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MAIN THEME: MOUNTAIN BIODIVERSITY

Status and trends of, and threats to, mountain biological diversity

Note by the Executive Secretary

EXECUTIVE SUMMARY

At its fourth meeting, held in 1998, the Conference of the Parties in its decision IV/16 selected mountain ecosystems as one of the items for in-depth consideration during its seventh meeting. In the same decision the Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA) and other subsidiary bodies were requested to prepare proposals for their programmes of work on this subject. At its seventh meeting, SBSTTA decided that mountain biological diversity would be the main theme for its eighth meeting.

In decision VI/30, the Conference of the Parties welcomed the proposals put forward by the Executive Secretary in his note on preparations for its seventh meeting, and requested the Executive Secretary the full preparation of the theme on mountain biological diversity. With regard to this theme, the Executive Secretary carried out an analysis on the status and trends of, and threats to, mountain biological diversity, including the information provided by Parties on the thematic report on status and trends of mountain ecosystems, pursuant to decision VI/25 of the Conference of the Parties. An analysis of the information indicates that, *inter alia*:

(a) Mountains cover about 25 per cent of the Earth's terrestrial surface. About 12 per cent of the world's population lives in the mountains, but over 50 per cent are directly or indirectly dependent on mountain resources. This imposes a threat to both the functioning of mountain ecosystems and the good and services they provide;

(b) Ecosystem types such as forests, dry and sub-humid lands, and inland waters, a well as agricultural ecosystems, are an integral part of mountain habitats and, therefore, most of the information

* UNEP/CBD/SBSTTA/8/1.

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that pertains to those thematic areas is also applicable to mountain ecosystems. In addition, there are some ecological attributes that specifically apply to montane regions. These features include, among others:

(i) The vertical superimposition of climatic zones and the varied topography—and the specialist plant and animal life in each zone—make mountains, for a given unit area, unique centres of biological richness in many parts of the world;

(ii) The alpine zones of temperate mountain areas contain large proportions of endemic species that are confined either to specific mountain tops or groups of mountains. In the tropics, the montane forest zone appears as another major area of high levels of endemism;

(iii) Species form community assemblages, the variety of which is related to landscape geomorphic diversity, parent rock material, and local climate. Because mountain terrain is topographically diverse, there is a high microhabitat diversity that, in turn, favours high levels of agricultural species diversity;

(c) Mountain biological diversity is of high importance for a number of ecological functions. The integrity of soils is the prime capital for ecosystem services and human needs. Soil retention and slope stability are closely connected with the extent of above-ground and below-ground vegetation, both essential to ecosystem resilience after disturbance (e.g., high rainfall, avalanches, trampling). The high plant functional diversity of mountain ecosystems may also add to their resiliency and, should extreme disturbances occur, often provides effective barriers to high-energy events such as rockfalls and avalanches. It also may reduce extensive damage levels at lower elevations;

(d) Mountain ecosystems are subjected to a variety of pressures and threats:

(i) Human land use has a long history of ever increasing proportions in the mountains world-wide. Timber, non-wood products, traditional medicines and game from forest, fish from mountain rivers and lakes, a number of domestic ungulates from grasslands, and an array of mountain crops are used by humans. Conversion from forest to crop or grazing-land greatly reduces species and structural diversity, and soil overuse leads to irreversible degradation involving complete soil loss due to accelerated erosion;

(ii) Global climate change is likely to increase high-energy disturbances naturally associated with mountains, and the frequency and intensity of these disturbances may increase with respect to background levels. Water provision to lowland areas is also likely to be affected as glaciers melt due to planetary warming. Additionally, global climate change is likely to—or it has already started—to exert negative effects on the mountain biota, in particular at promoting local extinctions;

(iii) Mountain environments are not isolated but inextricably linked. Deleterious impacts arising from uphill land-use changes will eventually manifest themselves downhill, both in environmental and economic terms. Human activities that typically concentrate on lowland areas (i.e., industrial pollution, emission of greenhouse gases) will have an impact on the environment uphill. Likewise, poorly conceived infrastructure projects, unsustainable tourism practices, and quarrying and mining, when carried out at high elevations, may affect low elevation areas. There is therefore a need for a holistic, upland-lowland vision;

(e) There is still no clear picture of the trends of mountain biological diversity. However, while several of the world's mountain areas are in relatively good ecological shape, many face accelerating environmental and cultural decline. Although it is beyond doubt that human land use has greatly altered mountain ecosystems, the exact nature of some of the changes and future trends has yet to be established. There is a strong need to foster the implementation of ecological monitoring programmes to ensure the sustainability of land-use systems, to develop indicators of environmental change, and to assist efforts for ecosystem restoration, particularly within tropical latitudes;

(f) Each mountain region is inherently complex, making conservation and sustainable use of mountain ecosystems at times a site-specific task. However, the lack of information for effective policy-making appears as a general trend across all mountain regions of the world. Management prescriptions based on scant scientific data, and cross-site extrapolations of mountain-based information, are common. About 80 per cent of the world's mountain population lives below the poverty line, warranting targeted research as a priority action in mountain environments;

(g) Biological inventories are at best incomplete for most mountain areas in developing countries, and the available data can neither be generalized nor used for effective monitoring. There should be further field data collection for a global database for monitoring, including existing data, which must incorporate climatic variables;

(h) For mountain environments, it is recommended that there should be an emphasis on taking an upland-lowland view, together with a functional-linkage approach in terms of priority actions for management and conservation, as well as research activities and information needs.

SUGGESTED RECOMMENDATIONS

Suggested recommendations on the status and trends of, and threats to, mountain biological diversity are included in the consolidated set of suggested recommendations under item 4 of the provisional agenda for the eighth meeting of SBSTTA contained in the note by the Executive Secretary on proposed elements for a programme of work on mountain biological diversity (UNEP/CBD/SBSTTA/8/7).

CONTENTS

I. INTRODUCTION

1. At its fourth meeting held in 1998 the Conference of the Parties in its decision IV/16, decided to consider mountain ecosystems as an in-depth item for consideration during its seventh meeting. The Subsidiary Body on Scientific, Technical, and Technological Advice decided at its seventh meeting that mountain biological diversity would be the main theme for its eighth meeting.

2. In its decision VI/30, the Conference of the Parties welcomed the proposals put forward by the Executive Secretary in his note on preparations for the seventh meeting, and requested the full preparation of the theme on mountain biological diversity. With regard to this theme, the Executive Secretary planned, *inter alia*, to compile information on the status and trends of, and threats to, mountain biodiversity, as a basis for drafting a programme of work on mountain biodiversity.

3. Accordingly, the Executive Secretary has prepared the present note on the status and trends of, and threats to, mountain biological diversity. It reviews the general environmental and biological characteristics of mountain environments as a function of altitude and latitude. Section II provides an overview of the characteristics of mountain biodiversity at the ecosystem, species and genetic level. Section III provides an assessment of main ecosystem functions in terms of goods and services, while section IV discusses threats and pressures, including current human activities that exert negative effects on mountain biota.

4. Previous drafts of the present note were circulated to a wide range of experts and relevant institutions dealing with mountain issues, and it was posted for peer review on the website of the Convention on Biological Diversity.

5. Pursuant to paragraph 10 of decision VI/25, on national reports, thirteen Parties and one non-Party submitted thematic reports on mountain biological diversity: Algeria, Canada, Colombia, Estonia, European Community, Netherlands, Peru, Poland, Singapore, South Africa, Switzerland, The former Yugoslav Republic of Macedonia and Thailand. Relevant information derived from these reports is included in specific sections of the note.

II. CHARACTERISTICS OF MOUNTAIN ECOSYSTEMS

A. Ecosystem level

1. Bioclimatological donation of mountain ecosystems

6. In the present note, the term "mountain" is used in a rather broad sense, and mountains are discussed in relation to bioclimatic altitudinal zones 1/ which are the composite outcome of latitude, altitude and local topography. Mountain ecosystems form a continuum along an altitudinal gradient. However, with regard to biodiversity, interconnected zones can be distinguished: (i) middle and lower forest montane; (ii) upper montane forest; (iii) tree line; and (iv) alpine life-zone.

Alpine life-zone

7. From an ecological standpoint, the altitudinal distribution of mountain life-zones largely corresponds to "belts" of similar temperature (isolines). The term alpine, throughout this document, refers to the bioclimatic zone above the natural tree-line across all latitudes. Accordingly, it includes local terms such as afro-alpine (for tropical Africa), tropical alpine, and *páramo* and *puna* for South American tropical mountains. Mountains whose elevations reach above the tree-line fall into two broad categories: humid alpine type and arid mountains. The humid alpine ecosystem features low atmospheric

1/ Corresponding to the GMBA-DIVERSITAS classification; see the figure on page 18 below.

pressure, low mean temperatures, either low (in the temperate zone) or high (in the tropics) daily temperature oscillations, high solar radiation levels, and a positive hydrological balance. Arid alpine environments, in contrast, have a desert-like habitat, and their plant and animal life usually shows different adaptations from their counterparts in wet localities.

8. The floristic diversity of the alpine zone partially results from both ancient and recent past climate changes and contemporary human land use. While distant mountains are very similar in terms of diversity of plant life forms (i.e., presence of trees, shrubs, rosettes, tussock grasses, and cushion plants), the species composition among them differs. For example, a unique feature of most tropical alpine zones is the presence of morphologically similar, "giant rosettes", from diverging plant genera (*Espeletia* and *Puya* in the New World, and *Senecio* and *Lobelia* in Africa).

9. Within the alpine zone, nival environments represent extreme abiotic conditions; successful adaptation to low temperature and nutrient limitation are keys to plant and animal survival and for site colonization after glacial retreat. 2/ The alpine and nival zones, when they occur, form inseparable units with the montane and lowland zones and are an integral part of mountain watersheds. Their functioning and the services they provide are closely interconnected.

Tree-line

10. The tree-line is a transition zone between the upper montane forest limit and the alpine zone. In arid mountains, there is usually a lower and an upper tree-line, thus generating a natural forest belt in between. In temperate mountains, one or very few tree species grow in the tree-line zone while tree-lines are far more species-rich in tropical mountains, particularly in the Andes. In the Eastern African high mountains, e.g., Mt. Kenya, the tree line is composed of a bamboo zone, tall scrub, and shrubs. In the subtropical arid mountains of South America, a tree-line is entirely lacking.

Upper montane forest

11. The upper montane forest is the uppermost part of any closed forest zone. It is sometimes referred to as "subalpine" forest. Its elevational range and floristic composition, vary with latitude and geographical region. For example, upper montane forest occurs between 900 and 1500-2000 m in the European Alps, in Tropical South America between 2 000 and 3 800 m, and, at much lower elevations, in the oceanic islands and isolated mountains.

Middle and lower montane forest

12. The middle and lower montane forest zones occur below the upper montane zone, and their altitudinal limits also vary with respect to latitude, rainfall paterrns, and geographic position (e.g., continental vs. oceanic mountains). In arid locations, middle and/or lower montane forests may be inexistent (e.g., in the Arabian Peninsula).

2. *Global distribution of mountain ecosystems*

13. About 3% of the terrestrial surface of the Earth is covered by alpine ecosystems (the montane zone, in turn, corresponds to about 14% of the Earth's surface). In most areas of the world, alpine habitats occur in isolation. A notable exception is the Andes range, where alpine ecosystems stretch almost uninterruptedly from tropical to sub-Antarctic latitudes.

2/ See, for example, Koerner C. (1999) Alpine plant life. Springer, Berlin, Heidelberg, New York, andKaufmann, R. (2002) Glacier foreland colonisation: distinguishing between short-term and long-term effects of climate change. Oecologia **130**: 470-475.

Tropical regions

14. According to published estimates from the *Forest Resources Assessment 2000*, produced by the Food and Agriculture Organization of the United Nations, about 3.4% of the Earth's area in the tropics falls in the montane 3/ and alpine (including nival) zones. The largest extensions of mountains within the tropical belt are found in South America (190 M ha), followed by Africa (147 M ha) and Asia (88 M ha). There are relatively smaller areas in North and Central America and in Oceania. The mountains of the tropics present a wide variety of geological, geomorphological, edaphical, climatological, and vegetational features. They range from comparatively flat highland plateaux (Ethiopia) to the anciently eroded glaciated volcanic peaks of East Africa (Mt. Kilimanjaro in Tanzania), the geologically young high ranges of the Andes, and to limestone peaks with patchily distributed vegetation in South-East Asia (Mt. Kinabalu).

15. The largest montane and alpine areas in the subtropics are found in Asia (351 M ha), with far smaller areas in North and Central America, Africa, South America and Europe. Many (seasonally) arid mountains belong to subtropical mountain environment, a notable feature being that of the Mediterranean alpine zone through the presence of thorny, cushion plants. Plant communities of endemic species typical of these habitats are found in the Sierra Nevada of Spain above 2,800 m and in the central Chilean Andes above 2,000 m. 4/ 5/

Temperate regions

16. The most extensive areas of montane and alpine areas are found in the Asian temperate zone (418 M ha), followed by North America (about 197 M ha), Europe (about 87 M ha), and South America (8 M ha). In Europe, nival summits are clustered in the Alps and the Caucasus, with a few peaks in the Pyrenees. In the nival zone, scattered assemblages of cushion plants, small rosette plants, and small grasses grow in favourable sites.

Boreal regions

17. Boreal montane and alpine areas occur in Europe (Scandes, Urals) and North America (Alaska Range and the Mackenzie Mountains). Boreal mountains are special in that their alpine zone grades into arctic tundra at high latitudes. Boreal and arctic alpine environments receive moderate snow in winter and are characterised by severe frosts leading to continuous erosive processes due to cryoturbation, solifluction and gelifluction, resulting in patterned ground over large areas. Glaciers cover most of the nival zone.

Other landscape elements common to mountains

18. Wetland ecosystems are associated with watercourses (springs and rills) and areas where topography, impaired drainage and excess irrigation (from snow/ice melt, rain, or upwelling ground water) provide all-year round waterlogged conditions. Wetlands have a distinct species composition at any elevation where they occur, much different from those of other ecosystems, because of the specific life conditions they offer.

3/ It should be noted that the FAO figures refer to montane forest at tropical latitudes from 1000 m elevation upwards. In the scientific literature, 1000 m is normally considered as the upper limit of lowland tropical evergreen forest. The lower limit of montane forest is put at c. 1500 m, with 500 m in between being considered as an ill-defined transition zone – sometimes called submontane.

4/ Grabherr G, Nagy L, Koerner C, Thompson DBA (in press) - Overview: an outline of Europe's alpine areas. *In* L Nagy, G Grabherr et al., eds, Alpine Biodiversity in Europe, Springer Verlag, Berlin Heidelberg New York,

5/ Cavieres et al. (2000) Cavieres LA, Peñaloza A, Arroyo MTK (2000). Altitudinal vegetation belts in the high Andes of central Chile (33ºS). Revista Chilena de Historia Natural 73: 331-344

19. Alpine lakes are affected by ice formation and breaking up, level changes through inflow, outflow, drainage, and evaporation. Alpine lakes are naturally low in nutrients, and support a specialist flora and fauna. Eutrophication as a result of human activities, and acidification from pollution, can seriously affect species composition, as can introduction of invasive alien plants and animals.

20. Mountain streams and rivers are the place where run-off concentrates and are characterized by rapid responses to precipitation and evaporation. They are fast flowing in usually deeply cut beds and supply a large amount of sediment downstream. Among aquatic invertebrates, changes in elevation bring concurrent changes in community composition, but not so much in species richness. 6/ Latitudinal changes in species richness are also apparent in glacier fed streams, increasing with decreasing latitude.

B. Species and genetic levels

21. The most conspicuous feature in mountain areas is a high species diversity because of the "compression" along a vertical projection, of a number of ecological life zones which, in the tropics in particular, may encompass the full array of climatic conditions ranging from the humid lowlands to the ice dominated peaks over relatively short horizontal distances. Overall, vegetation may change along a continuum from evergreen tropical rain forest, middle and upper montane forest, tree-line, and alpine vegetation (with the exception of mountains located in dry and sub-humid lands, where the lowlands lack closed forest). Usually above the tree-line, harsh climate requires adaptation to cold and high-altitude conditions resulting in a variety of ecological "strategies" adopted by different components of biodiversity. Specialist predators and scavengers with well-developed thermal and moisture regulation mechanisms are also present.

22. In addition a multitude of contrasting mosaics of habitat conditions for a given elevation such as differential exposure to winds, type of parent rock, local hydrology, and land use, makes mountains centres of high biological diversity. As a result, mountains often harbour a specialized flora and fauna, in particular at high elevations or otherwise isolated peaks, with many endemic species.

23. While moving towards tropical latitudes, overall mountain species richness increases, especially with regard to the number of endemics. Woody species diversity decreases with increasing latitude, and at the individual (mountain) level, it decreases with increasing altitude.

24. A large number of centres of known plant diversity coincide with mountain areas. The high diversity and high proportion of endemics in mountains have resulted in declaring many present "hotspots" as being centred around mountain areas. 7/

25. It is estimated that there are up to 420,000 flowering plants species in the world. 8/ On a global scale, tropical and subtropical mountain areas are the richest biomes in species. Five out of six of the most species-rich areas are centred around, or include mountain massifs: Costa Rica and Panama, tropical eastern Andes (including the mountains of the subtropical Andes and abutting mountains) eastern Himalaya-Yunnan region, and northern Borneo and New Guinea. Other species-rich mountain areas include the Mediterranean and arid mountains, parts of the Rocky Mountains in the United States, the Atlas Mountains, and parts of Central Asia. Overall, Neotropical mountains are very species-rich (over 90,000 species of flowering plants; some 45,000 in the highlands), with epiphytes being a floristically important component.

6/ Monaghan KA, Peck MR, Brewin PA, Masiero M, Zarate E, Turcotte P, Ormerod SJ (2000) - Macroinvertebrate distribution in Ecuadorian hill streams: the effects of altitude and land use. Archiv Fur Hydrobiologie **149**: 421-440

7/ See http://www.biodiversityhotspots.org/xp/Hotspots/hotspotsScience/.

8/ Bramwell D. (2002) - How many plant species are there? Plant Talk 28:32-34

26. In the alpine zone alone, plant species counts are estimated to range from about 8,000 to 10,000 worldwide. This represents about 4% of all the species occurring on about. 3% of the terrestrial surface. In the tropical alpine zones of the Andes, or *páramo*, species-richness is estimated to be between 3,000 to 4,000, with about 60% of them being endemic. 9/ In contrast, the estimated number of species in Europe's alpine areas, excluding the Caucasus, is 2,500. 10/ This contrasts with the alpine zone of east African mountains, where vascular species richness is much lower: 77-182. 11/ Some alpine areas show extraordinary levels of endemism: The vascular plant species richness for New Zealand is 613 species, with 93% being endemic. 12/

27. The number of endemic mountain vertebrate species is especially high in the tropical Andes (1,567, or about 46% of the total). Information on invertebrates is more local in scope, so global comparisons are not entirely possible. They are usually available from well-studied sites such as the European Alps, Rila and Balkan Mountains, and or the African mountains. Aquatic invertebrates are being intensively studied, particularly in glacier fed streams and rivers. Reviews of alpine and Arctic soil organisms in Europe are available. 13/

III. MOUNTAIN ECOSYSTEM FUNCTIONING: GOODS AND SERVICES

28. Mountain ecosystems are a source of a diverse array of goods and services at a variety of spatial and temporal scales, whose specific nature may derive from particular ecosystem types embedded within: forests, inland waters, and dry and sub-humid areas. Nevertheless, due to their unique biophysical characteristics (steep slopes, high microclimatic variability over short distances, storage of freshwater in form of ice and snow), mountains provide relatively specific goods and services that are usually linked to, and influenced from, topographical and altitudinal gradients. As such, mountains are important to the five key areas of focus of the 2002 World Summit on Sustainable Development: water, energy, health, agriculture, and biodiversity (WEHAB).

A. Mountain ecosystems and the five key areas of focus ("WEHAB") of the World Summit on Sustainable Development

Water and energy

29. Mountains store and release a large amount of water in a highly dynamic manner. It has been estimated that 68% of total freshwater on Earth is stored in glacier ice and snow. Precipitation falling as ice and snow accumulates, and fast flowing watercourses carry melted water. More than half of the world's people rely on mountain water, which is used for drinking and agricultural activities. The water supply from mountains is of utmost importance in seasonal environments; for example, areas of the eastern slopes of the Andes in central Argentina and the western Andean slopes in northern Chile and Peru are all dependent on mountain sources of water. Montane forests are also critical as water providers

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9/ Luteyn JL, Cleef AM, Rangel OC (1992) - Plant diversity in paramo: towards a checklist of paramo plants and a generic flora. *In* H Balslev, JL Luteyn, eds, Paramo - An Andean ecosystem under human influence, Academic Press, London San Diego New York, pp 71-84

10/ Väre H, Lampinen R, Humphries C, Williams P (in press) - Taxonomic diversity of vascular plants in the European alpine areas. *In* L Nagy, G Grabherr et al. , eds, Alpine Biodiversity in Europe, Springer Verlag, Berlin Heidelberg New York,

11/ Hedberg O. (1992) - Afroalpine vegetation compared paramo: convergent adaptations and divergent differentiation. *In* H Balslev, JL Luteyn, eds, Paramo - An Andean ecosystem under human influence, Academic Press, London San Diego New York, pp 15-29

12/ See Mark AF, Adams NM (1995) - New Zealand Alpine Plants (second edition) Godwit Publishing Ltd, Auckland and McGlone MS, Duncan RP, Heenan PB (2001) - Endemism, species selection and the origin and distribution of the vascular plant flora of New Zealand. Journal of Biogeography 28:199-216.

13/ For example, Broll G. (1998) – Diversity of soil organisms in alpine and arctic soils in Europe. Pirineos **151-152**: 43-72 because of their dual role as cloud interceptors and edaphic regulators of downhill water fluxes (i.e., limiting flooding).

30. Many rivers with high potential energy levels are often used for energy generation. Power generation is usually through hydroelectric development for urbanized areas; rural settlements in the developing world are often without electricity and rely on the use of nearby forest for fuel wood.

Agriculture health and biodiversity

31. A range of medicinal plants and numerous widespread crop types originate from, and have a very high number of varieties cultivated in, the upper montane/alpine *páramo* zones of the New World (e.g. potato, maize, tomato, tamarillo, peppers, chilis, arracacha). Likewise, wheat, rice, beans, oats, grapes, oranges, and rye found new homes in the mountains and evolved into many varieties. The Himalayas, where corn and potatoes were introduced at about the same time as in Europe, have become a secondary centre of diversification for these crops. Because of the high microclimatic variability in mountains—when compared for a given area with the lowlands—levels of genetic diversity are expected either to increase after plant introduction or be intrinsically high for indigenous crop species. In the Andes, farmers grow up to 50 different potato varieties, which are locally adapted to varying microclimatological and edaphical conditions. High genetic diversity is a critically important component for activities on crop genetics and selective breeding, and for adapting to local and global climate change.

Agricultural production

32. Agricultural production in mountains is limited by the specificity of the environment (restricted accessibility, ecosystem fragility, marginal returns, high landscape diversity) and associated social costs. Crop production is nevertheless widespread in the lower and middle montane zones, and in the upper montane and alpine zones in the tropics. For example, the potato zone is between 2,300 and 2,700 m in Costa Rica and it can reach 4,400 m in the central Andes.

33. About 2% of the world's population are alpine mountain-dwellers (*stricto sensu*), with another 8% living in highlands and middle mountain regions. 14/ Most of these people are found in developing countries where they have lived off subsistence farming for many generations. Traditional farming systems characteristically are small-scale and location-specific, and may use a large number of varieties of crop plants, partially as an insurance against crop failures. Amelioration measures included terracing and ridging with drainage management, and sometimes irrigation. Traditional farming systems at low population density have been found effective in sustainable resource use in mountain systems.

34. The fundamentals of modern agricultural production are based on concentration of land (cultivation of large fields) and, with globalization, often the imposition of cultivation technologies on producers. However, the practice of intensive agriculture in mountain environments is much restricted by the prevalent environmental conditions. The main limits relate to scale (field size), the responsiveness of the crops to inputs (of fertilizer and pesticides), the limited scope for the development of infrastructure, and the market rewarding the surplus product. Modern agricultural production systems are generally not suited for mountain environments, while traditional production at high population density is equally unsustainable.

Agro-forestry

35. Agro-forestry systems are perceived as dynamic, ecologically based, natural resources management systems that can diversify and sustain production for increased social, economic and

14/ Baatzing W, Perlik M, Dekleva M (1996) - Urbanisation and depopulation in the Alps. Mountain research and development **16**: 335-350 environmental benefits for land users at all levels. 15/ They usually comprise a mosaic of forest in an agricultural land matrix with much variation in forest stand or woody species cover and spatial arrangement. Many agro-forestry units reflect the natural progression in land use change from forest to agriculture, initiated by smallholders. In mountain areas, agro-forestry systems are of importance for soil, water and nutrient conservation for sustainable agricultural production. They have also been promoted for the rehabilitation of degraded agricultural land at mid- and high altitude mountains.

B. Other functions of mountain biodiversity

Soil stabilization

36. Soil-retention properties are largely influenced by the degree of ecosystem disturbance: overgrazed and otherwise deforested steep slopes become less stable than undisturbed areas. Extreme rainfall events exacerbate land-sliding and soil creep when the hydrological properties of the soil have been impaired by land use by humans. Surface run-off is enhanced by soil compaction and can result in soil erosion, in heavily perturbed areas. Therefore, adequate soil management on mountainsides is essential both for mountain dwellers and those living in the lowlands as degraded mountainsides offer little in the way of agricultural productivity and offer many hazards. Without a soil-vegetation system in the alpine and montane zones, hydrological regulation largely breaks down which can result in flash floods after major rainfall events downhill. Excessive soil erosion can lead to siltation at lower elevations.

Protection against natural hazards

37. Steep mountain slopes increase the incidence of natural hazards in mountains such as rockfalls, avalanches (ice, snow), debris flows, landslides, and fluvial, wind, and soil erosion. These hazards usually manifest more severely in heavily disturbed environments (e.g., after deforestation). For example, a close correlation has been found between the historical increase in deforestation in the Tyrol (Alps) and the concurrent increase avalanche frequency and severe soil erosion at lower elevations. 16/ The importance of ecosystem integrity in alpine and upper montane environments as an “insurance” against natural hazards to low-elevation areas has been recently emphasized. 17/

Climate regulation

38. Mountains comprise the equivalent of a range of latitudinal climate zones arranged along an altitudinal gradient, and, as mentioned before, have a diverse array of microclimates arising from their varied topography. For example, some of the most extensive highland plateaux such as those in the Tibetan and the Andes, are large enough to have their own climate system. Mountains can intercept moist air masses and create a rain shadow in areas lying opposite from the prevailing wind direction. In arid mountains, clouds may form around a mountain core and cause the girdle forests. In addition, mountains can give rise to local wind systems.

IV. THREATS AND PRESSURES

39. Mountain ecosystems are subjected to diverse natural disturbances, whose review is beyond the scope of this note. However, natural disturbances should be taken into account when designing management systems for mountain ecosystems. Their impacts are usually compounded by the negative effects of human activities.

15/ http://www.icraf.cgiar.org/ag_facts/ag_facts.htm#systems

16/ Ozenda P. (1994 La végétation du continent européen. Delachaux et Niestle, Lausanne

17/ Koerner C. and Spehn E.M. (2002) – Mountain biodiversity. Parthenon, London

40. Human pressure on mountain resources ranges from poorly planned agricultural activities and forest conversion, to global climate change. In addition, the effects of many threats and pressures on mountain ecosystems may be felt at very long distances from their origin. Mountain ecosystems are both fragile and may recover slowly from perturbations due to slope steepness, thin soils, and low ambient temperatures. Among underlying causes of mountain ecosystem degradation and loss of biodiversity, policy decisions that determine the fate of mountain natural resources are made in a centralized fashion, usually away from mountain environments themselves. Due to their remoteness, mountain regions and their people are thus marginalized and receive no or inadequate compensation for the loss of the goods and services mountains usually provide.

A. Land use and deforestation

Agricultural expansion

41. Mountain areas are considered as conservation "hotspots", or areas of exceptional species richness and endemism. The estimates of hotspot land affected by land use by humans can be very high for some regions: 75% in the tropical Andes; 90% in the Caucasus; and 92 % in the mountains of south-west China. 18/ Thus there has been a sustained loss of mountain biological diversity in these regions, especially so in developing countries. The rate of loss of montane forest cover in some of these regions may be the main direct cause of local plant extinction. 19/

42. Nevertheless, to satisfy the food requirement of an ever-increasing population, agricultural land use has largely expanded and low quality marginal lands in the mountains are increasingly being brought under cultivation. The opening up of mountain-dwelling societies to external influences has increased the demand for material goods, and agricultural production has intensified. Beyond their local impacts on biodiversity, both intensification and extensification of agriculture have wider environmental consequences. Excess fertilizer and pesticide outwash causes contamination, including eutrophication of water resources. Soils are being put under pressure, with, as discussed above, potentially negative consequences for downhill hydrological balance. The cost of environmental damage caused by the cultivation of marginal land is likely to far outweigh the benefits local farmers may derive.

Uncontrolled logging and deforestation

43. Mountain forest use has traditionally involved the lowering of the tree-line through land clearing for pasturing and agriculture, rural settlement, and small scale extractive uses. However, large-scale extraction of timber species characterizes today's forest harvesting. Selective logging schemes, particularly in the tropics, are often unsustainable as the levels of extraction of commercially valuable trees (allowable cut and return cycle) are such that they inevitably lead to forest degradation. 20/. Such approaches, which are concerned with profit maximization without taking into account the many associated environmental and social issues and environmental values are bound to cause lasting environmental damage. Nevertheless, ecological sustainability of selective, reduced-impact logging operations has been reported in some tropical, upper montane localities. 21/

44. Large-scale logging and the associated timber-extraction activities may have both local and downslope ecological and socio-economic consequences. If clear-cutting is a harvesting option, or when

18/ See http://www.biodiversityhotspots.org/xp/Hotspots/hotspotsScience/

19/ See, for example, Etter A. and van Wyngaarden W.(2000) - Patterns of landscape transformation in Colombia, with emphasis in the Andean region. Ambio 29: 432-439; and Etter A. and Villa LA (2000) - Andean Forests and farming systems in part of the Eastern Cordillera (Colombia). Mountain Research and Development **20**: 236-245

20/ See, for example, Thompson, I., et al. (2002). Review of the status and trends of, and major threats to, the forest biological diversity. CBD Technical Series 7. Secretariat of the Convention on Biological Diversity, Montreal.

21/ See, for example, Romero C. (1999) - Reduced impact logging effects on commercial non-vascular pendant epiphyte biomass in a tropical montane forest in Costa Rica. Forest Ecology and Management **118**: 117-125 deforestation occurs, the removal of forest cover negatively influences slope stability and hydrological properties. An estimated value of protection functions, such as flood and avalanche control, protection against erosion, and conservation of water quality of montane forests in Austria ranges from €130 billion to €290 billion using technical replacement costs without discounting. Costs can range from €36 billion to €87 billion, when assessed by replacement cost of technical intervention with high discounting for 50 years. 22/ Slope stability may suffer as increased water availability may penetrate deeper and cause earth flows. Surface run-off increases exacerbate erosion and losses in soil fertility. Sedimentation of streams is often an additional negative effect of large-scale logging.

Pasturing or range use

45. While grazing at low-to-moderate intensities has no appreciable negative impacts on ecosystems (low-to-moderate grazing is thought, for example, to have resulted in the varied plant life of the alpine meadows in the European Alps, as the abandonment of grazing reduced local species richness), vegetation changes associated with grazing can affect ecosystem function and structure. Heavy grazing causes simplification of ecosystem structure, presence of plant growth forms and species richness, and leads to trampling which can exacerbate erosion.

Hunting, gathering, and extractivism

46. In modern industrialized countries, hunting survives as a recreational activity and, in the absence of natural predators, a means of control of populations of ungulates. Hunting also serves ceremonial purposes in some mountain societies. Gathering of medicinal plants for local use and trade is also part of the heritage of mountain-dwelling people particularly in the Andes, Africa, or in the Himalayas. Various other non-timber forest products and fuelwood ar also collected in mountain areas. Inevitably, over-harvesting of all these goods take place partly as a result of increased local demand but also for trade.

Tourism and sports

47. Mountain tourism is a major source of income in many mountain areas of the world although not without an environmental cost. It constitutes between 15 to 20% of worldwide tourism (US$ 70 -90 billion per year), and it plays a significant role in national economies. At the local level, it can bring much more revenue than all other economic activities derived from mountains. Tourism impacts on mountain ecosystems are of great concern, both at the local and global scales because mountains are fragile. Cultural identities and their diversity in mountain regions are also under threat by the economic, social and environmental forces associated with mountain tourism.

48. The large increases in disposable income, particularly in the developed world, have led to explosive numbers of tourists and tourist resort development. For example, the number of visitors using the French Alps for outdoor activities increased twenty-fold between 1950 and 1997. Many of the tourist activities damage habitats and have the potential of disturbing wildlife. Changes in habitat use patterns and impacts on the condition of animals and plants, and their reproductive success may result. 23/ For example, recovery of vegetation cover after ski piste bulldozing and ski lift installation is a lengthy period and the original structure and composition is rarely achieved. An additional threat to biodiversity is the use of ski-lifts and cable cars to transport tourists to high elevations outside of the skiing season, when vegetation is especially susceptible to trampling. Trampling alone can much alter the composition of vegetation, locally reduce species richness, and initiate erosion.

49. Recreational tourism activities that utilize motorized equipment or major infrastructure (such as

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22/ OECD (2001) - Biodiversity, landscapes and ecosystem services of agriculture and forestry in the Austrian Alpine region - an approach to economic (e)valuation. OECD, Paris

23/ See, for example, Loison A, Toigo C, Gaillard J-M (in press) Large Herbivores in Continental European Alpine Ecosystems: Current Status and Challenges for the Future. *In* L Nagy, G Grabherr et al. , eds, Alpine Biodiversity in Europe, Springer Verlag, Berlin Heidelberg New York, alpine skiing, snow-mobiling, off-road-driving, mountain biking) generally have more immediate and intensive impacts on the natural environment than do lower intensity recreational activities (hiking, camping, mountain climbing). Many developing countries now strive for these high technology, higher-investment tourism activities that also have adverse environmental impacts (high energy needs, road construction, etc.).

50. One of the most dynamically growing branches of tourism is ecotourism. Ecotourism is often hailed as a potential saviour of biological diversity through its contribution to local economies; however, it may be a potentially harmful activity if degree of ecosystem resiliency is ignored. Undoubtedly, ecotourism generates income and as such, it is a promising alternative to sustainable mountain resource use. Nevertheless, low resilience in mountain ecosystems such as upper montane forests and alpine life zones may easily become damaged by increases in tourist numbers through trampling, extra resource use, and excessive waste generation. A careful balancing of short-term benefits and, importantly, the distribution of the benefits, and long-term environmental impacts are required to prevent irreversible loss of biodiversity and its associated effects on ecosystem function.

Human settlements

51. Settlements at high elevations are concentrated on the extensive plateaux, especially those in Central and South America, and in the densely populated Himalayas. Rural settlements in mountain environments have traditionally been established in the foothills and in the montane zone; however, especially in the tropics, rural settlements are not uncommon at higher elevations. A relatively recent type of settlement is that associated with tourism and winter sports. They consist of a number of hotels, service areas and service buildings. Both traditional and recreational settlements require power, access roads, and waste disposal facilities. They pose formidable challenges for developers.

52. In recent years, human conflicts have impacted negatively many mountain ecosystems.

Industrial uses

53. Mountains are environments where stored levels of potential energy are very high (i.e., steep slopes, fast flowing rivers), making them as suitable for energy generation as they are likely to pose environmental hazards (e.g., rock falls, landslides, avalanches). As a consequence, many hydroelectric developments have taken place to harness the energy of the rivers. The construction of dams changes the ecology of the flooded area altogether, turning terrestrial habitats into lake bottoms. Dams can interfere with abiotic and biotic exchanges between up and downstream areas.

54. Although the bulk of mining takes place in the lowlands, a large proportion of many non-ferrous and precious metals (e.g. copper, lead, zinc, tin, gold) are being mined in the Andes (Bolivia, Chile, Peru), Sierra Maestra (Mexico), Western Ranges (U.S.A.), Magadan Ranges (Russia), and New Guinean mountains (Papua New Guinea, Indonesia) with concomitant impacts from disposal of mining waste, processing, and inadequate management of tailings and reservoirs. Mining developments can have devastating results on the landscape, vegetation, and water resources far down slope from the mines. 24/

55. Air-borne pollution of nitrogen and sulphur compounds in industrialized countries increased since 1950 in the upper montane forest zone and has equally affected plant and animal communities there.

24/ See Fox DJ (1997) Mining in mountains. *In* B Messerli, JD Ives, eds, Mountains of the world. A global priority, Parthenon Publishing, London, pp 171-198

Road construction

56. The construction of new roads and an increase in mountain road used by heavy vehicles has dramatically increased worldwide. 25/ For example, in the French Alps and the Pyrenees, there was an estimated threefold increase between 1984 and 1995. Road construction can directly affect the local survival of species, can cause habitat fragmentation, and can have serious wider consequences by initiating soil erosion. Habitat fragmentation, together with other impacts can speed up local extinctions. In the case of animals, it can, for example, disrupt migration routes for amphibians and prevent natural exchanges of ungulates between mountain massifs. In addition, roads provide improved access to previously inaccessible areas and thereby can indirectly contribute to the major and rapid spreading of agents detrimental to biodiversity and to the wider environment.

B. Other threats and pressures

Invasive alien species

57. Perturbations by human activities to ecosystems make them susceptible to plant and animal invasion of non-native species. Introduced plants may become invasive if their establishment and spread is facilitated by the existence of potential mutualistic partners, and if environmental conditions are conducive for the establishment of various alien/alien synergisms. 26/

58. In particular, some islands with a large proportion of mountain areas (e.g. Hawaii, Madagascar, New Zealand) are among those which have been most affected by invasive alien species. Introduced/alien species have invaded many ecosystem types in most mountain life zones, with the exception of the alpine, where the opportunities for establishment of a non-native pool of colonists are biologically-limited.

Global change

59. Global climate change manifests in changes in temperature and circulation patterns, which can modify precipitation and wind and related snow accumulation. The south-central Andes for example have shown a major drying trend in the last few decades. 27/ In Africa, Mount Kilimanjaro has been progressively receiving less precipitation above the montane rain forest zone, causing a high incidence of forest fires. As a result, the tree-line has been receding there. The frequency of extreme events from changes in permafrost distribution, cloudiness, precipitation and slope stability may increase, and melting of mountain glaciers may be exacerbated by global warming. From the wide range of scenarios considered by the Intergovernmental Panel on Climate Change (IPCC), the Earth's mean surface temperature is projected to warm 1.4 to 5.8^{o}C by the end of this century. 28/

60. Recent global warming is thought to have negative impacts on mountain species distribution and abundance, especially in tropical cloud forests, which are defined by constant interception of atmospheric moisture. In Costa Rica, 20 out of 50 species of frogs and toads in a 30-km^2 study area, have disappeared since 1987, a phenomenon thought to be the result of drastic environmental changes associated with atmospheric warming. 29/ In this instance, warming raised the average altitude where the base of the

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25/ UNEP (2002) Global Environment Outlook 3. Earthscan, London

26/ See the note by the Executive Secretary on progress in the work on invasive alien species, prepared for the sixth meeting of SBSTTA (UNEP/CBD/SBSTTA/6/6).

27/ Halloy SRP, Mark AF (2002) - Climate change effects on alpine plant biodiversity: a New Zealand perspective on quantifying the threat. Arctic, Antarctic, and Alpine Research (submitted)

28/ Intergovernmental Panel on Climate Change (2002). Climate change and biodiversity, WMO, UNEP, CBD.

29/ Pounds, A. J., M. P. L. Fodgen, J. H. Campbell. 1999. Biological response to climate change on a tropical mountain. Nature **398**: 611-615.

orographic clouds originate, making moisture interception by forest vegetation less frequent, with a concomitant decrease in mist-related precipitation. Epiphytic plant species may also be particularly susceptible to global warming and its consequences.

61. Land use/climate change interactions can have a negative, synergistic effect on mountain biota. For example, it is postulated that climate change impacts on species potential migrations would be minimal along mountains with continuous native cover, as repetitive "up and down" plant migrations in response to climate change have been recorded in the geological past. However, with today's high level of habitat fragmentation, which interrupts potential migration routes, climate change could cause rapid extinction of susceptible species.

62. One of the clearest evidences of climate warming on mountain environments is the accelerating rate of retreat of glaciers worldwide. The disappearance of glaciers will largely restrict water availability for large areas downhill and is likely to force changes in land use. Climate warming has been attributed to an increase in species richness on nival summits in the Alps. In general, theoretical models predict an upward shift of vegetation zones and habitats for animals. Thus, montane forest would advance at the expense of alpine grasslands; high-alpine organisms may become locally or globally extinct, particularly narrow-range endemic species, especially where the extent of the alpine-nival zone is small. 30/ Aquatic ecosystems are likely to undergo marked transformation too; species with a narrow temperature-tolerance

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30/ See, for example, Kappelle M, Van Vuuren MM, Baas P (1999) - Effects of climate change on biodiversity: a review and identification of key research issues. Biodiversity and Conservation **8**: 1383-1397; Foster P (2001) - The potential negative impacts of global climate change on tropical montane cloud forests. Earth-science Reviews **55**: 73-106; Kienast F, Wildi O, Brzeziecki B (1998) - Potential impacts of climate change on species richness in mountain forests - An ecological risk assessment. Biological Conservation **83**: 291-305; Villers-Ruiz L, Trejo-Vazquez I (1998) - Climate change on Mexican forests and natural protected areas. Global Environmental Change-human and Policy Dimensions **8**: 141-157; Theurillat JP, Guisan A (2001) - Potential impact of climate change on vegetation in the European Alps: A review. Climatic Change **50**: 77-109; Guisan A, Holten JI, Spichiger R, Tessier L (1995) - Potential ecological impacts of climate change in the Alps and Fennoscandian mountains. Editions des Conservatoire et Jardin botaniques, Genève; Halloy SRP, Mark AF (2002) - Climate change effects on alpine plant biodiversity: a New Zealand perspective on quantifying the threat. Arctic, Antarctic, and Alpine Research (submitted); Haeberli W, Beniston M (1998) - Climate change and its impacts on glaciers and permafrost in the Alps. Ambio **27**: 258-265; Hauer FR, Baron JS, Campbell DH, Fausch KD, Hostetler SW, Leavesley GH, Leavitt PR, McKnight DM, Stanford JA (1997) - Assessment of climate change and freshwater ecosystems of the Rocky Mountains, USA and Canada. Hydrological Processes **11**: 903-924; and Tulachan P. M. (2001) Mountain agriculture in the Hindu Kush-Himalaya: A regional comparative analysis. Mountain Research and Development **21**: 260-267.

range may become extinct from formerly cold waters and increasing temperatures may confine cold-water fishes to headwaters. 31/

V. CONCLUSIONS

63. There is a rich literature on status of mountain biodiversity. However, as far as decision makers are concerned for the development of plans and programmes for the conservation and sustainable use of mountain ecosystem goods and services there is an urgent need for:

(a) Information on the linkages between the livelihoods of population inhabiting mountain areas and the status of mountain biodiversity on the one hand, and the policies and activities impacting mountains being carried out away from the mountain communities;

(b) A clearer picture of the trends of mountain biological diversity and information, including qualitative data, on threats and pressures imposed on mountain biodiversity as well as data on non-use value of this biodiversity.

64. Biological inventories and monitoring initiatives—initial steps for developing meaningful indicators of ecosystem change—are at best incomplete for most mountain areas, particularly in developing countries. Field data collection should be made for a global database including climatic variables.

31/ Hauer et al. (1997) Hauer FR, Baron JS, Campbell DH, Fausch KD, Hostetler SW, Leavesley GH, Leavitt PR, McKnight DM, Stanford JA (1997) - Assessment of climate change and freshwater ecosystems of the Rocky Mountains, USA and Canada. Hydrological Processes **11**: 903-924

Figure

THE MONTANE AND ALPINE ELEVATION ZONES