand has prevailed; the income generated has typically accrued principally to the collecting enterprise, variously a state agency or individual entrepreneur. In the latter case, some level of fee is usually levied by the state or the forest owner. In neither case has it been common for benefits to be shared with indigenous or local communities, except where their resource or property rights have been recognised explicitly.

79. However, access to forest genetic resources is increasingly subject to the negotiation of formal agreements with a range of stakeholders, offering a mechanism for more equitable benefit sharing. Similarly, it is only recently that, in a few cases, pricing mechanisms have acknowledged the potential future value of forest genetic resources, and sought to establish mechanisms to direct substantive benefits - in some form - to local communities, in recognition of their roles as both contributors to and custodians of forest biological diversity; the “biodiversity prospecting” agreement between the pharmaceutical company Merck and the Costa Rican National Institute of Biological Diversity remains the best-known example.

80. A number of limitations apply to the development of regimes which better share benefits arising from the utilisation of forest biological diversity amongst those who have contributed to its development and conservation. These include:

- the diversity of interests at a sub-national level, with national and sub-national governments and management agencies, indigenous peoples and local communities, and individual owners of forest and agro-ecosystems variously responsible for ownership of and access to forest genetic resources (Article 15);

- the consequent difficulties, both pragmatically and politically, of obtaining prior informed consent to access forest genetic resources (Article 15);

- the limited acknowledgement of traditional resource rights by many modern societies, and the consequent difficulties experienced both by groups wishing to exercise such rights and those wishing to recognise them (Article 15);

- the divergence in intellectual property rights regimes between Western legal systems, which require individual and identifiable innovation, and most traditional cultures, which do not assign such rights (Article 16). In the case of forest biological diversity, issues of intellectual property assignment are further confounded by the dynamic nature and evolutionary timescale of biological diversity itself;

- divergent opinions as to the inherent value of forest genetic resources relative to that of the research and development activities which translate genetic resources into marketable products, particularly for the case of biotechnologies (Articles 16 and 19).

81. Overcoming the barriers these issues pose to the fair and equitable sharing of benefits arising from the utilisation of forest genetic resources will require the development of access agreements and property rights regimes which recognise the respective roles of individuals, communities - including indigenous peoples and farmers, and enterprises and agencies, in conserving and developing forest biological diversity. The emerging experience of collaborative resource management, which has its genesis in the rural communities of the South but growing applicability in the North, offers a platform for the development of benefit sharing regimes which are locally-appropriate.

3.4.2 Applications of biotechnologies

82. The potential of biotechnologies to exploit forest genetic resources has focused attention on the relative magnitudes of the inherent and developed values of forest genetic resources. The wild relatives of crop plants or of the few intensively-domesticated tree species have potential value as a source of genes for incorporation, whether by classical breeding or genetic engineering, into domesticated populations. Similarly, those forest organisms with potential pharmaceutical value are recognised as of sufficient potential value to justify substantial expenditure. In these cases, genetic engineering does offer the prospect of substantial financial returns, but its application is dependent on highly-domesticated populations, high levels of genetic information, and high levels of technology, all of which imply high costs.

83. In other - more typical - cases, though, the financial benefits arising from the application of biotechnologies to forest genetic resources seem limited in the foreseeable future. This is because the biotechnologies of most application to the undomesticated populations which typify forest biological diversity are the molecular markers which, whilst of great value in assessing genetic diversity, deliver no financial gain in themselves. Their value lies instead in the provision of information to enable development of more effective strategies for the conservation and sustainable use of forest biological diversity. Existing co-operative institutional structures (3.1.2) have an important role in maximising the benefits derived from the application of these technologies.

3.4.3 Conclusions

84. As with the conservation of forest biological diversity and the sustainable use of its components, realising the objective of the fair and equitable sharing of the benefits arising out of the use of forest genetic resources depends fundamentally on political choice; in this case, about relative responsibilities, rights and values.

The terms of discussion about these political choices reflect the diversity of opinions about:

- the relative responsibilities and rights of various stakeholder groups, in the development and conservation of forest biological diversity, and;

- the relative values of forest genetic resources, the products developed from them, and the technologies which effect that development.

4. Conclusions

85. Forest biological diversity is complex, heterogeneous and dynamic. Although still rich in both absolute and relative terms, it has been much diminished by the impacts of human societies. Those impacts are greater now than at any time in human history, and they are still accelerating. They are eroding contemporary forest biological diversity, and challenging the processes which maintain it in forest communities and their constituent populations.

86. Forest biological diversity is shaped by complex interactions between the physical environment, the biology of forest systems and populations, and the influences of individuals and societies. Our response to its loss must recognise these forces and their interdependencies. The Convention on Biological Diversity offers an effective framework for such a response. Priorities for the conservation and sustainable use of forest biological diversity are:

- Recognition that the conservation and sustainable use of forest biological diversity, and the fair and equitable sharing of benefits arising from utilisation of genetic resources, are inseparable and mutually supportive goals;

- Development of policies, national strategic plans, intersectoral linkages, laws and a common vision to promote and support new initiatives in integrated conservation and sustainable use of biological diversity;

- More effective support for those institutions already active in research, training, education and the exchange of information relevant to the conservation and sustainable use of biological diversity;

- Expansion of the network of areas managed for the conservation of forest biological diversity, to adequately represent the variety of forest ecosystems, key forest habitats, priority forests in terms of the richest biodiversity and/or uniqueness, and forests which host rare, endemic or endangered species. Development of mechanisms and instruments to ensure long-term financing of protected areas and other conservation measures. Continuous monitoring and financial control are essential during this process;

- Acknowledgement of the fundamental importance of forests and trees outside reserves to *in situ* conservation of forest biological diversity, and therefore of the roles of indigenous and local communities, and of the managers of forests and trees outside reserves, in the conservation and sustainable use of forest biological diversity;

- Acknowledgement of traditional access and user rights of forest-dependent people to utilise and benefit from forest products, where this is consistent with conservation of biodiversity.

Develop and strengthen cross-sectoral linkages to provide appropriate support mechanisms covering all sectors relevant to local community needs;

- Research to better define and describe

  1. landscape-level ecosystem processes and forest metapopulation structure

  2. site and region specific management practices based to ecosystem approach along biomes, ecoregions, formations and life-zones as well as according to disturbance regimes and natural regeneration dynamics and site-specific edaphic conditions

  3. impacts of historic and modern human influence to the biological diversity of forests

  4. economic incentives which may provide means to reduce deforestation and improve the quality of forests

  5. indigenous and local peoples' knowledge of, and practices which impact on, forest biological diversity

  6. criteria and indicators for sustainable forestry;

- Restoration of forest ecosystem services and functions at key sites;

- Strengthening monitoring and evaluation process to better assess the impacts of forest management regimes, and implementing adaptive management to continually improve the outcomes of these regimes for the conservation and sustainable use of forest biological diversity;

- The integration of modern and traditional knowledge of forest biological diversity;

- The development of access agreements and property rights regimes which recognise the respective roles of diverse stakeholders in conserving and developing forest biological diversity.

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