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Cloud forest agenda

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The UNEP World Conservation Monitoring Centre is the biodiversity assessment and policy implementation arm of the United Nations Environment Programme (UNEP), the world's foremost intergovernmental environmental organization. UNEP-WCMC aims to help decision-makers recognize the value of biodiversity to people everywhere, and to apply this knowledge to all that they do. The Centre's challenge is to transform complex data into policy-relevant information, to build tools and systems for analysis and integration, and to support the needs of nations and the international community as they engage in joint programmes of action.

UNEP-WCMC provides objective, scientifically rigorous products and services that include ecosystem assessments, support for implementation of environmental agreements, regional and global biodiversity information, research on environmental threats and impacts, and development of future scenarios for the living world.

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Foreword

Cloud forests are a rare habitat of tropical mountains which have not received sufficient attention for their exceptional concentrations of biodiversity and as sources of freshwater. As *Cloud Forest Agenda* demonstrates, these forests make up no more than 2.5 per cent of the world's tropical forests, but they harbour a disproportionately large number of the world's species. This wealth of biodiversity includes the wild relatives and sources of genetic diversity of many of our staple crops, such as beans, potatoes and coffee.

Cloud forests are also of vital importance to local communities and downstream people for their unique ability to capture water from the clouds, in addition to direct rainfall. Cloud forests face many of the same threats to their existence as other tropical forests, but their unique ecology and their location on mountain slopes make them particularly susceptible to habitat fragmentation and especially to climate change.

Cloud Forest Agenda is a product of the Mountain Cloud Forest Initiative, which is a partnership between the United Nations Environment Programme (UNEP) and its World Conservation Monitoring Centre (WCMC), the United Nations Educational, Scientific and Cultural Organization (UNESCO) and its Man and the Biosphere (MAB) Programme and International Hydrological Programme (IHP), and IUCN–The World Conservation Union and its Commission on Ecosystem Management.

We present this report with the aim of stimulating new initiatives and partnerships for the conservation and restoration of cloud forests around the world. We invite governments, non-governmental organizations (NGOs) and the private sector to join us in making the vision and actions presented in *Cloud Forest Agenda* a reality. We call on leaders and organizations in the countries with cloud forests to become 'champions for cloud forests', recognizing the central conclusions of the Mountain Forum electronic conference on mountain people, forests and trees (Butt and Price, 2000):

1. Mountain people rely on the whole landscape for their livelihoods. Consequently, policies and institutions for mountain forests and agroforestry must recognize interactions between agricultural land use, forests and trees.
2. Every strategy for ensuring that mountain people derive sustainable livelihoods from their forests and trees must be tailor-made for the local biological, cultural and political environment – ways of responding to change must always be included.

As representatives of international bodies we see opportunities for the *Cloud Forest Agenda* to contribute to the UN Millennium Development Goal to ensure environmental sustainability, particularly with regard to access to safe drinking water; to carrying out the World Summit on Sustainable Development (WSSD) Plan of Implementation regarding mountain ecosystems and biodiversity; to the Programme of Work on Mountain Biodiversity of the Convention on Biological Diversity; and to the implementation of the Proposals for Action agreed by the Intergovernmental Panel and Forum on Forests. We will also continue to build the Mountain Cloud Forest Initiative in the following roles:

- UNEP and the UNEP World Conservation Monitoring Centre – by seeking to work with national and regional agencies to conduct assessments of cloud forest status and develop conservation strategies; and by continuing to develop conservation-relevant information on the world's cloud forests and promoting networking through the UNEP-WCMC website (http://www.unep-wcmc.org/forest/cloudforest).
- UNESCO – by promoting the conservation of cloud forests and the identification of successful approaches to sustainable mountain development through the Man and the Biosphere (MAB) Programme; by continuing to develop and disseminate knowledge on the management and restoration of cloud forest watersheds through the International Hydrological Programme (IHP).
- IUCN – by promoting initiatives by its government and NGO members for conservation and sustainable use of cloud forests, with the assistance of its Commission on Ecosystem Management and the IUCN regional and country offices.

Through this partnership between UNEP, UNESCO and IUCN, we hope that the Mountain Cloud Forest Initiative will stimulate wider cooperation and greater action to promote the conservation, restoration and sustainable development of mountain cloud forests everywhere.

Klaus Toepfer, Executive Director
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United Nations Educational, Scientific and Cultural Organization

Achim Steiner, Director General
IUCN–The World Conservation Union

Contents

L.S.Hamilton

Introduction

Tropical montane cloud forests represent a rare and fragile ecosystem that is under threat in many parts of the world. Urgent action is needed to conserve these rich mountain forests, not only because they harbour concentrations of endemic and threatened species but to maintain their vital role in the provision of freshwater. All tropical forests are under threat but cloud forests are uniquely threatened both by human pressures and by climate change impacting on temperature, rainfall and the formation of clouds in mountain areas.

This report aims to stimulate new initiatives to conserve and restore cloud forests around the world. It provides maps of their distribution, regional overviews of the threats they face, and an agenda for priority actions. The particular qualities of cloud forests and issues in their conservation are identified, alongside examples of successful conservation approaches.

THE MOUNTAIN CLOUD FOREST INITIATIVE

Cloud Forest Agenda is a product of the Mountain Cloud Forest Initiative, which is a partnership between the IUCN Commission on Ecosystem Management, UNEP and its World Conservation Monitoring Centre (UNEP-WCMC), and the UNESCO Man and the Biosphere and International Hydrological Programmes.

The vision of the Mountain Cloud Forest Initiative is a future where all cloud forests, with their unique plants and animals and water catchment functions, are valued and protected by mountain communities and downstream users. Cloud forests are also recognized both as sensitive indicators of climate change and areas that are under particular threat from these changes. Their conservation is strongly supported by the global community.

The Mountain Cloud Forest Initiative programme of action includes:

- promotion of prioritized agendas for the conservation and management of cloud forests at regional and local levels;
- promotion of Ecosystem Approaches to cloud forest management and restoration;
- supporting local champions for cloud forest conservation;
- generation and dissemination of information to decision-makers and practitioners;
- development of practical tools and models for the conservation of cloud forests.

The latest information on the Mountain Cloud Forest Initiative is available on its web pages (http://www.unep-wcmc.org/forest/cloudforest).

WHAT ARE TROPICAL MONTANE CLOUD FORESTS?

Cloud forests are mountain forests defined and limited by the persistent presence of clouds and mists. The term tropical montane cloud forest is used to include all forests in the humid tropics that are frequently covered in clouds or mist and so, in addition to rainfall, capture water droplets that condense on the vegetation. The presence of clouds and this additional input of water significantly influence the hydrology, ecology and soil properties of cloud forests (Stadtmuller, 1987).

The experience of being in a cloud forest is typically one of an abundance of lush, evergreen vegetation in a cool, humid atmosphere. If the clouds are in the forest, or have recently passed through, there is a constant sound of water dripping from the leaves. One of the characteristics of cloud forests is the quantity and diversity of ferns, mosses, orchids and other plants growing on every rock, tree trunk and branch surface.

L.Brecht

The form and appearance of tropical montane cloud forests vary greatly according to how exposed they are to the prevailing winds and clouds, their altitude and local soil types. On lower mountain slopes, cloud forest trees are usually 15-20 m tall. At higher altitudes, where the forest is more consistently in the clouds and winds are greater, the trees are more stunted and covered in more epiphytes. Descriptions of the different types of cloud forest, such as lower and upper montane and subalpine, can be found in Bruijnzeel and Hamilton (2000) and on the Mountain Cloud Forest Initiative web pages.

Cloud forests occur within a wide range of annual and seasonal rainfall patterns, from 500–6 000 mm/year. They are found wherever clouds and mist are frequently in contact with a mountain slope. They typically form a belt of vegetation over an elevational range of about 500 m, but there is considerable variation in the altitude at which they are found. On large inland mountain systems cloud forests may typically occur between 2 000 and 3 500 m, whereas in coastal and insular mountains this zone may descend to 1 000 m. Under exceptionally humid conditions a cloud forest zone may develop on steep, tropical island or coastal mountains at elevations as low as 500 m.

K.Schaefer

W.Ferwerda

Mapping cloud forests

Mapping the area of tropical montane cloud forests is complicated because so many factors can influence their location. Their exact distribution depends upon latitude, altitude, winds, rainfall patterns, and the size of the mountains and their distance from the sea. The concept of cloud forests as a distinct forest type has emerged from work in the Americas but they are also of vital importance in the other tropical regions.

This report presents the first global maps of potential cloud forest distribution, produced from remote-sensing data. The maps show forest cover in mountains within defined altitudinal ranges that are likely to include cloud forests. This forest distribution will also include montane rainforests and drier forest types which are not subject to frequent or seasonal cloud cover at vegetation level. The maps are therefore a potential distribution of cloud forest and may over-represent its occurrence to some degree.

A second complicating factor in mapping cloud forests is the fact that these forests tend to occur at higher altitudes on higher mountains and at lower altitudes in coastal and island areas. The altitudinal ranges upon which we have based our assessment of potential cloud forest distribution are shown on each map.

Ideally the distribution of cloud forests would be determined from a combination of the location of frequent cloud cover and of forest cover. Frequent cloud cover could, in principle, be determined from satellite imagery, but no such analyses have yet been conducted.

The distribution of cloud forests could also potentially be determined from the occurrence of indicator species restricted to cloud forests. Mosses and other bryophytes have been suggested as such indicators, because they are particularly sensitive to levels of atmospheric humidity. An analysis by Long (1995) of threatened and restricted-range bird species restricted to cloud forests shows a clear correlation with the maps in this report. The potential cloud forest distribution was based upon:

1. A GIS base layer of the mountains of the world, using the definition of mountains in Kapos *et al.* (2000).
2. An overlay of the mountain layer with coverages of tropical montane rainforest, tropical lowland evergreen and semi-evergreen rainforest, taken from the UNEP-WCMC global forest coverage (Iremonger *et al.*, 1997) compiled from national sources up to 1997.
3. An overlay of the MODIS satellite coverage for vegetation greater than 40 per cent canopy cover for the year 2000, to update the coverage of forest.
4. Lastly, areas of mountain forest outside the altitudinal ranges for the likely occurrence of cloud forests, as determined for different mountain and island systems of the world, were excluded.

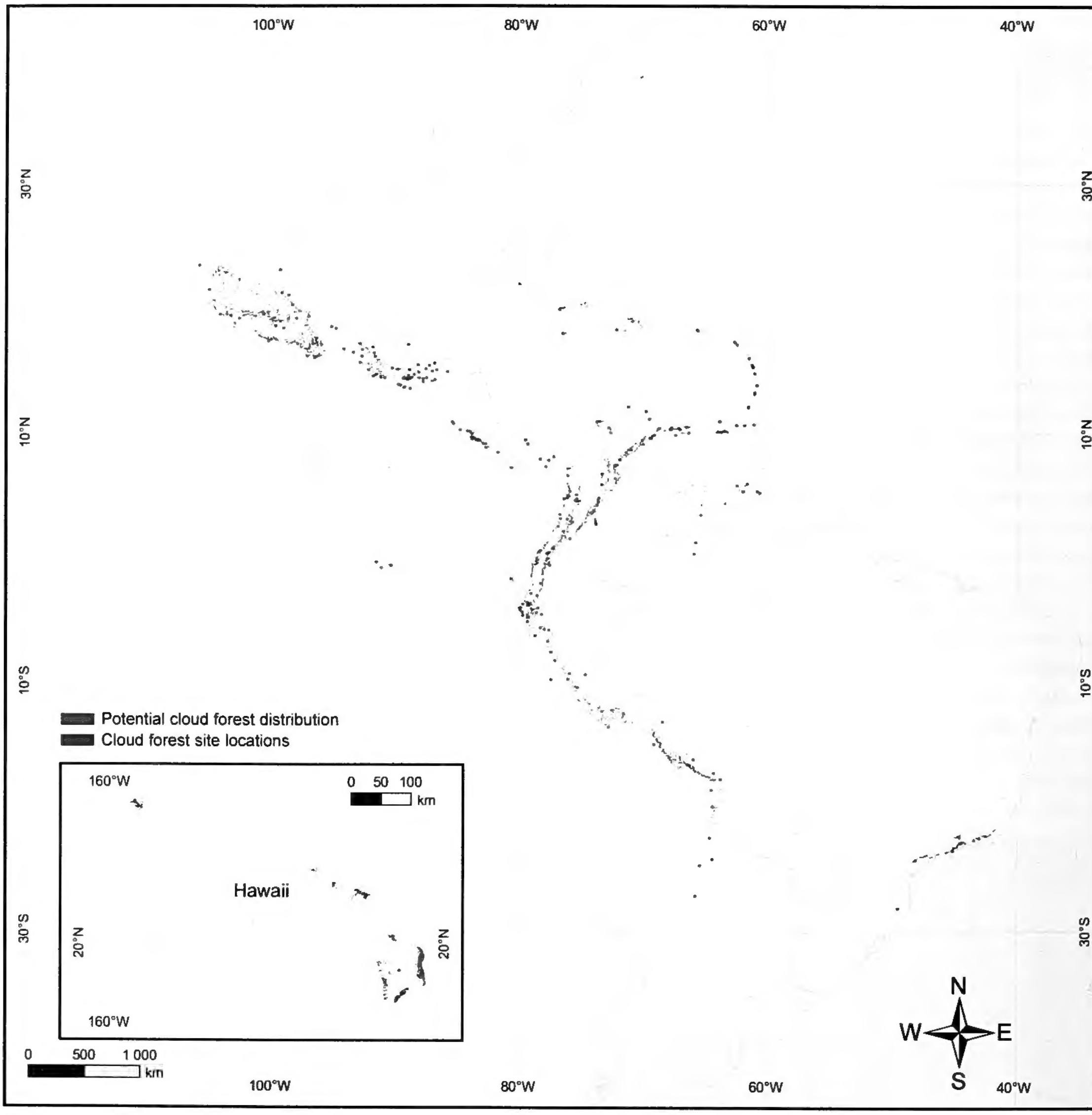
M.E.D'amato/UNEP/Banson

The maps also include the location of cloud forest sites as recorded in a worldwide inventory compiled by UNEP-WCMC (Aldrich *et al.*, 1997). This inventory was compiled from literature searches and correspondence with regional experts, and contains a total of 605 sites from 41 countries. The maps show a central location for each site and do not distinguish the great variability in their size, which ranges from 50 hectares to hundreds of square kilometres.

The maps can also be viewed on the Mountain Cloud Forest Initiative web pages, including separate maps for potential distribution and sites (www.unep-wcmc.org/forest/cloudforest).

The maps of potential distribution do not include areas of sub-tropical montane cloud forest, such as the 'Yungas' of northern Argentina. The Arabian Highland woodlands and shrublands in Iran, Oman, Saudi Arabia, United Arab Emirates and Yemen, which are seasonally blanketed in fog and mists, are also not included.

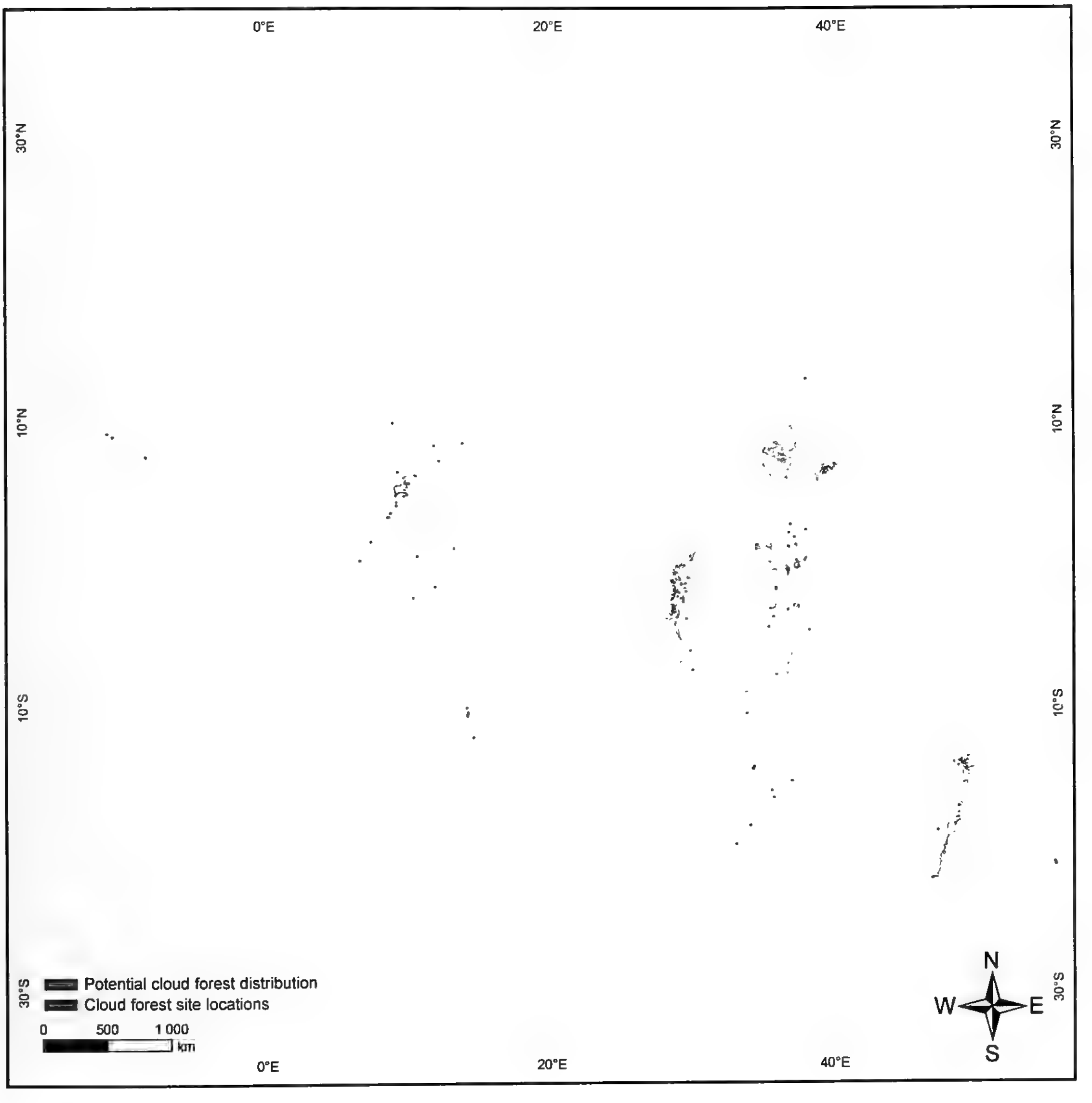
Map 1. Potential cloud forest distribution and sites in the Americas



Altitude range of potential cloud forest distribution:
Mexico, Central America and South America: 2 000-3 500 m, except:

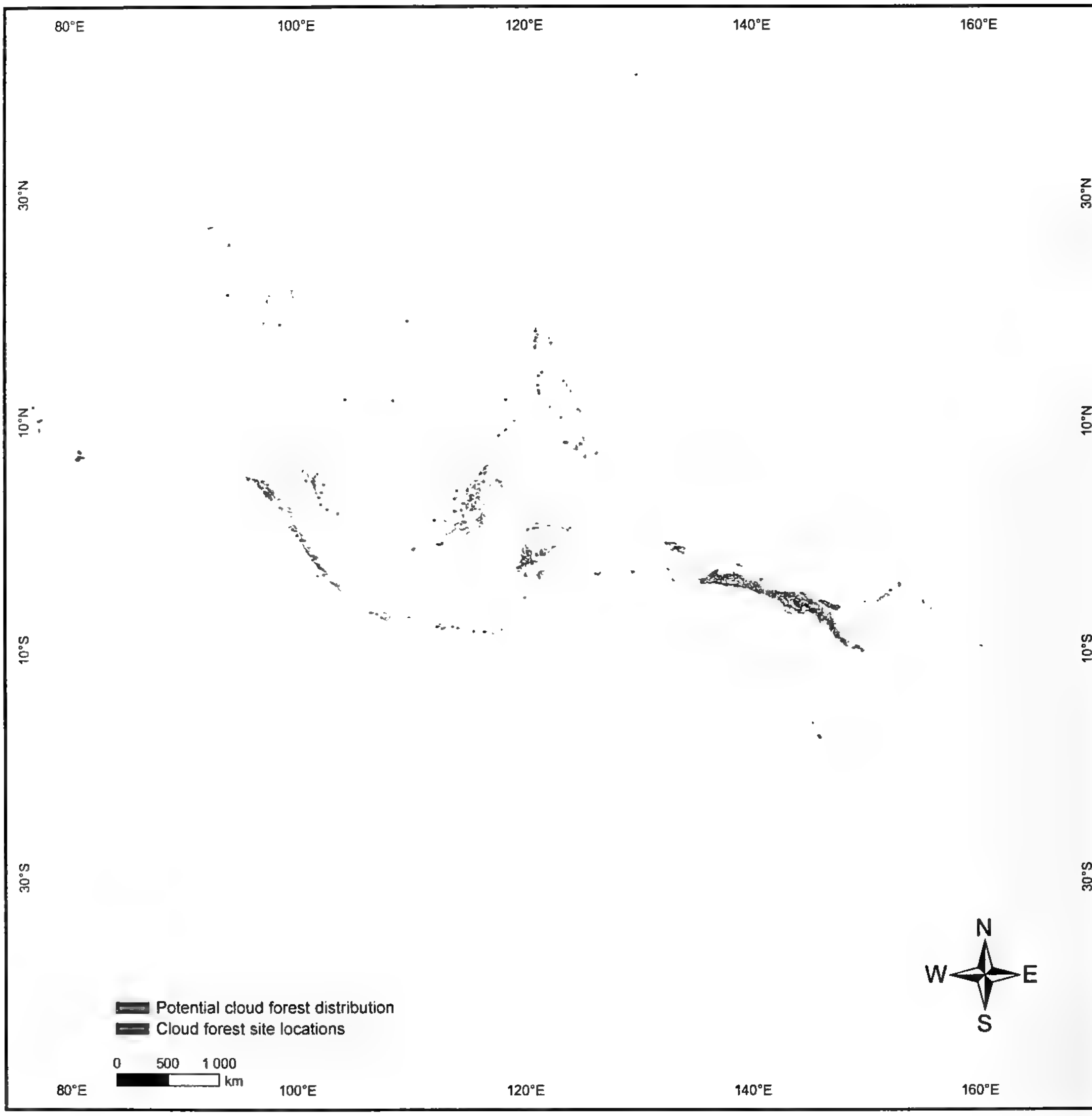
- Caribbean islands and coastal Venezuelan mountains: above 660 m
- Galapagos islands and coastal Ecuadorian mountains: above 400 m
- Atlantic coast of Brazil: above 700 m
- Hawaii: 1 000-3 000 m.

Map 2. Potential cloud forest distribution and sites in Africa



Altitude range of potential cloud forest distribution:
African Atlantic coast countries: 1 000-3 500 m
Eastern and Central African countries from Ethiopia south to northern Tanzania: 2 000-3 500 m
Southern Tanzania, Malawi, Mozambique and Madagascar: 1 000-3 500m.

Map 3. Potential cloud forest distribution and sites in Asia



Altitude range of potential cloud forest distribution:
Insular Asia-Pacific, India, Sri Lanka, Australia: 1 000-3 500 m
Continental Southeast Asia: 1 500-3 500 m.

The importance of cloud forests

CLOUD FOREST IS A RARE RESOURCE

The potential global area of cloud forest is about 380 000 km^2, which is approximately 0.26 per cent of the Earth's land surface. This figure is likely to be an overestimation of the true area of cloud forest, as other forest types are included within the altitudinal ranges used for this analysis. This estimate of global area is considerably less than the only other published figure of an estimated 500 000 km^2 of cloud forests in the humid tropics (Bockor, 1979).

Cloud forest is not distributed equally across the tropical regions. Of the global area of potential cloud forest 25.3 per cent occurs in the Americas, 15.0 per cent in Africa and 59.7 per cent in Asia (Table 1). One of the most noteworthy results of this analysis is the very large extent of potential cloud forest in Asia, principally in Indonesia and Papua New Guinea.

Cloud forest is a rare type of forest, making up only 2.5 per cent of the total area of the world's tropical forests (Table 2). In the Americas and Africa cloud forest is an even rarer forest habitat, forming 1.2 per cent and 1.4 per cent, respectively, of the tropical forests of these regions. Cloud forests are also a scarce habitat amongst all forest types in tropical mountain regions, occupying 8.4 per cent, 10.5 per cent and 14.6 per cent of tropical mountain forest in the Americas, Africa and Asia, respectively (Table 2 and Figure 1).

Like cloud forests, tropical dry forests have been identified as a forest type with high levels of species endemism and deforestation rates. A comparison of the areas of these forest types (Table 3) shows that cloud forests are much scarcer than tropical dry forest in the Americas (13.8 per cent of dry forest area) and in Africa (41.4 per cent). In Asia the relatively large area of potential cloud forest is

Table 1. Area of potential cloud forest by continental region

Region	Potential cloud forest area (km^2)	% of global cloud forest
Americas	96 394	25.3
Africa	57 190	15.0
Asia	227 582	59.7
Global total	381 166	100.0

Table 3. Potential cloud forest as a percentage of tropical dry forest

Region	Total dry forest	Cloud forest as % tropical dry forest
Americas	697 007	13.8
Africa	138 025	41.4
Asia	191 830	118.6
Global total	1 026 863	37.1

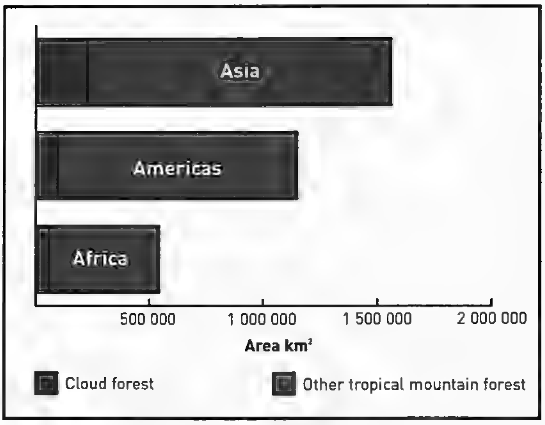
Source: Data from Iremonger *et al.* (1997).

Table 2. Potential cloud forest as a percentage of all tropical forest and tropical mountain forest

Region	All tropical forest (km^2)	Cloud forest as % all tropical forest	Tropical Mountain Forest (km^2)	Cloud forest as % all tropical mountain forest
Americas	7 762 359	1.2	1 150 588	8.4
Africa	4 167 546	1.4	544 664	10.5
Asia	3 443 330	6.6	1 562 023	14.6
Global total	15 373 235	2.5	3 257 275	11.7

Source: Data from Iremonger *et al.* (1997) and Kapos *et al.* (2000). The calculations by Kapos *et al.* (2000) of the areas of the world's mountain forests included altitudinal ranges from 300 m to above 4 500 m.

Figure 1. Area of potential cloud forest and tropical mountain forest by continental region



slightly greater in extent (118.6 per cent) than that of tropical dry forests.

CLOUD FORESTS ARE VITAL WATER SOURCES

All mountain forests have an important role in stabilizing water quality and maintaining the natural flow patterns of the streams and rivers originating from them. Tropical montane cloud forests have the unique additional value of capturing water from the condensation from clouds and fog. This 'stripping' of wind-blown fog by the vegetation becomes especially important during the non-rainy season and in areas with low rainfall but frequent cloud. Water originating from cloud forests is also increased because water loss from vegetation wetted by rain or fog is reduced. This results in streamflows from cloud forest areas that are greater and more dependable in dry periods.

Under humid conditions the amount of water directly intercepted by the vegetation of cloud forests can be 15-20 per cent of the amount of direct rainfall, and can reach 50–60 per cent under more exposed conditions. These values tend to increase in cloud forests at higher altitudes. In areas with lower rainfall, or during extended dry periods, these percentages can be higher still and equivalent to 700–1 000 mm of rainfall per year (Bruijnzeel and Hamilton, 2000; Bruijnzeel, 2000).

A major element of the hydrology and ecology of cloud forests is the abundance of epiphytic plants, that is plants such as mosses, ferns and bromeliads that grow on the trunks and branches of trees. Up to a quarter of all cloud forest plant species may be epiphytes (Foster, 2001). The epiphytes capture water directly from the fogs and clouds and provide a variety of microhabitats for invertebrates, amphibians and their predators (Benzing, 1998). Water storage in epiphytes has been calculated as ranging from 3 000 litres/ha (Richardson *et al.*, 2000) up to 50 000 litres/ha (Sugden, 1981). Up to half the total input of nitrates and other ions and nutrients to the forest can come from water stripped from clouds by epiphytes (Benzing, 1998).

The year-round and unpolluted water from cloud forests is a vital resource in many regions. For example, the cloud forests in La Tigra National Park in Honduras provide over 40 per cent of the water supply for the 850 000 people in the capital city, Tegucigalpa. Other capitals where cloud forests augment water supplies are Quito, Ecuador, with 1.3 million people, and Mexico City with its 20 million people. In the dry season 100 per cent of the water used by Dar es Salaam, Tanzania, for drinking supplies and hydroelectricity generation originates in the cloud forests of the Uluguru Mountains. In Guatemala the Sierra de las Minas Biosphere Reserve protects 60 per cent of the country's remaining cloud forest habitat. More than 60 permanent rivers drain the reserve, making it the country's biggest single water resource. This is especially significant for the Motagua Valley to the southeast of the Sierra, which is a rain-shadow desert and heavily dependent on irrigation.

Similarly, the montane forests of Mount Kenya guarantee the dry-season river flows to the semi-arid lowlands, with the headwaters of the Tana River supplying water to over 5 million people (Lambrechts, 2000). The Mount Kenya catchment also provides 97 per cent of Kenya's hydropower. The water from the river systems originating from this mountain is used in several lowland urban centres. In addition it supplies large-scale horticulture for international markets, agro-pastoral smallholders, large-scale ranches, pastoralists, tourism and wildlife populations. These diverse users are increasingly in conflict over the use of water resources, with 60-95 per cent of available river water in the Ewaso Ng'iro

L.S.Hamilton

Basin abstracted during the dry season and the river drying up completely in many years (Wiesmann *et al.*, 2000).

CLOUD FORESTS ARE CONCENTRATIONS OF BIODIVERSITY

Cloud forests have very high levels of endemism and are home to many threatened species. On a global scale the importance of cloud forests for biodiversity conservation is demonstrated by the fact that 86 per cent of the cloud forest sites identified in the UNEP-WCMC inventory are found within the Global 200 Priority Forest Ecoregions identified by the World Wide Fund for Nature (WWF) (Table 4).

The distribution of cloud forests shows an even closer correlation with the Endemic Bird Areas identified by BirdLife International (Table 5). Ten per cent of the world's 2 609 restricted-range bird species (those with a range of less than 50 000 km^2) are confined to or mainly found in cloud forests, with a further 315 species (12 per cent) found in both cloud forests and other habitats (Long, 1995). An analysis of all 327 threatened bird species of the Americas found that 38 species (11.6 per cent) are cloud forest species. This concentration of threatened bird species in northern Andean cloud forests is illustrated in Map 4.

Examples of the exceptional endemism of cloud forests at a national scale are shown by data from Latin America. In Mexico cloud forests cover less than 1 per cent of the country but contain about 12 per cent of the country's 3 000 plant species (Rzedowski, 1996). Up to 30 per cent of these are endemic to the country. Young and León (CPD, 1997) estimate that the eastern Peruvian Andean forest harbours 14 per cent of Peru's flora in 5 per cent of the country's area. Similarly, Balslev (1988) estimates that half of Ecuador's species occur in the 10 per cent of the country represented by middle-elevation (900-3 000 m) Andean forests, and 39 per cent of these species are endemic to Ecuador, compared with 16 per cent of lowland species. Half the lowland species have a wide distribution, compared with one quarter of the mid-elevation species and only one sixth of the high-altitude species.

Gentry (1992) identified the Andean region as 'of exceptional importance as a repository for a disproportionate part of the world's biodiversity'. This high species richness is due to the much greater endemism in Andean forests than in other parts of the world: 'some plant families seem to have evolved locally endemic species in every patch of isolated Andean forest' (Gentry, 1992). For example, 21 endemic tree species of Magnoliaceae were discovered during the preparation of the *Flora de Colombia* (Lozano, 1983). Gentry (1992) considered that, 'while a high proportion of the endemic [plant] species of Andean cloud forests probably have not yet been described, it is clear from what we do know that local endemism is a common evolutionary theme, with isolated ridges or ecologically isolated habitat islands typically harbouring ca. 20 per cent endemic species. A good example is the Centinella ridge in western Ecuador where about 90 species were apparently endemic to a forest area of ca. 20 km^2'.

E.A.Andrade/UNEP/Banson

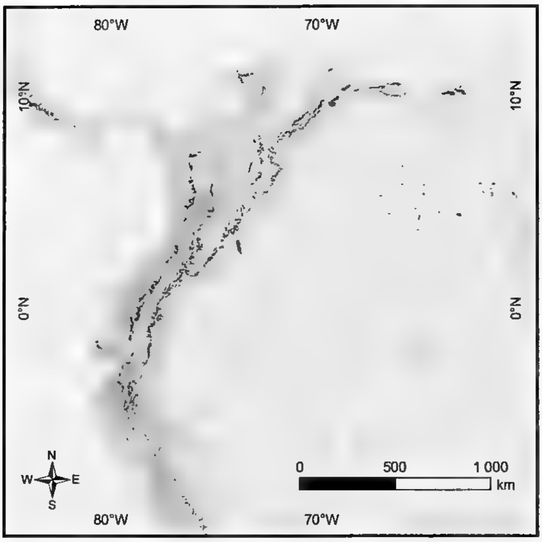
Table 4. Cloud forest sites in WWF Global 200 Priority Forest Ecoregions

Region	No. of cloud forest sites in Global 200 Forest Ecoregions	% of cloud forest sites in region in Global 200 Forest Ecoregions
Latin America & Caribbean	210	75
Africa	86	92
Asia	223	98
Global total	519	86

Table 5. Cloud forest sites in Endemic Bird Areas

Region	No. of cloud forest sites in Endemic Bird Areas	% of cloud forest sites in region in Endemic Bird Areas
Latin America & Caribbean	272	97
Africa	70	72
Asia	217	95
Global total	559	93.

Map 4. Potential cloud forest distribution and density of threatened bird species in the northern Andes



Number of threatened bird species per 50 km²

0 6 12 18

Potential cloud forest

Source: Data from BirdLife International.

High levels of endemism are also found amongst the vertebrate fauna of Andean cloud forests. In Peru 32 per cent of the 272 species of mammals, birds and frogs endemic to the country are restricted to cloud forest (Leo, 1995). Mares (1992) showed that although the eastern Andean montane forests occupy only 3.2 per cent of the continental area, they are the habitat of 63 per cent of its endemic mammals.

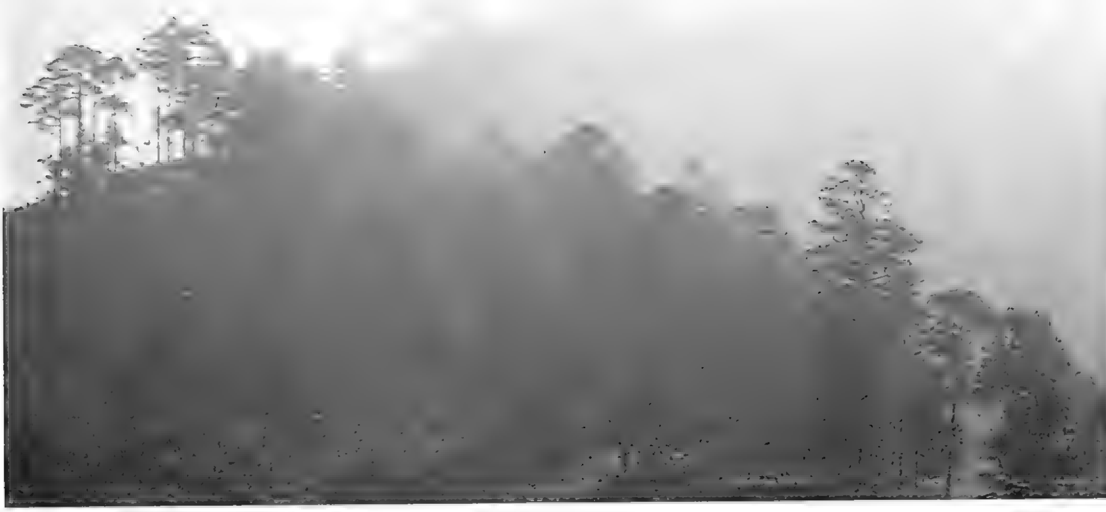
Fjeldså and Hjarsen (1999) analysed areas of 'hotspot' richness of highland bird species in the Andes, using the distribution in 15-minute grid cells (ca. 27 x 27 km) of species that are well established above 2 500 m. The areas identified are mainly humid montane forest and the analysis found that all bird species in the tropical Andes can be covered in just 80 grid cells. Amongst these the 50 highest scoring cells would contain 99.1 per cent of all highland birds and 94.9 per cent of all those classified as endangered. 'Because of the aggregated (or nested) distribution of the endemic species, the total Andean [bird] fauna might be conserved in less than two percent of the land area' (Fjeldså and Hjarsen, 1999).

Species inventories and analyses of endemism have rarely been undertaken for invertebrates in cloud forests. However, Anderson and Ashe (2000) surveyed 13 cloud forest sites in Honduras for beetles that inhabit leaf litter and found 173 of 293 species (58.7 per cent) of Curculonidae and 126 of 224 species (56.3 per cent) of Staphylinidae were restricted to single sites.

One of the consequences of the high levels of endemism in cloud forests is the regular discovery of new species, even for well-known groups such as birds. For example, in the Andes two narrowly endemic bird species were discovered in the 1990s. The Jocotoco Antpitta *Grallaria ridgelyi* was found in about 5 000 ha of cloud forest in Ecuador in 1997 (Krabbe *et al.*, 1999). In 1996 the Scarlet-banded Barbet *Capito wallacei* (O'Neill *et al.*, 2000) was discovered in the cloud forest on one mountain near the headwaters of the Rio Cushabatay, Peru. A new genus of the cow family and two new barking deer species were discovered in the Annamite cloud forests of Laos and Viet Nam in 1996.

An important but often overlooked characteristic of cloud forests is that they are the natural habitat of the wild relatives of many crop species. They are therefore important gene pools for the continued improvement of these plants. Debouck and Libreros Ferla (1995) identified 12 crop genera with wild relatives in Neotropical montane forests. These include relatives of the papaya *Carica papaya*, the tomato *Lycopersicon esculentum*, the tree tomato *Cyphomandra betacea*, species of passion fruit, the avocado *Persea americana*, beans of the genus *Phaseolus*, the blackberry *Rubus* spp., the cucumber *Solanum muricatum* and the potato *Solanum* spp. A wild relative of another crop genus of major economic importance, the peppers *Capsicum* spp., was recently rediscovered in a Guatemalan cloud forest reserve (Bosland and Gonzalez, 2000).

Philip Bubb



Philip Bubb

Threats to cloud forests

Cloud forests face many of the same threats to their existence as other tropical forests, but their unique ecology and their location on mountain slopes make them particularly susceptible to some deforestation forces and especially to climate change.

This report presents a first assessment of the relative importance of these threats to cloud forests, using information from the database of tropical montane cloud forest sites (the WCMC directory) (Aldrich *et al.*, 1997). The database was compiled from correspondence with people knowledgeable about cloud forests in different regions of the world and from literature searches. A summary was written of the locations and principal species of cloud forests and their conservation issues for 41 countries. The amount of information for each country is very variable, but threats to cloud forests are mentioned for 15 African countries, 11 Latin American countries and ten Asian countries (see Appendix 1).

Conversion to agricultural land

Clearance of cloud forests for farming is the most widely recorded threat. It is reported from 90 per cent of Latin American and Asian countries and 53 per cent of African countries. It is likely to be a major deforestation pressure in all countries with cloud forests. The cleared land is principally used for subsistence agriculture by resource-poor farmers, although commercial production of temperate-zone fruits and vegetables is expanding in cloud forest areas in Asia.

There are complex processes driving this agricultural clearance. They include poverty, population growth, land degradation and marginalization of mountain communities and indigenous groups. Clearance for commercial production of temperate-climate vegetables, fruits and flowers is being driven by demand from expanding urban centres in Asia and by the ease of transporting these products by air to European and North American markets.

The other major commercial crop in cloud forest areas is coffee, which is grown on the lower altitude slopes of many cloud forest regions throughout the world. In Sri Lanka and Tanzania cardamom is a significant tree crop in cloud forest areas. In many regions lower montane forests may have been cleared to a greater extent than higher altitude cloud forests, due to their suitability for crops such as coffee and their greater accessibility. In the Uluguru Mountains of Tanzania this has resulted in the local extinction of forest species restricted to lower slopes, with the higher altitude cloud forest remaining as a watershed protection forest (Burgess *et al.*, 2002).

Conversion to grazing land

Clearance of cloud forests for cattle ranching was reported in the WCMC directory from eight of 11 Latin American countries, including all the Andean countries. Only Costa

Rica and Mexico reported this threat in the Mesoamerican region. In Colombia extensive cattle ranching has continued to expand, at the cost of both Andean forests and arable agriculture. This is despite a trend towards rural depopulation. It is leading to a simplification of the landscape as cattle pasture expands and erosion increases (Etter and van Wyngaarden, 1999).

For Africa, grazing and conversion of cloud forests to pasture was reported from eight of 15 countries. This pressure is particularly significant in seasonally dry regions where the moisture in the cloud forest zone attracts farmers and herders. In contrast, in Asia livestock grazing is only reported as a threat to cloud forests in the Philippines.

Hunting

The most widely reported threat to cloud forests in Africa (ten of 15 countries) is the hunting of their wildlife for subsistence use and sale of meat. This is likely to be a significant pressure in the cloud forests of all African countries, whether they have a protected area status or not. Hunting is particularly intense in areas of high human population and social conflict, such as the Albertine Rift Mountains of Burundi, the Democratic Republic of Congo and Rwanda. Hunting is the third most widespread threat to cloud forests in Latin America (seven of 11 countries) and Asia (three of ten countries). Hunting threatens more than the survival of animal species, as their loss can also have a major impact on the ecology and regeneration of the cloud forest.

This effect on the ecosystem is exacerbated where cloud forests are fragmented, which is commonly the situation. Tabarelli and Peres (2002) found that in the montane Atlantic coast forests of Brazil the vertebrates most vulnerable to extinction within forest fragments were those with a large body size and a predominantly fruit-eating diet (e.g. primates, cracids and toucans). These species play a key part in the dispersal of medium- to large-seeded plants (e.g. Myrtaceae, Lauraceae) in the forest. Ongoing local extinction of large-bodied animals in the remnants of these forests is a result of both habitat fragmentation and subsistence hunting. Small forest fragments can only accommodate small populations, are more accessible to hunters, and cannot easily be recolonized from nearby forests as these are also exposed to hunting pressure.

Fire

In Africa fire was recorded as the second most widespread threat to cloud forests (eight of 15 countries), but was reported from only four Andean countries in Latin America and only from Australia in Asia. The prevalence of fire as a threat in Africa is probably because cloud forests occur in areas with a pronounced dry season and the forests are vulnerable to fires started in surrounding lands.

Timber harvesting

Cloud forests were reported as being affected by timber extraction and commercial logging in seven of the ten Asian countries, with several reports from Indonesia, Malaysia and the Philippines. This may reflect the presence of major logging industries in these countries. Timber harvesting was recorded for six African and six Latin American countries, principally for local construction use. Cloud forests are rarely managed for commercial timber exploitation due to the steep topography, and the lower stature and slower growth rates of trees at high altitudes.

Fuelwood harvesting

Collection of fuelwood and charcoal production were reported from seven African and five Latin American countries and only from the Philippines in Asia. However this threat is probably widespread. It may be a locally significant pressure on many cloud forests, especially in areas with a high density of human population and few other energy sources.

Roads

The construction of roads through cloud forests was recorded as a threat in six Latin American countries. For example, Sangay National Park in Ecuador has been bisected by a major road. Road construction can have a major impact in fragile montane environments. In a Puerto Rican cloud forest it was estimated that soil biomass in areas disturbed during road construction would take 200-300 years to recover to the levels of a mature forest (Olander *et al.*, 1998). The effects of roads in cloud forest areas include fragmentation of the forest and increased deforestation pressures, resulting from the ease with which products can be extracted and the improved access to markets (Young, 1994). In Ecuador montane forests have been cleared by land speculators in anticipation of the arrival of roads in remote areas (Rudel, 1999).

The WCMC directory of cloud forests does not record roads as a threat in Africa, but road development and associated tourist infrastructure such as hotels and golf courses is threatening the montane forests of peninsular Malaysia's Genting and Cameron Highlands and Sabah's Mount Kinabalu.

Mining

Some cloud forest sites are severely affected by mining. In the WCMC directory, mining is recorded as a threat in the Democratic Republic of Congo and Rwanda, in Bolivia, Ecuador and Venezuela, and in Indonesia and Malaysia. Bruijnzeel and Hamilton (2000) also report cloud forests affected by gem mining in Sri Lanka, geothermal development in the Philippines and Java, and gold mining in New Guinea.

Deforestation for drug cultivation

Clearance of cloud forests for the illegal production of opium in Colombia is documented by Cavelier and Etter (1995). This threat continues to increase (Etter and van Wyngaarden, 1999). Cloud forest clearance for cultivation of coca leaf is also a significant threat in Bolivia, Colombia, Peru and Venezuela, where it is associated with high rates of land degradation and rural poverty (Salis, 1999).

Alien species

The introduction of alien species was reported in the WCMC directory as a threat to cloud forests only for Malawi and Réunion. In these locations alien species have a major impact. Cloud forests in Jamaica are being invaded by the Australian tree *Pittosporum undulatum* (Goodland and Healey, 2001), which is able to grow at higher densities than any native species and, because it has a dense crown, achieves a much greater dominance than the native trees. In Hawaii feral pigs in the cloud forests have contributed to plant and bird extinctions (Bruijnzeel and Hamilton, 2000).

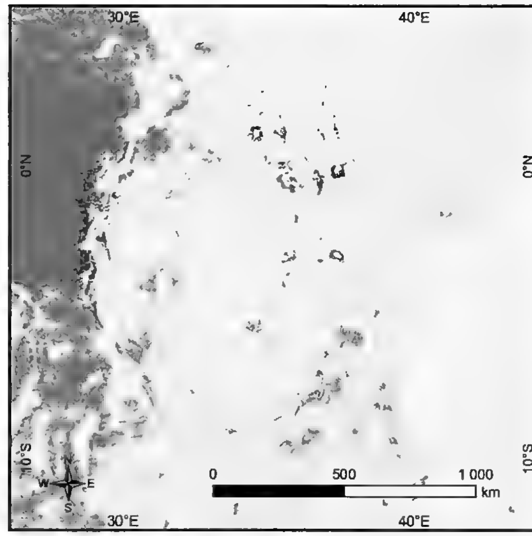
HABITAT FRAGMENTATION AND DISTURBANCE

A feature of many cloud forest sites is their occurrence as 'islands' of evergreen forest on mountain tops or along ridges. Cloud forests are often bounded both above and below by drier vegetation types. Alternatively they may intergrade with other humid tropical forests at lower elevations. This is illustrated by Maps 5 and 6. Map 5 shows how most of the Albertine Rift montane forests form the eastern limit of the Congo Basin rainforest, whilst the cloud forests of Kenya and Tanzania are 'islands' of humid forests in drier lowlands. Map 6 shows how the cloud forests of the northern Andes form broken 'chains' of this habitat along the humid slopes of the Andean ranges. The eastern Andean cloud forests grade into the lower montane rainforests of the Amazon in southern Colombia and Ecuador. The western Andean cloud forests form part of the Choco rainforest system.

Deforestation and the building of roads, power lines and pipelines have made habitat fragmentation and isolation an even more pronounced threat to cloud forests in many regions. This has a major impact on the ecology of the 'islands' of remaining cloud forests and has important implications for their conservation.

At a fragmented cloud forest site in the western Andes, 31 per cent of the original bird fauna became locally

Map 5. Forest in East Africa ranked by an index of spatial integrity and potential cloud forest



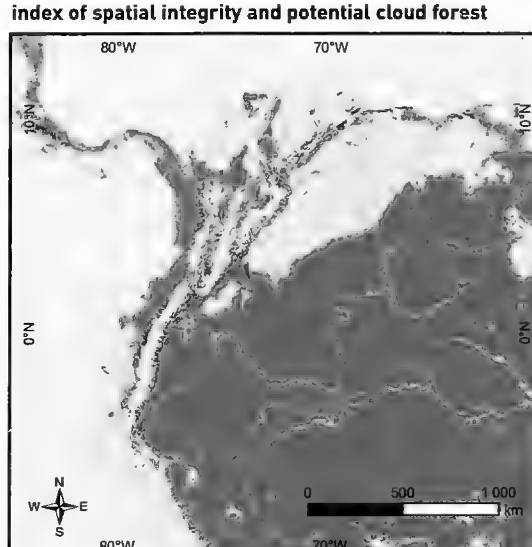
The Forest Spatial Integrity index*

0 20   20 4   40 60   60 80   80 100

Potential cloud forest

* A combination of indices of patch size (the area of each contiguous unit of forest cover), spatially weighted forest density (the percentage of cells within a given radius that are occupied by forest), and connectivity (the distance from each forest cell to 'core' forest distance along a forested route).

Map 6. Forest in northwest South America ranked by an index of spatial integrity and potential cloud forest



Philip Bubb

extinct over an 80-year period (Kattan *et al.*, 1994). The terrestrial and understorey insect-eating birds were particularly susceptible to extinction. There is also evidence in Colombia that the smallest and largest fruit-eating bird species are most likely to be eliminated from disturbed and fragmented montane forest habitats (Restrepo *et al.*, 1997).

One of the factors in the extinction of bird species in cloud forest fragments is nest predation, which was higher in three small Andean cloud forest fragments (11, 13 and 29 ha) than in larger fragments of 75 and 300 ha (Arango-Vélez and Kattan, 1997). This was considered not to be due to an edge effect but the result of a greater abundance of nest predators (small mammals) in the smaller fragments. A similar pattern and explanation of higher predation of experimental bird nests was found in Tanzanian montane forest fragments (Carlson and Hartman, 2001).

Habitat fragmentation combined with subsistence hunting can quickly cause local extinctions of large vertebrates, with smaller forest fragments being more accessible to hunters (Tabarelli and Peres, 2002). This loss of large vertebrates has been hypothesized to have major effects on future regeneration of the forest, as the vertebrates are key dispersal agents for many trees. Tabarelli and Peres (2002) predict that the species richness of woody plants in secondary forests of highly fragmented Brazilian Atlantic forest could eventually be reduced by as much as one half, because of the failures in seed delivery and plant recruitment in large-seeded plant species (e.g. Myrtaceae, Lauraceae).

Habitat disturbance can have smaller scale ecological effects similar to those of habitat fragmentation. In montane forest in the Tam Dao Mountains of northern Viet Nam, gaps created by illegal logging threatened restricted-range butterfly species that required closed canopy habitat (Spitzera *et al.*, 1997). In a seasonal cloud forest in the Western Ghats of India habitat disturbance reduced the reproductive success of three dioecious plant species (Somanathan and Borges, 2000). Forest regeneration was significantly affected by logging, firewood extraction and grazing in a cloud forest in southern Mexico, resulting in the formation of a species-poor forest, dominated by pines (Ramírez-Marcial *et al.*, 2001).

CLIMATE CHANGE

Of all the types of tropical forest, tropical montane cloud forests are especially vulnerable to climate change (Markham, 1998). A wide range of potential negative impacts has been identified (Foster, 2001). It is predicted that the optimum climatic conditions for many mountain habitats will increase in altitude by hundreds of metres in the second half of the 21st century. This will be a direct result of temperature and rainfall changes caused by a doubling of carbon dioxide levels. This will lead to the replacement of cloud forests by lower altitude ecosystems, and the extinction of cloud forests currently found on mountain peaks where they are unable to spread upslope. Cloud forests are also likely to be uniquely affected by climate change due to a reduction in cloudiness at lower altitudes as temperatures increase. This phenomenon is supported by observations from Costa Rica and is predicted by climate models. It will result in less-frequent immersion of the forest in the clouds and reduced capture of water by the vegetation, with a consequent drying out of the ecosystem.

Cloud forest epiphytes and amphibians are especially sensitive to changes in humidity and to water stress. At the Monteverde cloud forest in Costa Rica, 25 of 50 frog and toad species disappeared in 1987 during an El Niño event, including the golden toad *Bufo periglenes*, and only five have reappeared since. At Monteverde the annual abundance of amphibians is correlated with the number of dry days in the dry season (Pounds *et al.*, 1999). The observed increase in the number of dry days and decrease in the diurnal temperature range is correlated with a rise in the overhead cloud bank. Still *et al.* (1999) found results from climate change modelling for four cloud sites supported an elevation of cloud banks.

The formation of cloud banks is affected not only by global climate change; there is also evidence that regional land-use change can have a significant influence. Lawton *et al.* (2001) found that the deforested Caribbean lowlands of Costa Rica remained relatively cloud-free in the dry season, whilst adjacent forested regions had well-developed cumulus cloud fields. These deforested lowlands are upwind of the Monteverde cloud forests, where reduced cloud cover had already been documented.

Cloud forest conservation and livelihoods

SUSTAINABLE FARMING FOR CLOUD FOREST CONSERVATION

Since one of the most widespread threats to cloud forests is conversion to agricultural land and pasture, many cloud forest conservation projects have promoted sustainable farming. Both human population growth and degradation of farmed land are common major driving forces for the clearance of more cloud forests. For example montane forests, some of which are cloud forests, in the Eastern Escarpment of Madagascar declined from 8 million ha in 1900 to 7 million ha in 1950, and to less than 1 million ha by 1995. This deforestation resulted from slash-and-burn cultivation practised by a rapidly increasing human population. These Madagascan farming systems need to be intensified and made sustainable if they are to provide sufficient food for the people and permit the survival of the montane forests (Messerli, 2000).

Another cloud forest region with considerable population pressure occurs in Burundi and Rwanda. These two countries have a combined area of about 55 000 km^2 and a population of about 13 million people, the highest density in Africa at over 230 inhabitants per km^2. More than 90 per cent of the people are farmers and cattle breeders. However, Burundi and Rwanda still maintain afromontane forests in protected areas, all of which are located in the Albertine Rift Mountains. In Burundi these reserves total about 438 km^2, representing 1.6 per cent of the total area of the country.

In the Andes, historically, the eco-climatic zone below the cloud forest belt has been preferred for agriculture and human settlement (Fjeldså and Hjarsen, 1999). This pattern is maintained in Colombia, with rural population density in the Andean region increasing with altitude, from 20 people per km^2 at 500-1 000 m to 48 people per km^2 at 2 500-3 000 m (Etter and van Wyngaarden, 1999).

Fjeldså and Hjarsen (1999) have found that the peak concentrations of Andean endemic bird species are often within or immediately adjacent to areas of dense human population. Some of the rarest Andean birds are found today in the tiny patches of natural woodland or scrub that are left in areas which have been populated for long periods – or they survive on adjacent mountain ridges. Whilst traditional land-use systems in these areas have many features to ensure sustainability, the remaining fragments of natural ecosystems are still very susceptible to degradation.

Law Cheng Tean/UNEP/Topham

Burning for extensive pastoralism is identified as a particular threat.

These examples demonstrate that the future of cloud forests is inextricably tied up with the future livelihoods of the farmers in surrounding areas. Ecologically sustainable land management and improved livelihoods in areas with cloud forests are fundamental to securing forest conservation. However, they will not be sufficient by themselves. The maintenance of the values and services of the cloud forest must itself be a goal of the development process. This has occurred in the indigenous community of Loma Alta in Ecuador. When the people understood the importance of water from their cloud forests for their lowland agriculture they used their own system of governance and decision-making to preserve the forest (Becker, 1999). This example also illustrates the importance of strong local institutions for forest management and the role of participatory research and environmental education in bringing about change.

A contrasting approach to livelihood development and conservation around a cloud forest is reported by Abbot *et al.* (2001) for a project in the Kilum-Ijim forest in Cameroon. More positive attitudes to forest protection measures were found after a ten-year period of development of improved farming and livelihood activities.

This also led to a strengthening of the institutions and legal environment for forest management.

However, the wider socio-economic environment affected progress in these areas. For instance, economic recession resulted in people returning to the villages from cities and clearing the forests for farming. This phenomenon of tropical forests being used as a 'safety net' by the rural poor is also identified by Wunder (2001). A similar process has been reported from a simulation analysis of the land-use decisions of farmers in the buffer zone of La Amistad Biosphere Reserve in Costa Rica and Panama, an area that includes cloud forest. Modelled decisions over whether to clear forest for farmland or not were much more sensitive to economic and social factors than to ecological ones (Duffy *et al.*, 2001).

The fundamental principles for developing sustainable livelihoods whilst ensuring cloud forest conservation are the same as the two central conclusions of a Mountain Forum electronic conference on mountain people, forests and trees (Butt and Price, 2000):

1. Mountain people rely on the whole landscape for their livelihoods. Consequently, policies and institutions for mountain forests and agroforestry must recognize interactions between agricultural land use, forests and trees.
2. Every strategy for ensuring that mountain people derive sustainable livelihoods from their forests and trees must be tailor-made for the local biological, cultural and political environment – ways of responding to change must always be included.

ENVIRONMENTAL SERVICES FROM CLOUD FORESTS

In Latin America there is considerable interest in developing means to promote forest conservation by providing payments to forest owners for the environmental services the forests provide to the rest of society. In addition to the sequestration of carbon, the maintenance of biodiversity and the prevention of landslips, in the case of cloud forests one of the most tangible environmental services is the provision of a year-round source of unpolluted freshwater.

Compensation mechanisms for these services have been most highly developed in Costa Rica, with the creation of a legal mechanism through the 1996 Forestry Law. A National Fund of Forest Financing of Costa Rica was set up to collect funds and pay people who retained or re-established forest on their land. In 1997, US$14 million was paid out for environmental services, which resulted in the reforestation of 6 500 ha, the sustainable management of 10 000 ha of natural forests, and the preservation of 79 000 ha of private natural forests. Eighty percent of this funding originated nationally, with the other 20 per cent generated by the international sale of carbon fixation services under the Clean Development Mechanism. The National Fund has been able to negotiate payment for watershed services with several hydroelectric corporations, with payments varying from US$10 to US$40/ha/year (Campos and Calvo, 2000). Some 60 per cent of Costa Rica's forests are privately owned.

TIMBER AND NON-TIMBER PRODUCTS FROM CLOUD FORESTS

Cloud forests are generally unsuitable for commercial timber harvesting because the canopy trees have slow growth rates, short stature and contorted shapes. In addition, the rugged terrain makes logging difficult (Scatena, 1995). However, in the relatively benign topographical conditions of the Cordillera de Talamanca of Costa Rica the dominant oak trees of the cloud forest have shown potential for sustainable timber production (Chaverri and Hernandez, 1995). Where cloud forests are near major urban centres they are often exploited for charcoal production, which can be a significant deforestation pressure.

A diversity of non-timber forest products (NTFPs) is exploited from cloud forests. These products include medicinal plants, fruits and herbs, game meat and ornamental plants. Tree ferns and the abundant epiphytes such as orchids, bromeliads and mosses are extracted for horticultural markets. This represents a major threat to the cloud forest flora in many countries, including Colombia, Costa Rica, Guatemala, Mexico and the Philippines. The trade is not only for local markets but also for export to Europe and North America.

There is little published research on the sustainable management of these non-timber products, but Romero (1999) reported that the abundance of pendant bryophyte epiphytes harvested in Costa Rica was not reduced in montane oak forests nine years after careful selective timber harvesting. In pine-oak forests in Chiapas, Mexico, Wolf and Konings (2001) determined sustainable harvesting levels for epiphytic bromeliads used by local people to adorn houses and religious sites.

Two important examples of medicinal products that are extracted from cloud forest trees are quinine and pygeum. Until it was replaced by synthetic products, the local indigenous people extracted quinine from the bark of the Ecuadorian cloud forest tree *Cinchona succirubra.* Pygeum is an effective treatment for prostate cancer and is extracted from the bark of *Prunus africana*, found in the cloud forests and other montane forests of Africa. Destructive harvesting of the *Prunus africana* bark is threatening the survival of the trees and also of the US$220 million annual market for *Prunus* remedies in Europe and the United States (http://www.futureharvest.org/news/Prunus.shtml consulted January 2004).

RESTORATION OF CLOUD FORESTS

Restoration is becoming recognized as a necessary part of ensuring the maintenance of ecosystem services and biodiversity in tropical montane landscapes (Sarmiento, 2000). Cloud forest restoration is also part of programmes to establish biological corridors between highland and lowland forests, to allow the annual altitudinal migrations of many species. The Choco-Andean corridor in Ecuador is an example of landscape-scale forest restoration, linking cloud forests with Pacific lowland rainforests.

Most interest in montane forest restoration has been in Latin America and studies are starting to identify some of the issues involved. A review of succession across different types of Neotropical forest found that such forests have a high ability to regenerate if propagule sources are close by and land-use intensity before abandonment has not been severe (Guariguata and Ostertag, 2001). However, in the central Andes the natural regeneration of cleared cloud forests can be prevented by a stage of arrested natural succession in the form of fire-climax grasslands. This can result in the mountain landscapes remaining fragmented (Sarmiento, 1997). Forest regeneration by seeding may only be possible through removal of the aerial tillers and the extensive root mass of grass species.

Natural regeneration of cleared cloud forest is favoured if some tree 'survivors' remain, to enhance the arrival of seeds via fruit-eating birds, to provide shade and regeneration of interspersed patches, and to stimulate dispersal for rapid initiation of ecological succession (Sarmiento, 1997). The key role of frugivorous birds in cloud forest vegetation structure, composition and regeneration has also been identified in Costa Rica (Kappelle and Wilms, 1998). It is recommended that forest-edge tree species should be included in programmes for the ecological restoration of tropical montane cloud forests.

Andean alder (*Alnus acuminata*) is a tree species often used in the Colombian Andes for revegetation programmes. It is native to the area and grows rapidly, even in nitrogen-poor soils. Although alder may create a forest cover in a shorter time, natural regeneration may be a better strategy for the recovery and conservation of cloud forest biodiversity, as long as a propagule source is available (Murcia, 1997). The presence of both alder and cloud forest species may increase species richness and spatial heterogeneity at the landscape level.

Studies in Jamaica indicate that for cloud forests cleared from steep slopes, following the cessation of agriculture, soil condition and fertility are effectively restored after about 20 years of secondary succession. This results in the re-establishment of a forest with effective nutrient conservation, a high degree of protection of soil and water resources, and the potential to sustain another cycle of agricultural production (McDonald and Healey, 2000).

CLOUD FOREST TOURISM

Many cloud forest sites throughout the world are significant tourist attractions. People are attracted by their beauty, the mountain environment and the rare birds, such as the resplendent quetzal *Pharomachrus mocinno* in Central America. In the Americas, from Mexico to Bolivia, a large number of ecotourism enterprises now include visits to cloud forests in their itineraries. Some cloud forests are included in private reserves, such as Monteverde in Costa Rica. Many such reserves have associated facilities for researchers. Government-managed protected areas have also established tourist facilities and in some cases these have involved local communities supported by NGOs and international development projects.

Philip Bubb

In Africa revenues from tourism are vital for the management of the national parks where mountain gorillas *Gorilla gorilla beringei* inhabit the cloud forests on the Virunga volcanoes of the Democratic Republic of Congo, Rwanda and Uganda. Other cloud forest sites with significant tourism potential include Mount Stanley in Uganda, Luquillo National Forest in Puerto Rico, Mount Makiling and Mount Pulog in the Philippines, the Cameron and Genting Highlands in peninsular Malaysia and Mount Kinabalu in Sabah, Malaysia (Hamilton *et al.*, 1995).

CASE STUDY: THE RESILIENT QUENOAL MOUNTAIN CLOUD FORESTS OF THE HIGH PERUVIAN ANDES

- *Polylepis*, known in native Qechua as *Quenoal*, is a unique type of mountain cloud forest in the Andes. There are 20 species of *Polylepis* trees, one of which is the highest growing angiosperm on the planet, reaching an altitude of 5 200 metres in Bolivia. These are environments where freezing nights throughout the year and high insolation of soils create conditions that are particularly adverse to the growth of trees. Hence the peculiar adaptive features of *Polylepis* species include twisted branching, dwarfed size and multiple layers of peeling bark to protect trees from the cold.

- There are 93 700 hectares of *Polylepis* forests in highland Peru, mostly in patches which are typically less than 30 hectares each. Trees growing at this altitude provide habitat to 25 highland bird species that are endemic to these forests. The understorey of *Polylepis* forests is associated with wild relatives of Andean food crops, including wild relatives of potatoes and other Andean tubers, as well as medicinal plants.

- Given the observed high rates of glacier loss in the Andes, the forests' role in regulating the water cycle, in association with high-altitude grassland, becomes particularly important. What is now left of these forests are relicts, pushed by natural and human agency to areas like boulder fields associated with glaciers, where access by humans or by cattle is very difficult. However, despite the small size of these *Polylepis* patches, they are critical to Andean biodiversity. Some of the most important hotspots are protected by Huascaran National Park, whilst other protected areas immediately east along the headwaters of the Marañon River require urgent attention.

- Key to successful conservation of the forests is the intense involvement of rural Andean families and communities. Although the forests traditionally provided fuelwood, construction materials for houses and farming tools, and medicinal plants, it is nonetheless evident that these forests have been subject to fire and cutting in order to keep the open-range landscape that Andean farmers require for grazing cattle and native Camelidae. One of the most striking features shown by recent studies of the forests is the extraordinary resilience of *Polylepis* relicts which, located in landscape areas marginal to humans, show resistance to fires and heavy grazing up to their borders, where a high density of seedlings and saplings can be found.

Jorge Recharte

- Successful examples of forest restoration and protection of *Polylepis* forests by Andean communities in the Cordillera Blanca in Ancash and in the Cusco area should urgently be replicated to preserve Andean biodiversity and ecosystem health through protection of this true survivor and unique mountain cloud forest.

Jorge Recharte
The Mountain Institute, Peru

Cloud Forest Agenda

SUMMARY OF THE ISSUES AND OPPORTUNITIES

Tropical montane cloud forests are a relatively rare ecosystem, with a potential area of about 380 000 km², forming 2.5 per cent of all tropical forest. Their two outstanding features are the year-round freshwater flowing from them and their exceptional numbers of endemic species. Recognition of these values has led to cloud forest protected areas being established in many countries. However, the continuing existence of many cloud forests is often due more to their inaccessibility for conversion to agriculture rather than to conservation measures *per se*. Pressures for clearance for new farmland are increasing as a result of population growth, degradation of existing farmland, and complex socio-economic processes involving highland and lowland economies. The construction of roads into montane areas also increases these pressures.

In many parts of the world cloud forests exist as islands of natural forest in human-modified landscapes. They are sources of vital forest products and services for local people, as well as refuges for their own unique species lost from surrounding areas. Habitat fragmentation is a common feature of cloud forest sites. However, even areas of cloud forest only tens of hectares in extent are likely to contain endemic species found nowhere else (Anderson and Ashe, 2000; Bosland and Gonzalez, 2000). Every cloud forest site is valuable in terms of biodiversity conservation and its potential to contribute to sustaining local livelihoods and cultures.

Protected areas are a central tool in the conservation of cloud forests. All the different categories of protected area may be needed depending upon the local situation, including strict nature reserves, national parks, biosphere reserves and protected watersheds. Two emerging trends are the creation of more privately owned reserves, particularly in Latin America, and the establishment of more local community and municipal reserves, often on the lands of indigenous peoples.

For cloud forest reserves to be maintained in the long term they need to be fully integrated into local economies. Societies will support this if they understand the value of cloud forests and if ways are found for this value to be captured by local economies. However, building awareness of cloud forest values is not in itself sufficient. In many situations the survival of cloud forests will depend on the sustainability of the farming systems of the people living in the area. Major investments are needed in addressing the farming and other rural development needs of rural mountain people.

Building sustainable livelihoods in cloud forest regions can be financed in some situations through payments for the environmental services of these forests. There is some experience with payment mechanisms for water supplies from mountain forests in Latin America. Such payment mechanisms require a number of conditions, including a suitable legal and policy environment, organized and informed groups of upland peoples and water users, and reliable and politically credible information on the value of the services provided by the forest.

RESEARCH AND INFORMATION PRIORITIES FOR CLOUD FOREST CONSERVATION

Research and conservation needs for cloud forest conservation were identified in the 1993 international tropical montane cloud forest symposium (Hamilton *et al.*, 1995), the 1998 WCMC workshop (Aldrich, 1998) and in some regional meetings, such as the Andean Mountains Association in 2001 (Kappelle *et al.*, 2001). There is considerable consistency in the recommendations of these meetings. The principal needs that have been identified are:

- ❑ detailed mapping of cloud forest areas and assessment of their conservation value (locally and globally) and status (current land tenure, level of protection, threats to their integrity);
- ❑ inventories of the biodiversity of cloud forest sites;
- ❑ quantification of the hydrological properties of cloud forests at watershed scale;
- ❑ studies and monitoring of climate change in cloud forests, including in relation to regional land use;
- ❑ recording and dissemination of uses and knowledge of cloud forests by indigenous peoples and other groups;
- ❑ research into the effects of fragmentation of cloud forests and means of ecological restoration.

The Second International Symposium on Tropical Montane Cloud Forests in Hawaii in July 2004 will present the latest research in many of these areas.

AN AGENDA FOR ACTION

The vision of the Mountain Cloud Forest Initiative is a future where all cloud forests, with their unique plants and animals and water catchment functions, are valued and protected by mountain communities and downstream users. Cloud forests are also recognized both as sensitive indicators of climate change, and areas that are under particular threat from these changes. Their conservation is strongly supported by the global community.

To achieve this vision requires local and national organizations to act as champions for their cloud forests.

The following questions are proposed as a series of actions or steps for 'cloud forest champions' to develop the necessary strategies and support for long-term success.

Information on status and threats

- Are cloud forests recognized as a distinct forest type?
- Are maps of cloud forest distribution available?
- Are there assessments of cloud forest protection status?
- Are there assessments of the biodiversity values, threats and conservation priorities of cloud or humid montane forests?
- Are there studies of watershed and other economic values of cloud forests?

Awareness-raising and conservation strategies

- Are there educational and awareness-raising activities for cloud forests?
- Are cloud forests recognized in national biodiversity strategies, action plans, etc.?
- Are there government agencies, NGOs or research centres that include actions for cloud forests?

Capacity and tools

- Are there projects and legislation for payment schemes to maintain cloud forest water supplies?
- Are there networks and training courses relevant to cloud forest conservation, management and identification of lessons learned?

Appendix 2 contains a preliminary assessment of the status of these actions at the continental scale.

GOALS AND CAPACITY FOR CLOUD FOREST CONSERVATION

The members of the Mountain Cloud Forest Initiative identify the principal goals for cloud forest conservation as:

- major investment in achieving sustainable livelihoods in montane regions with cloud forest, including landscape and ecosystem approaches to environmental management and restoration;
- integration of cloud forest conservation into development policies by governments and the international conservation community;
- active and effective management of protected areas and sustainable use of cloud forests;
- national and regional cloud forest conservation strategies, identifying priority sites and issues for action;
- supportive and enforced environmental laws and policies for the conservation of montane forests and payments for environmental services, which include broad-based stakeholder participation.

To achieve these goals requires significant national and international investment in building the capacity of 'cloud forest champions'. This must include:

- innovative funding mechanisms to promote cloud forest conservation, especially in recognition of their water services;

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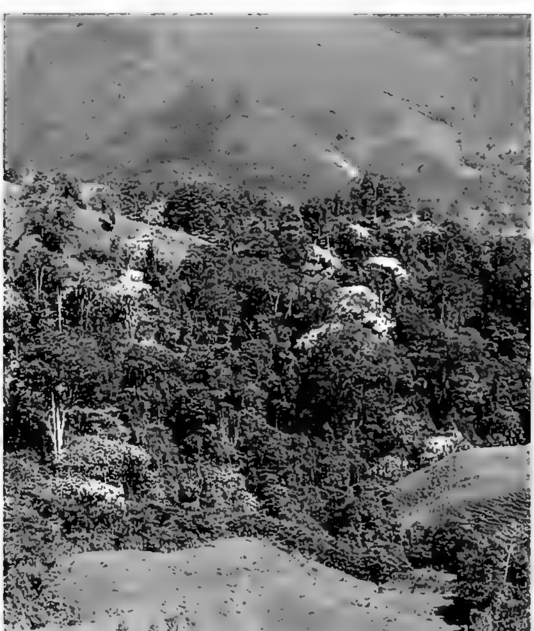

W.Ferwerda

- networks promoting collaboration amongst conservationists working on cloud forests, the development of cloud forest conservation strategies and measures to support lesson-learning and research;
- training in cloud forest management and conservation for the leaders of NGOs, community organizations, government agencies and researchers;
- awareness-raising tools and decision-support materials (maps, databases, websites, videos, etc.).

NATIONAL AND REGIONAL AGENDAS

Information on the status, management and threats to tropical montane forests is much more readily available for the Neotropical realm (e.g. Kappelle and Brown, 2001; Webster, 1995), than for Africa and Asia. A preliminary overview of regional conservation priorities for cloud forest conservation is presented, based on the analyses given in this report.

Cloud forest conservation priorities in Asia

Since approximately 60 per cent of the world's cloud forest habitat is in the Asian region, much greater recognition needs to be given to the importance of these forests. As lowland forests are converted to agriculture the significance of the less-accessible cloud forests increases, providing forest goods and services and refuges for once-widespread forest species.

Most of the cloud forest in Asia is found in Indonesia and Papua New Guinea, and Indonesia experienced high rates of forest loss and degradation during the 1990s (Barber and Schweithelm, 2000). Actions are urgently needed in Indonesia to promote the recognition of cloud forests in land-use and development planning, as well as to ensure the effective management of those protected areas with cloud forests. Identification of the many smaller areas of cloud forest on the islands of Indonesia is also a priority. In Papua New Guinea actions should include assessments and awareness-raising of the globally significant areas of cloud forest and other montane forest, in conjunction with analysis and support for ecologically sustainable farming and livelihood systems in the mountain regions.

The watershed and biodiversity importance of the cloud forests of the Philippines has been recognized in national legislation and the creation of protected areas, but they are under considerable deforestation pressure for land to grow temperate-zone vegetables (Penafiel, 1995). A priority for some areas of Philippine cloud forest is restoration to maintain watershed services.

In peninsular Malaysia a programme of action has been promoted by the Malaysian World Wide Fund for Nature for sustainable highland development (WWF

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Malaysia, 1998), including conservation of the cloud forests threatened by roads and housing development. The examples and lessons learned from this combination of scientific research and policy work for the management and conservation of highland habitats may be relevant for other tropical mountain regions.

In the continental Asian countries of India, Laos, Myanmar, Thailand and Viet Nam, cloud forests occupy relatively small areas. The national importance of these forests is very high for their endemic species as well as their local watershed services. Priority actions for these countries could include documenting and ensuring recognition of these values in land-use and development planning at the national and local scales. The cloud forests of Myanmar in particular are poorly known.

Cloud forest conservation priorities in Africa

Cloud forests are rarely distinguished from the Afromontane forest type in Africa. As well as clearance for agriculture, African cloud forests are particularly threatened by hunting of their wildlife, encroachment by fire and grazing animals, and firewood and charcoal production. One of the largest areas of African cloud forest is in the Albertine Rift Mountains of Burundi, the Democratic Republic of Congo (DRC), Rwanda, Tanzania and Uganda. The Albertine Rift Conservation Society (ARCOS) is a partnership of national and international biodiversity conservation organizations and government agencies. Their priorities include identification of unprotected cloud forest sites and supporting the effective management of protected areas in the region. The Itombwe Mountains of the southeastern portion of the DRC are one conservation priority because of their extensive areas of montane and lowland forest with no protection.

In Tanzania the cloud forest and other forests of the Eastern Arc mountains have been mapped and biodiversity conservation priorities identified by the Tanzania Forest Conservation Group (2000). In Kenya a priority is ensuring the effectiveness of protected areas with cloud forests. Some of the montane forests of Ethiopia may be drier than cloud forests, but extensive areas are recorded on the map of potential cloud forest distribution (Map 2). The relatively unexplored Harenna forest in southern Ethiopia is one priority for further attention. The montane forests of Madagascar contain concentrations of endemic species, but are highly fragmented and threatened by agriculture and fires.

Cameroon contains the other large areas of moist montane forest in Africa. Long-term work by BirdLife International and the Government of Cameroon in the Bamenda Highlands is leading to forest regeneration, resulting from the establishment of forest boundaries and improved agricultural practices and use of forest resources. Other African countries with smaller areas of montane or cloud forest include Angola, Côte d'Ivoire (Mount Nimba), Equatorial Guinea, Gabon, Malawi, Mozambique, Nigeria and Sierra Leone. Priority actions for these countries could include documenting and ensuring recognition of the values of cloud forest in development and conservation planning. Burgess *et al.* (in press) and Fishpool and Evans (2001) provide information on priority conservation sites and issues in Africa.

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Cloud forest conservation priorities in the Americas

Kappelle and Brown (2001) provide a detailed overview of the cloud forests of the Neotropical region, including environmental conditions, ecology, diversity of flora and fauna, biogeography and conservation. This greater awareness of cloud forests and availability of information is also reflected in the formation of a network and action plan for the conservation of Mexican cloud forests (Instituto de Ecologia, 1999) and a review of the state of conservation of cloud forests in Central America (Chaverri, 2001).

The most wide-ranging cloud forest conservation need in the Americas is the integration of sustainable farming systems and effective management of protected areas in mountains with cloud forest. In some parts of the Andes particular issues are extensive cattle ranching and drug cultivation, whilst habitat fragmentation and increased pressures on cloud forests from the construction of roads in mountain areas are also widespread. Latin America and the Caribbean is the region where most research has been conducted on the effects of climate change on cloud forests, cloud forest hydrology and land-use change, and the development of payment mechanisms for water services from montane forests.

In Mexico cloud forest conservation priorities include identifying and disseminating the lessons learned from several well-established protected areas with cloud forests, and surveys of unprotected areas in western Mexico. In El Salvador, Guatemala and Honduras priorities include expansion and strengthening of cloud forest protected areas. Priorities in Costa Rica include identification and dissemination of lessons learned from the variety of protected areas with cloud forest, especially regarding revenues from ecotourism and payments for environmental services. In Panama a priority is increased recognition of the particular characteristics of cloud forests within development policies designed for the environmental conditions of the country's mountain regions (Samudio, 2001).

For the Andean countries of Bolivia, Colombia, Ecuador, Peru and Venezuela the opportunities and priorities for conservation include ensuring recognition of cloud forests in development planning, and increased networking and dissemination of lessons learned amongst the many government agencies, NGOs and research groups promoting conservation and development in the region. Emerging issues include payment for environmental services, biological corridors, cloud forest restoration, and multinational approaches such as the Regional Biodiversity Strategy of the Andean Community of Nations. The cloud forests of the Brazilian Atlantic coast require much greater recognition as a unique forest type within the country.

Tropical islands with cloud forests

Many islands in the tropics have relatively small but very important areas of cloud forest, which contain endemic species and are sources of freshwater. These forests require adequate recognition as protected areas in land-use planning. As with all island ecosystems, they are particularly vulnerable to invasive alien species.

The global-scale analysis of potential cloud forest distribution does not adequately demonstrate the location of tropical island cloud forests. Many of these sites are, however, recorded in the UNEP-WCMC cloud forest database. The Caribbean islands with cloud forest are Cuba, Dominica, Dominican Republic/Haiti, Grenada, Guadeloupe, Jamaica, Martinique, Puerto Rico, San Cristobal, Saint Lucia, Saint Vicente and Trinidad. Islands with cloud forest off the coast of Africa include Bioko (Equatorial Guinea), the Canary Islands, the Comoros, Mauritius, Réunion, São Tomé and Principe, and the Seychelles. Pacific Ocean islands with records of cloud forest are American Samoa, the Cook Islands, Fiji, French Polynesia, Galapagos, Hawaii, Micronesia, New Britain and New Ireland Islands, New Caledonia, the Solomons, Tonga and Western Samoa.

GLOBAL AGENDA

The members of the Mountain Cloud Forest Initiative urge all international agencies and environmental agreements to ensure adequate recognition and financial resources for the conservation and management of the world's cloud forests. Opportunities to achieve this goal include the following.

- **Convention on Biological Diversity**: inclusion of actions for cloud forests in its Programme of Work on Mountain Biodiversity and other Programmes and Targets.
- **Global Environment Facility**: a review of its coverage of projects in areas with cloud forests, to identify geographical gaps and opportunities for disseminating lessons learned, particularly within its Operational Programme on Mountains. This could include establishment and effective management of protected areas and promotion of sustainable livelihoods with local communities, and integration of cloud forest conservation objectives in land use and natural resource use management plans.
- **UN Forum on Forests**: development of actions for cloud forests in the implementation of the Proposals for Action agreed by the Intergovernmental Panel and Forum on Forests.
- **UNEP and the UNEP World Conservation Monitoring Centre**: working with governments and regional agencies to raise awareness and additional resources for assessments of cloud forests and the development of conservation strategies; promoting conservation of mountain gorillas through the WSSD Partnership for great apes (GRASP) jointly with UNESCO; enhancing the capacity of countries to establish regulatory and administrative regimes for access and benefit sharing of genetic resources (ABS) through the UNEP Initiative on ABS; seeking actions for cloud forests within the International Partnership for Sustainable Development in Mountain Regions; continuing to develop conservation-relevant information on the world's cloud forests and to promote networking through the website (http://www.unep-wcmc.org/forest/cloudforest).

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- **IUCN–The World Conservation Union**: promoting government and NGO members' initiatives for cloud forests through the Commission on Ecosystem Management and regional offices, including application of the Ecosystem Approach. It is proposed to submit a resolution on cloud forests at the World Conservation Congress in November 2004. This will advocate the priorities presented in *Cloud Forest Agenda*, calling for support for national or regional institutions willing to promote the formulation and implementation of cloud forest conservation and management strategies and research, including monitoring progress and learning from experience.
- **UNESCO**: promoting the conservation of cloud forests and the identification of successful approaches to sustainable mountain development through the Man and the Biosphere (MAB) Programme; continuing to develop and disseminate knowledge on the management and restoration of cloud forest watersheds through the International Hydrological Programme (IHP).

References

Abbot, J.I.O., D.H.L.Thomas, A.A.Gardner, S.E.Neba and Mbony W.Khen (2001) Understanding the links between conservation and development in the Bamenda Highlands, Cameroon. *World Development* Vol. 29 (7): 1115-1136.

Aldrich, M. (1998) Tropical Montane Cloud Forests. Planning and Advisory Workshop Report. World Conservation Monitoring Centre, Cambridge, UK. 23 pp (unpublished).

Aldrich, M., C.Billington, M.Edwards and R.Laidlaw (1997) A Global Directory of Tropical Montane Cloud Forests – Draft. World Conservation Monitoring Centre, Cambridge, UK. 268 pp.

Anderson, R.S. and J.S.Ashe (2000) Leaf litter inhabiting beetles as surrogates for establishing priorities for conservation of selected tropical montane cloud forests in Honduras, Central America (Coleoptera; Staphylinidae, Curuclionidae) *Biodiversity and Conservation* 9: 617-653.

Arango-Vélez, N. and G.H.Kattan (1997) Effects of forest fragmentation on experimental nest predation in Andean cloud forest. *Biol. Conserv.* 81: 137-143.

Balslev, H. (1988) Distribution patterns of Ecuadorean plant species. *Taxon* 37: 567-577.

Barber, C.V. and J.Schweithelm (2000) *Trial by Fire: Forest Fires and Forestry Policy in Indonesia's Era of Crisis and Reform.* World Resources Institute, Washington DC.

Becker, C.D. (1999) Protecting a Garua forest in Ecuador: the role of institutions and ecosystem valuation. *Ambio* 28 (2): 156-161.

Benzing, D.H. (1998) Vulnerabilities of tropical forests to climate change: the significance of resident epiphytes. *Clim. Change* 39: 519-540.

Bockor, I. (1979) Analyse von Baumartenzusammensetzung und Bestandesstruckturen rined andinen Wolkenwaldes in Westvenezuela als Grundlage zur Waldt-typengliederung. Dissertation Universitat Gottingen. 138 pp (cited in Stadtmuller, T. (1987) *Cloud Forests in the Humid Tropics.* A bibliographic review. United Nations University, Tokyo and CATIE, Turrialba, Costa Rica).

Bosland, P.W. and M.M.Gonzalez (2000) The rediscovery of *Capsicum lanceolatum* (Solanaceae), and the importance of nature reserves in preserving cryptic biodiversity. *Biodiversity and Conservation* 9: 1391-1397.

Bruijnzeel, L.A. (2000) Hydrology of tropical montane cloud forests: a re-evaluation. In: Gladwell J.S. (ed.) *Proceedings of the Second International Colloquium on Hydrology of the Humid Tropics.* CATHALAC, Panama City, Panama.

Bruijnzeel, S. and L.S.Hamilton (2000) *Decision Time for Cloud Forests.* IHP Humid Tropics Programme Series No. 13. UNESCO Division of Water Sciences, Paris.

Burgess, N., J.D'Amico, E.Underwood, I.Itoua and D.M.Olson (in press) *Terrestrial Ecoregions of Africa: A Conservation Assessment.* World Wildlife Fund, Washington DC.

Burgess, N., N.Doggart and J.C.Lovett (2002) The Uluguru Mountains of eastern Tanzania: the effect of forest loss on biodiversity. *Oryx* 36 (2): 140-152.

Butt, N. and M.F.Price (2000) Mountain People, Forests and Trees: Strategies for Balancing Local Management and Outside Interests. Synthesis of an Electronic Conference on the Mountain Forum, April 12-May 14, 1999. The Mountain Forum, Harrisonburg, VA, USA. http://www.mtnforum.org

Campos, J.J. and J.Calvo (2000) Compensation for environmental services from mountain forests. In: *Mountain Forests and Sustainable Development.* Mountain Agenda, CDE, University of Berne, Switzerland. pp 26-27.

Carlson A. and G.Hartman (2001) Tropical montane forest fragmentation and nest predation – an experiment. *Biodiversity and Conservation* 10: 1077-1085.

Cavelier, J. and A.Etter (1996) Deforestation of montane forests in Colombia as a result of illegal plantations of opium (*Papaver somniferum*). In: Churchill, S.P., H.Balslev, E.Forero and J.Luteyn (eds) *Biodiversity and Conservation of Neotropical Montane Forests: Proceedings of the Neotropical Montane Forest Biodiversity and Conservation Symposium, The New York Botanical Garden, 21-26 June 1993.* The New York Botanical Garden.

Chaverri, A. (2001) Estado de la conservación de los bosques nubosos en Mesoamérica. UICN-ORMA, San José, Costa Rica (unpublished).

Chaverri, A. and O.Hernandez (1995) Ecology and management in montane oak forests: an option for conserving biodiversity. In: Churchill, S.P., H.Balslev, E.Forero and J.Luteyn (eds) *Biodiversity and Conservation of Neotropical Montane Forests: Proceedings of the Neotropical Montane Forest Biodiversity and Conservation Symposium, The New York Botanical Garden, 21-26 June 1993.* The New York Botanical Garden. pp 609-617.

CPD (1997) Centres of Plant Diversity – The Americas. Available at http://www.nmnh.si.edu/botany/projects/cpd/

Debouck, D.G. and D.Libreros Ferla (1995) Neotropical montane forests: a fragile home of genetic resources of wild relatives of new world crops. In: Churchill, S.P., H.Balslev, E.Forero and J.Luteyn (eds) *Biodiversity and Conservation of Neotropical Montane Forests: Proceedings of the Neotropical Montane Forest Biodiversity and Conservation Symposium, The New York Botanical Garden, 21-26 June 1993.* The New York Botanical Garden. pp 561-577.

Duffy, S.B., M.S.Corson and W.E.Grant (2001) Simulating land-use decisions in the La Amistad Biosphere Reserve buffer zone in Costa Rica and Panama. *Ecological Modelling* Vol. 140 (1-2): 9-29.

Etter, A. and W.van Wyngaarden (1999) Población y transformación de los paisajes de la región andina en Colombia. In: *III Simposio Internacional de Desarrollo Sustentable de Montañas: entiendo las interfaces ecologicas para la gestion de los paisajes culturales en los Andes. Quito 9-14 December 1998.* pp 239-248.

Fishpool, L.D.C. and M.I.Evans (eds) (2001) *Important Bird Areas in Africa and Associated Islands. Priority Sites for Conservation.* Birdlife International, Pisces Publications.

Fjeldså, J. (2001) Cartografiar la avifauna andina: una base científica para establecer prioridades de conservación. In: Kappelle, M. and A.D.Brown (eds) *Bosques nublados del neotrópico.* Instituto Nacional de la Biodiversidad (INBio), Santo Domingo de Heredia, Costa Rica. pp 125-154.

Fjeldså, J. and T.Hjarsen (1999) Needs for sustainable land management in biologically unique areas in the Andean highland. In: *III Simposio Internacional de Desarrollo Sustentable de Montañas: entiendo las interfaces ecologicas para la gestion de los paisajes culturales en los Andes. Quito 9-14 December 1998.* pp 151-162.

Foster, P. (2001) The potential negative impacts of global climate change on tropical montane cloud forests. *Earth-Science Reviews* Vol. 55 (1-2): 73-106.

Gentry, A.H. (1992) Diversity and floristic composition of Andean forests of Peru and adjacent countries: implications for their conservation. In: Young K.R. and N.Valencia (eds) *Biogeografía, ecología y conservación del bosque montano en el Perú.* Memorias Museo de Historia Natural, Vol. 21. UNMSM, Lima. pp 11-29.

Goodland, T. and J.R.Healey (2001) The invasion of Jamaican montane rainforests by the Australian tree *Pittosporum undulatum.* Website consulted January 2004. http://www.bangor.ac.uk/%7Eafs101/iwpt/pittorep.doc

Guariguata, M.R. and R.Ostertag (2001) Neotropical secondary forest succession: changes in structural and functional characteristics. *Forest Ecology and Management* Vol. 148 (1-3): 185-206.

Hamilton, L.S., J.O.Juvik and F.N.Scatena (1995) The Puerto Rico Tropical Cloud Forest Symposium: Introduction and Workshop Synthesis. In: Hamilton, L.S., J.O.Juvik and F.N.Scatena (eds) *Tropical Montane Cloud Forests,* Springer Verlag, New York. pp 1-16.

Instituto de Ecologia (1999) Encuentro Nacional: Plan de accion para la conservacion de los bosques mesofilos de montaña en Mexico. http://www.ecologia.edu.mx/cloud/

Iremonger, S., C.Ravilious and T.Quinton (eds) (1997) A Global Overview of Forest Conservation. CD-ROM. World Conservation Monitoring Centre and Center for International Forestry Research, Cambridge, UK. Also available at http://www.unep-wcmc.org/forest/global_map.htm

Kapos, V., J.Rhind, M.Edwards and M.F.Price (2000) Developing a map of the world's mountain forests. In: Price, M.F. and N.Butt (eds) *Forests in Sustainable Mountain Development: A State-of-knowledge Report for 2000.* CAB International, Wallingford, UK.

Kappelle, M. and A.D.Brown (eds) (2001) *Bosques nublados del neotrópico.* Instituto Nacional de la Biodiversidad (INBio), Santo Domingo de Heredia, Costa Rica. 704 pp.

Kappelle, M., A.D.Brown, M.Ataroff and F.Sarmiento (2001) Results from the Andean Cloud Forest Workshop held during the 'IV Simposio Internacional de Desarrollo Sustentable en Los Andes: La Estrategia Andina para el Siglo XXI', November 25-December 2, 2001, at the Universidad de los Andes, Mérida, Venezuela.

Kappelle, M. and J.J.A.M.Wilms (1998) Seed dispersal by birds and successional change in a tropical montane cloud forest. *Acta Botanica Neerlandica* 47: 155-156.

Kattan, G.H., H.Alvarez-Lopez and M.Giraldo (1994) Forest fragmentation and bird extinctions: San Antonio eighty years later. *Conservation Biology* 8: 138-146.

Krabbe, N., D.J.Agro, N.H.Rice, M.Jacome, L.Navarrette and F.Sornoza M. (1999) A new species of *Antpitta* (Formicariidae: *Grallaria*) from the southern Ecuadorian Andes. *The Auk* 116 (4): 882-890.

Lambrechts, C. (2000) The threatened forests of Mount Kenya. In: *Mountain Forests and Sustainable Development,* Mountain Agenda, CDE, University of Berne, Switzerland. pp 30-31.

Lawton, R.O., U.S.Nair, R.A.Pielke Sr. and R.M.Welch (2001) Climatic impact of lowland deforestation on nearby montane cloud forests. *Science* 294: 584-587.

Leo, M. (1995) The importance of tropical montane cloud forest for preserving vertebrate endemism in Peru: the Rio Abiseo National Park as a case study. In: Hamilton, L.S., J.O.Juvik and F.N.Scatena (eds) *Tropical Montane Cloud Forests,* Springer Verlag, New York. pp 126-133.

Long, A. (1995) Restricted-range and threatened bird species in tropical montane cloud forests. In: Hamilton, L.S., J.O.Juvik and F.N.Scatena (eds) *Tropical Montane Cloud Forests,* Springer Verlag, New York. pp 47-65.

Lozano, C.G. (1983) Magnoliaceae. *Flora de Colombia* 1: 1-119.

Mares, M. (1992) Neotropical mammals and the myth of Amazonian biodiversity. *Science* 225: 967-979.

Markham, A. (1998) Potential impacts of climate change on tropical forest ecosystems (guest editorial). *Clim. Change* 39 (2-3): 141-143.

McDonald, M.A. and J.R.Healey (2000) Nutrient cycling in secondary forests in the Blue Mountains of Jamaica. *Forest Ecology and Management* Vol. 139 (1-3): 257-278.

Messerli, P. (2000) Tropical mountain forests – myths and realities of conservation and development. In: *Mountain Forests and Sustainable Development.* Mountain Agenda, CDE, University of Berne, Switzerland. pp 31-32.

Murcia, C. (1997) Evaluation of Andean alder as a catalyst for the recovery of tropical cloud forests in Colombia. *Forest Ecology and Management* Vol. 99 (1-2): 163-170.

Olander, L.P., F.N.Scatena and W.L.Silver (1998) Impacts of disturbance initiated by road construction in a subtropical cloud forest in the Luquillo Experimental Forest, Puerto Rico. *Forest Ecology and Management* Vol. 109 (1-3): 33-49.

O'Neill, J.P., D.F. Lane, A.W.Kratter, A.P.Capparella and C.F.Joo (2000) A striking new species of barbet (Capitoninae: *Capito*) from the eastern Andes of Peru. *The Auk* 117: 569-577.

Penafiel, S.R. (1995) The biological and hydrological values of the mossy forests in the central Cordillera Mountains, Philippines. In: Hamilton, L.S., J.O.Juvik and F.N.Scatena (eds) *Tropical Montane Cloud Forests,* Springer Verlag, New York. pp 171-175.

Portilla, A.C. (2001) Valoracion economica del bosque de proteccion Cordillera Escalera San Martin. IRG/BIOFOR, USAID/Perú, Av. José Gálvez Barrenechea 1086-701, Lima 27.

Pounds, J.A., M.P.L.Fogden and J.H.Campbell (1999) Biological response to climate change on a tropical mountain. *Nature* 398: 611-615.

Ramírez-Marcial, N., M.González-Espinosa and G.Williams-Linera (2001) Anthropogenic disturbance and tree diversity in montane rain forests in Chiapas, Mexico. *Forest Ecology and Management* Vol. 154 (1-2): 311-326.

Restrepo, R., L.M.Renjifo and P.Marples (1997) Frugivorous birds in fragmented neotropical montane forests: landscape pattern and body mass distribution. In: Laurance, W.F. and R.O.Bierregaard Jr. (eds) *Tropical Forest Remnants: Ecology, Management and Conservation of Fragmented Communities.* The University of Chicago Press, Chicago.

Richardson, B.A., M.J.Richardson, F.N.Scatena and W.H.McDowell (2000) Effects of nutrient availability and other elevational changes on bromeliad populations and their invertebrate communities in a humid tropical forest in Puerto Rico. *J. Trop. Ecol.* 16: 167-188.

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* Vol. 118: 117-125.

Rudel, T. (1999) Carreteras, especuladores y degradación ambiental en una sociedad montañosa. In: *III Simposio Internacional de Desarrollo Sustentable de Montañas: entiendo las interfaces ecologicas para la gestion de los paisajes culturales en los Andes. Quito 9-14 December 1998.* pp 171-177.

Rzedowski, J. (1996) Analisis preliminar de la flora vascular de los bosques mesofilos de montana de Mexico. *Acta Botanica Mexicana* 35: 25-44.

Salis, A. (1999) Gestión del paisaje en economías campesinas andinas: externalidades positivas y negativas. In: *III Simposio Internacional de Desarrollo Sustentable de Montañas: entiendo las interfaces ecologicas para la gestion de los paisajes culturales en los Andes. Quito 9-14 December 1998.* pp 305-312.

Samudio, R. (2001) Panama. In: Kappelle, M. and A.D.Brown (eds) *Bosques nublados del neotrópico.* INBio, Heredia, Costa Rica. pp 371-396.

Sarmiento, F. (2000) Restoration of Andean forests for conservation and development. In: Price, M.F. and N.Butt (eds) *Forests in Sustainable Mountain Development: A State-of-knowledge Report for 2000.* IUFRO-FAO. Oxford. CAB Publishing Co. pp 59-70.

Sarmiento, F. (1997) Arrested succession in pastures hinders regeneration of Tropandean forests and shreds mountain landscapes. *Environmental Conservation* 24(1): 14-23.

Scatena, F.N. (1995) The management of Luquillo elfin cloud forest ecosystems: irreversible decisions in a nonsubstitutable ecosystem. In: Hamilton, L.S., J.O.Juvik and F.N.Scatena (eds) *Tropical Montane Cloud Forests*, Springer Verlag, New York. pp 266-273.

Somanathan, H. and R.M.Borges (2000) Influence of exploitation on population structure, spatial distribution and reproductive success of dioecious species in a fragmented cloud forest in India. *Biological Conservation* Vol. 94 (2): 243-256.

Spitzera, K., J.Jaroa, J.Havelkaa and J.Lepb (1997) Effect of small-scale disturbance on butterfly communities of an Indochinese montane rainforest. *Biological Conservation* Vol. 80 (1): 9-15.

Stadtmuller, T. (1987) *Cloud Forests in the Humid Tropics.* A bibliographic review. United Nations University, Tokyo and CATIE, Turrialba, Costa Rica. (Also available at http://www.unu.edu/unupress/unupbooks/80670e/80670E00.htm)

Still, C., P.N.Foster, S.H.Schneider (1999) Simulating the effects of climate change on tropical montane cloud forests. *Nature* 398: 608-610.

Sugden, A.M. (1981) Aspects of ecology of vascular epiphytes in two Colombian cloud forests: II. Habitat preferences of Bromeliaceae in the Serrania de Macuira. *Selbyana* 5: 264-273.

Tabarelli, M. and C.A.Peres (2002) Abiotic and vertebrate seed dispersal in the Brazilian Atlantic forest: implications for forest regeneration. *Biological Conservation* 106(2): 165-176.

Tanzania Forest Conservation Group (2000) The Eastern Arc Mountains. A Forest Cover Map. PO Box 23410, Dar es Salaam, Tanzania.

Webster, G.L. (1995) The panorama of Neotropical cloud forests. In: Churchill, S.P., H.Balslev, E.Forero and J.Luteyn (eds) *Biodiversity and Conservation of Neotropical Montane Forests: Proceedings of the Neotropical Montane Forest Biodiversity and Conservation Symposium, The New York Botanical Garden, 21-26 June 1993.* The New York Botanical Garden. pp 53-77.

Werner, W.L. (1995) Biogeography and ecology of the upper montane rain forest of Sri Lanka (Ceylon). In: Hamilton, L.S., J.O.Juvik and F.N.Scatena (eds) *Tropical Montane Cloud Forests*, Springer Verlag, New York. pp 224-230.

Wiesmann, U., F.N.Gichuki, B.P.Kiteme and H.Liniger (2000) Mitigating conflicts over scarce water resources in the highland-lowland system of Mount Kenya. *Mountain Research and Development* 20: 10-15.

Wolf, J.H.D. and C.J.F.Konings (2001) Toward the sustainable harvesting of epiphytic bromeliads: a pilot study from the highlands of Chiapas, Mexico. *Biological Conservation* 101: 23-31.

Wunder, S. (2001) Poverty alleviation and tropical forests - what scope for synergies? *World Development* 29(11): 1817-1833.

WWF Malaysia (1998) *Fragile Beauty. Peninsular Malaysia's Highland Forests.* Booklet. 32 pp.

Young, K.R. (1994) Roads and the environmental degradation of tropical montane forests. *Conservation Biology* Vol. 8 (4): 972-976.

Appendix 1. Regional cloud forest threats analysis (as recorded in Aldrich *et al.*, 1997)

	Small size/ fragment	Timber	Fuelwood & charcoal	Unprotected	Hunting	High population	Fire	Agriculture	Grazing	Mining	Plant harvest	Drug crops	Roads	Tourism develop't	Resort	Power station/ radio
Latin America																
Costa Rica	X				X			XXXX	XX							
El Salvador			X					X								
Guatemala		X			X			X					X			
Mexico	XX	XXXXX	X	X	XX			XXXXX	XXXX		X	X	XX			
Panama								XXX					X			
Bolivia		XXX		X	XX		X	X	X	X			X			
Brazil			X	XX			X		X		X					
Colombia	X	XX		XX	X			XXXX	X			XX	X			
Ecuador		XXX	XX	X	XXXX		XX	XXXXX	XXXXX	XX	X					
Peru	X	X	X		XXX		XX	XX	XXXX			X	XX			
Venezuela								X	XX	XXX		X				
Total no. threats	5	15	6	7	14		6	27	20	6	3	5	8			
No. countries	4	6	5	5	7		4	10	8	3	3	4	6			
Africa																
Angola	X	X	XX	X	X			X								
Burundi			X		X	X										
Cameroon					XX		X	X	X							
DR Congo			X	XXX	XXXX			XXX	X	X						
Equatorial Guinea					X											
Gabon					X											
Kenya		XX	X				XXX	XXX	X							
Madagascar							X									
Malawi		X					X									
Mozambique								X								
Nigeria	X				X		X		X							
Réunion							X		X							
Rwanda		XX	XX		XX	X		XX	X	X						
Tanzania		XX	XX		X	X	X	X	X							
Uganda		XXX	XX		XXX	X	X	XX	XX							
Total no. threats	2	11	11	4	17	4	10	14	9	2						
No. countries	2	6	7	2	10	4	8	8	8	2						
Asia																
Australia		X					X									
Indonesia		XXX						XXX		XX			XX	XX		
Laos		X						X								
Malaysia		XXXXXX						XXX		X	XXXX		XX	XXX	XXX	X
Myanmar					X			X								
Papua New Guinea		X						X								
Philippines		XXXXXX	X	X	XXX			XXXXXXXXXX	X							XX
Sri Lanka	X							XX								
Thailand					X			X								
Viet Nam		X						X								
Total no. threats	1	19	1	1	5		1	23	1	3	4		4	5	3	3
No. countries	1	7	1	1	3		1	9	1	2	1		2	2	1	2

Appendix 2. Cloud Forest Agenda – regional issues

Information on status and threats	Americas	Africa	Asia
Are CFs recognized as a distinct forest type?	Yes, in Mexico & Central America; rarely separated from humid montane forest in South America	No, not distinguished within the Afromontane forest classification	No, not distinguished from montane rainforest except for 'mossy forest' classifications in Philippines & Malaysia
Are maps of cloud forest distribution available?	Yes, for Mexico, Central America and South America[1,2], except Brazil (?)	For Cameroon, Albertine Rift and mountains of Kenya & Tanzania[3], Madagascar	For Philippines[4], India, Sri Lanka[5], Malaysia?
Are there assessments of the protection of cloud forests?	Mexico, Central America, Northern Andes ecoregion	Cameroon, Albertine Rift, Kenya, Tanzania, WWF humid montane forest ecoregions?	WWF humid montane forest ecoregions?
Are there assessments of the biodiversity values, threats & conservation priorities of cloud or humid montane forests?	Mexico, Central America, Andes[6]	Albertine Rift, Tanzania[3], Madagascar?	Philippines?, Viet Nam?, Malaysia?
Are there studies of watershed & other economic values of cloud forests?	Costa Rica, Ecuador[7]	Tanzania?	
Are there educational & awareness-raising activities for cloud forests?	Costa Rica?	Tanzania	Malaysia
Are cloud forests recognized in national biodiversity strategies, action plans, etc.?		Kenya, Uganda, Cameroon, Mozambique	Philippines, Sri Lanka
Are there government agencies, NGOs or research centres which include actions for cloud forests?	Mexico, Costa Rica, Venezuela, Colombia, Ecuador	Cameroon, Albertine Rift, Tanzania	Malaysia
Are there projects and legislation for payment schemes to maintain cloud forest water supplies?	Mexico, Costa Rica, Ecuador		
Are there networks and training courses relevant to cloud forest conservation, management and identification of lessons learned?	Mexican Cloud Forest Network, Andean Mountains Association	African Mountains Association, Albertine Rift Conservation Society	

1. Kappelle and Brown (2001). 2. Chaverri (2001). 3. Tanzania Forest Conservation Group (2000). 4. Penafiel (1995). 5. Werner (1995). 6. Fjeldså (2001). 7. Portilla (2001).

Cloud forest **agenda**

Cloud Forest Agenda is designed to encourage new conservation actions for the world's tropical montane cloud forests, bringing together the latest maps and information for 'cloud forest champions' to design effective conservation strategies. These 'cloud forest champions' could be national policy makers or environmental non-governmental organizations in the more than 60 countries with cloud forests. Equally the leaders of the local communities and towns in cloud forest areas can be 'champions' in the conservation and wise management of their forests, maintaining them as sources of freshwater, forest products, and in some cases income from tourists.

This report provides the first global maps of cloud forests, alongside information on their biodiversity and watershed importance, and a regional analysis of the threats to cloud forests. *Cloud Forest Agenda* summarizes the issues for cloud forest conservation and sustainable livelihoods in mountain regions, including the particular ecological properties of cloud forests. The report concludes with an agenda for action, identifying global to national priorities and opportunities.

Cloud Forest Agenda was compiled by the UNEP World Conservation Monitoring Centre as a product of the Mountain Cloud Forest Initiative, which is a partnership between the United Nations Environment Programme (UNEP), the UNEP World Conservation Monitoring Centre (UNEP-WCMC), the United Nations Educational, Scientific and Cultural Organization (UNESCO) Man and the Biosphere (MAB) Programme and International Hydrological Programme (IHP), and the Commission on Ecosystem Management of IUCN–The World Conservation Union. The latest information on the Mountain Cloud Forest Initiative can be found at http://www.unep-wcmc.org/forest/cloudforest

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