

Mountain Forests in a Changing World

Realizing values, addressing challenges



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Mountain Forests in a Changing World

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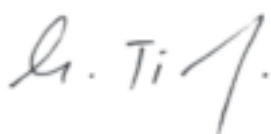
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Foreword

Covering over 9 million square kilometres of the Earth's surface, mountain forests represent a remarkable 23 percent of the Earth's forest cover. They play a key role in mountain areas, providing goods and services essential to the livelihood of both highland and lowland communities. Freshwater streaming down from mountains is accessible to more than half of the world's population and available for the most varied needs, such as drinking, cooking and washing, farming, hydropower, industry and transportation. The biodiversity stored in healthy mountain forests provides a range of products, such as timber, fuel, medicinal and aromatic plants, fodder and a wide variety of foods that ensure the well-being of local populations. Mountain forests also occupy a crucial position in terms of climate change, representing fundamental ecosystems for the health of the planet. As a matter of fact, they protect the Earth and contribute to shielding the atmosphere from CO₂ emissions. Moreover, mountains covered by green, thick and healthy forests are undeniably one of the most outstanding visions offered on Earth. Human spirituality and culture as well as tourism have always drawn on these landscapes.

Nevertheless, these beautiful and profitable landscapes are under threat. Deforestation has been widely practiced with a view to short-term profits and without paying due attention to long-term impacts. Population growth and the expansion of intensive agriculture have forced smallholder farmers to move higher towards marginal areas or steep slopes and therefore caused the clearing of forest areas. Furthermore, the conservation of healthy forests often may not be the main priority for private business. Crucially, mountain forests perform a protective function against natural hazards, so that when the forest cover is lost and the land is left unprotected, runoff and soil erosion increase, provoking landslides, avalanches and floods, to the detriment of villages, transport systems, human infrastructures and of the food security of vulnerable populations.

This publication is intended to raise awareness of the global importance and the need for sustainable management of these unique ecosystems. It was prepared in 2011, to coincide with the world's celebration of the International Year of Forests as well as of the International Mountain Day on December 11th, dedicated this year to the theme of mountain forests. To mark these occasions, the Mountain Partnership Secretariat at the Food and Agriculture Organization of the United Nations (FAO) and the Swiss Agency for Development and Cooperation (SDC) have jointly issued this volume, the fourth of a series, including Mountains and Climate Change, Mountain Biodiversity and Global Change, and Highlands and Drylands. We thus hope that, through this publication, communities, scientists and policy makers at national and international level will support the creation and implementation of long-term policies in order to conserve and protect these fundamental ecosystems and to benefit and improve the lives of their people for the benefit of both mountain people and inhabitants of adjacent lowlands.



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1

Why focus on the
world's mountain
forests?

Why focus on the world's mountain forests?

Robert Mc Morran and Martin F. Price

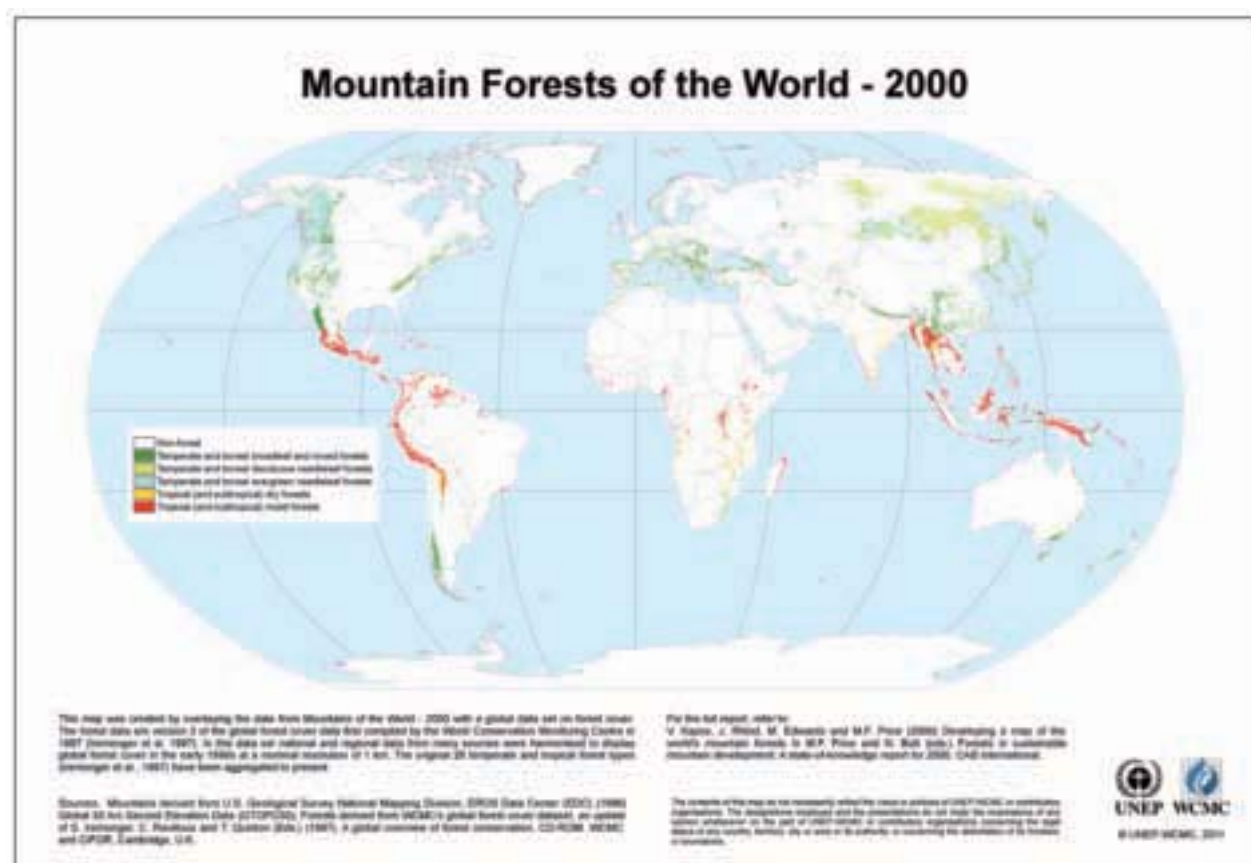
Over the past two decades, since the Rio Earth Summit in 1992, there has been increasing global awareness of the importance of the world's mountain areas, which cover a quarter of the Earth's land surface, are home to an eighth of the world's people, and provide diverse goods and services to well over half of the Earth's 7 billion people. Many of these goods and services derive from mountain forests, which cover a quarter of the global mountain area.

Forests cover a significant proportion of most mountain regions, except those that are particularly dry or cold year-round. In Europe, for instance, forests cover 41% of the total mountain area – over half of the Alps, Balkans, Carpathians, and Pyrenees – and are the dominant land cover except in the Nordic mountains which extend well into the Arctic. Other mountain regions with particularly high proportions of forest cover include the Appalachians, the Australian Alps, the Guiana Highlands, and the mountains of Central Africa, Southeast Asia, Borneo, and New Guinea. Particularly in tropical countries, these mountain forests are vital for the livelihoods of large numbers of people.

Mountain forests are found from the Equator to quite high latitudes, north and south, and include both coniferous needle-leaved and

broadleaved forests (Figure 1). Evergreen needleleaf forests are particularly dominant in North America and parts of Europe and Asia, while deciduous needleleaf forests are more common in Russia and Asia. Deciduous and coniferous boreal forests are absent in the Southern hemisphere, due to the lack of land within the appropriate latitudinal zone. Boreal broadleaved forests have a relatively wide global distribution, while tropical mountain forests mainly occur in South and Central America, Australasia and Africa. The altitude of the climatic treeline – beyond which trees fail to grow in significant density and number – varies widely, depending on both latitude and climate: from 700m or below in the far North, to over 4500m in parts of the sub-tropical Andes.

Figure 1. Major forest types in mountain regions. © United Nations Environment Programme – World Conservation Monitoring Centre.



Much of the high biodiversity that is characteristic of mountain areas is in their forests. As the diversity of tree species generally decreases with altitude and also with increasing latitude, species richness in tropical forests is up to ten times greater than in temperate forests. Primary forests, particularly tropical moist forests, are some of the most species-rich ecosystems and comprise a higher proportion of the forest cover in mountain areas than for the Earth as a whole. These forests are particularly important for protecting fragile slopes from soil leaching and erosion, as well as acting as reservoirs of biodiversity from which to establish new areas of habitat and resettle new species. However, rates of loss of primary forests, largely due to selective logging and other human activities, are particularly high in tropical mountain areas: tropical upland forests have disappeared at a greater rate than forests in any other biome (major ecosystem type). Thus, most mountain forests are semi-natural or naturally regenerating forests which, through forest management activities, provide diverse ecosystem services and livelihood opportunities. Forest plantations are also on the increase, particularly in temperate areas, though the proportions in mountain areas are not easily identified.

In recent decades, there have been two distinct trends in the area covered by mountain forests, as for forests around the world: continual loss in developing countries (particularly in tropical regions) and gradual expansion in industrialized countries. In Europe, widespread reforestation has occurred in many mountain regions, in conjunction with agricultural land abandonment and declining deforestation, accounting for about two-thirds of land cover changes from 1990 to 2006. Over a longer timescale, the area of forests in Switzerland, for example, has increased by 60% since the main period of deforestation ended in the 1860s. However, in some industrialized countries, the expansion of mountain forests has been offset to some extent by losses due to epidemics of diseases and pests, or fire.

The importance of ecosystem services provided by mountain forests

Mountains are fragile and often remote regions, whose human populations are often highly vulnerable to environmental, economic and social changes at all scales from local to global. Ninety percent of mountain people live in rural areas in developing countries. Levels of ethnic diversity and poverty in these communities are typically high. Globally, 90 million mountain people live in poverty.

In mountain areas, poor communities, both rural and urban, tend to be heavily dependent on their forests to provide them with a diverse range of services, including fundamentals such as fuel, food, clean water, and protection from natural hazards. The ecosystem services provided by mountain forests are also of critical importance for rural and urban lowland populations.

Ecosystem services may be divided into three main categories: provisioning services (e.g., timber extraction); regulating and supporting services (e.g., carbon sequestration); and cultural services (e.g., the role of forests in local belief systems and customs). Mountain forests provide diverse ecosystem services, delivering a range of both private and wider public benefits (Table 1). Productive functions are particularly well recognized due to their role in contributing to lowland and highland economies. However, regulating and supporting services such as reliable water supplies, protection against natural hazards, mitigation of climate change often represent the most important functions of mountain forests to communities living within and around mountain regions. In addition, cultural services are vital for both mountain people and many others, particularly as recreation and tourism increase in importance for the population of our increasingly urbanized world.

In mountain areas, poor communities, both rural and urban, tend to be heavily dependent on their forests to provide them with a diverse range of services, ...

Table 1. Ecosystem services provided by mountain forests worldwide. Adapted from the Millennium Ecosystem Assessment (2005) Chapter 21; Forest and Woodland Systems and Chapter 24: Mountain Systems (<http://www.maweb.org/en/Condition.aspx#download>).

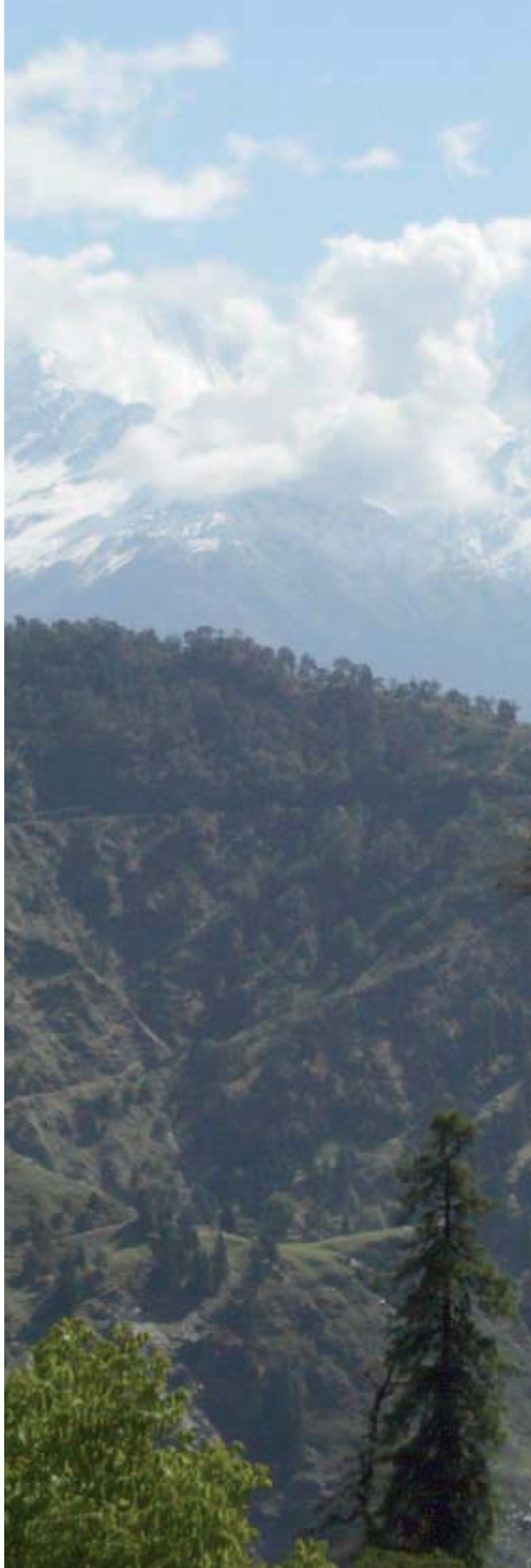
Provisioning Services	Timber for use in buildings and infrastructural initiatives; fuelwood (critical for local populations); Non-timber forest products (NTFPs), including wild game, foods (mushrooms, berries, edible plants etc.); the availability of grazing for subsistence farming .
Regulating and supporting services	Critical stability/protection function – forest cover enables soil retention and acts as a barrier to the impacts of avalanches and rockfalls on valley communities; mountain forests (particularly cloud forests) have high water retention capacity , intercepting and storing water from rainfall, mist and snow and releasing it gradually, thereby maintaining hydrological cycles at large scales – limiting peak stream flow rates, reducing soil erosion and the severity of avalanches and downstream flooding ; mountain forests represent a major carbon sink , with ongoing carbon sequestration a critical component of climate change mitigation ; due to their relative isolation and contrasting climates, mountain forests are high in endemism and commonly represent global hotspots for biodiversity , which is linked to tourism, recreation, hunting and fishing benefits.
Cultural services	Mountain forests have intrinsic spiritual and aesthetic values ; their characteristics allow for considerable recreational opportunities globally; the customs and belief systems of many mountain communities are intricately linked with forest ecosystems.

Addressing the key challenges

This report has been produced in the International Year of Forests to draw attention to the many values of mountain forests and the challenges they face. These forests face ever growing demands from local and regional users, as well as national and international markets. Population growth and associated demands for food and fuel within and outside mountain regions are increasing pressures on mountain forests, threatening their resilience and integrity. Primary forest cover continues to be fragmented and decrease rapidly. The development of infrastructure also contributes to the fragmentation and loss of forest cover and the destabilization of underlying rocks and soils. Further pressures include encroaching urbanization, more frequent wildfires, development projects such as roads, dams and hydropower plants, the development of tourism infrastructure, and the transformation of primary forest to other land uses. The establishment of plantations does not fully compensate for such ongoing losses. Planting in tropical countries typically occurs in humid mountains, where slower growing natural hardwoods are often replaced with faster growing hardwoods. Such changes can lead to higher levels of water extraction and associated reductions in catchment yields – a key issue in the Andes and South Africa. Large-scale plantations of single species also exclude wild and domestic animals, which can lead to increased densities of herbivores and a shift in habitat selection towards remaining fragments of primary or semi-natural forest – resulting in the further loss and fragmentation of these habitats from overgrazing. They are also often highly prone to erosion and soil degradation.

In many regions, population expansion has led to increasing migration from urban to rural areas, resulting in the intensification of lowland farms and the displacement of lowland farmers. Displaced farmers commonly move to higher, steeper ground, often clearing areas of forest to establish new smallholdings. In areas of high population density with high food demand from nearby urban settlements, fallow periods are often neglected, which can lead to irreversible losses of soil nutrients and topsoil, resulting in a decline in ecosystem integrity and further loss of forest cover. Such unsustainable practices, combined with the long-term loss of forest cover, can have detrimental effects on the functioning of river catchments and the overall stability of mountain systems, and result in decreases in, or even losses of, biodiversity and fuelwood availability. Excessive levels of disturbance in mountain forests can also lead to the spread of invasive species, which can have further negative impacts on ecosystem integrity.

All of these trends need to be considered in the context of climate change, which will bring many new challenges for those depending on and managing mountain forests worldwide. Thus, after addressing the diverse values of, and challenges for mountain forests, this report concludes with a discussion and presentation of proactive approaches, and desirable actions by the many stakeholders involved, to ensure that mountain forests continue to provide vital goods and services in future decades.









2

Sources of fresh water

Sources of fresh water

Georg Gratzer, Lalisa Alemayehu Duguma and Herbert Hager

Mountains provide 60–80% of the world's freshwater resources despite covering only 24% of the Earth's surface. In regions with dry climates, mountains cover 30% of the area but contribute 67% of the discharge; in the temperate zone, the respective proportions are 43% and 61%. Mountains owe this significant role in the world's hydrology to orographic effects: as altitude increases, so does precipitation, while evaporation decreases. Moreover, in many mountain regions, part of the precipitation falls as snow and is stored in snowfields and/or glaciers, melting so that it is available at a time when it is most needed.

Mountain forests strongly influence both the quantity and quality of water supplies to mountain and lowland communities and industries. Many capital cities depend heavily on mountain water: for example, 95% of the water for Vienna, Austria comes from the mountain forests of the Northern Alps; almost all the water used in the dry season for drinking and hydroelectricity generation for Dar Es Salaam, Tanzania, comes from the cloud forests of Uluguru Mountain; 40% of the water for Tegucigalpa, Honduras, comes from the cloud forests of La Tigra National Park. At larger scales, the Tibetan plateau acts as a water tower for around 3 billion people in Asia; the entire population of California, USA relies on mountain water; and in Kenya, water from Mount Kenya generates 97% of the hydroelectric power and provides water for drinking and domestic purposes to over 7 million people.

Plants drive hydrology

The hydrology of mountain areas is strongly influenced by their vegetation cover, in terms of both base flows driving the continuity of water supplies and peak flows which often cause floods in both headwaters and nearby lowlands; though these may also derive from heavy rains in lowland areas. Plants intercept precipitation which either drips to the ground or evaporates from leaf surfaces. They consume water through transpiration and shade the ground, and thus reduce evaporation from the soil. They delay snow melt and influence infiltration into the soil through rooting, as well as through the associated soil fauna and decomposer communities.

Mountain forests play major roles in preventing erosion and reducing the risk of floods. For example, maximum surface runoff during heavy rain in the Austrian Alps is 40-80% lower in forests than pasture. The root systems and decomposer macrofauna of many tree species contribute to the increased infiltration of water into soils. Deep-rooted trees remove more soil water for transpiration, creating a larger soil water storage buffer, which may contribute to reducing peak runoffs. Particularly in drier areas, trees redistribute water through their root systems vertically and horizontally to areas of lower soil moisture at night.

A key resource for life

The conversion of land from forest to agriculture has major impacts, decreasing evapotranspiration and increasing runoff. At watershed

scales, such changes greatly modify hydrology: as forests have higher evapotranspiration and better surface infiltration, their clearing leads to increased surface flows, steeper discharge peaks, and lower base flows, especially in the dry season. The steepness of slopes and the infiltration characteristics of soils influence such changes; if water infiltration after forest clearing is strongly reduced and slopes are steep, water runs off quickly and reduces the water recharge of soils.

In contrast, afforestation leads to decreases in overall water yields. A global synthesis of data from 26 watersheds converted from grassland, shrubland or pasture to tree plantations showed that runoff in over a fifth of the catchments decreased by at least 75% for a year or more; and, in over a tenth of the catchments, by 100%. Decreases in runoff lasted for 30 years where grasslands had been planted, with maximum reductions in 15-20 year old plantations. On average, runoff was reduced by at least 30% in afforested grass- and shrublands. While reductions in water yields from afforestation can be beneficial, they can, especially in dry areas, enhance water shortages and cause severe socio-economic problems.

Forest ecosystems not only influence water quantity but can improve water quality through soil infiltration and phyto- and bioremediation of water. For example, forest buffers along agricultural fields can reduce nitrate concentrations in runoff from fields by 5-30% per meter width of the forest. In contrast, erosion and large peak flows resulting from the loss of forests, as well as roads and associated drainage systems, act against these improvements of water quality and may cause large water treatment costs.

Water – a manageable resource

The management of water is complex: different management objectives such as preventing erosion or producing drinking water call for different and often competing interventions. Yet even a single hydrological attribute can be influenced by differing and often competing hydrological processes. For example, while deforestation can increase water yield, the associated decreases in soil infiltration may lead to water scarcity in dry seasons; while forests intercept much snow, they delay snow melt and reduce the early spring peak flows which often lead to floods. Responses of the hydrology of watersheds to the same land use vary greatly,



Río San Antonio, Selva de Florencia Natural National Park, Colombia. Photo: Julián Infante

depending on climate; soil conditions, especially soil depth; slope morphology and geology; and the characteristics, age, and density of plants. Consequently, site-specific watershed-based management is essential.

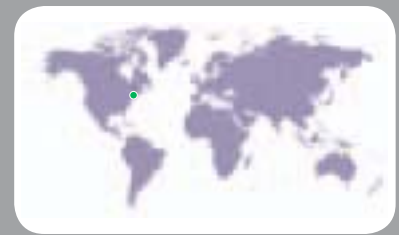
The complexity and challenges of adaptive water management lie not only in the specifics of hydrology but also in the multitude of human demands. The provision of water is an environmental service from upstream land users for lowland areas: land use in headwater areas influences water quantity and quality downstream, where the major users are located. As poverty levels in mountain headwaters are often high, and the degrees of freedom for choosing a certain land use are low, payment schemes based on public funding are often not sufficient to induce the necessary management activities. This calls for Integrated Water Resource Management approaches which promote “the coordinated development and economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems”. One example is the green water credit programme: a compensation scheme for upland management activities geared towards soil and water conservation, such as mulching or strips along contour lines covered by permanent vegetation. Pilot projects are currently being implemented in countries including, Canada, China, Kenya, Morocco, and the USA. Such coordinated land management schemes, which conserve valuable ecosystems and habitats, and can mitigate potential water scarcities and avoid high costs for technical measures downstream, are so far practiced in only a few river basins, but as the idea is spreading, the outlook for the future is hopeful.

How trees intercept and use water

Tree canopies enhance exchanges of water vapour with the atmosphere because of their high aerodynamical roughness and through evapotranspiration. Their structure, seasonality and density determine how much is lost by interception. Conifer forests intercept 30–50% of precipitation, temperate broadleaf forests 15–30% during the vegetation period, subtropical evergreen broadleaf forests 10–30%, and tropical forests 15–30%. In contrast, agricultural crops intercept less than 10%. Trees also intercept snow, which is partly lost through sublimation; and reduce winter snowmelt and delay spring snowmelt, which can offset the interception losses.

The volumes of water that trees use to grow and return to the atmosphere through transpiration are considerable, thus modifying the hydrological cycle. Trees use 170–340 kg of water for each kg of biomass they accumulate. Because of the height of trees, their rooting depths and rough canopies, forests consume more precipitation than other vegetation types. Temperate forests transpire 300–600 mm per year, montane tropical forests 500–850, and tropical tree plantations 1000–1500. Comparably, agricultural crops in temperate areas transpire 400 – 500 mm of precipitation per year.

The forests of the Catskill Mountains, USA: Watershed for a megalopolis



Nearly half of New York State's population, including 8 million in New York City and 1 million upstate residents, rely on high-quality water from the forested Catskill Mountains for drinking, bathing, cleaning or outdoor watering. Each day, these mountains provide over 5 billion litres of unfiltered water for domestic, commercial and industrial uses - probably the world's largest unfiltered water supply system.



Ashokan reservoir, Appalachian mountains. Photo: Josh Dick



New York City. Photo: Karen Wright

Today, watershed protection is a major concern of land management in the Catskills. However, in the 1700s, the forests were heavily exploited. During the 1800s, large areas were converted to farmland, though much was abandoned after 1870. Recreational resorts became important from the early 1900s.

In 1885, responding to uncontrolled exploitation and increasing concern for water and recreation, the State Legislature designated Catskill Park. Within its 285,000 ha, all State-owned land was set aside as a Forest Preserve, "to be kept forever as wild forest lands". In 1905, New York City began to buy land; it now owns about 5% of the Park. Three of its major reservoirs, and part of a fourth, are within the Park. The Preserve has expanded from 13,760 to 117,300 ha; other land in the Park is privately owned.

In 1993, the Environmental Protection Agency (EPA) called for greater quality safeguards. One option was for the City to build a water filtration plant, estimated to cost \$10-12 billion, with annual operating costs of \$300 million. Instead, EPA allowed the City to protect its drinking water supply by developing a comprehensive watershed management and protection programme. Through this, since 1997, the City has spent \$1.6 billion to improve water quality, including: land acquisition; conservation easements (agreements to restrict development on land and use it for conservation purposes); upgrading agricultural practices to control farm pollution; Best Management Practices for private forests; improving residential septic systems; waste treatment upgrades for villages; riparian and floodplain revegetation. The City's financial contribution comes from consumers' water rate payments - an excellent example of payment for environmental services, much cheaper than the option of building treatment facilities.

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Ensuring the provision of environmental services from Selva de Florencia Natural National Park, Colombia



Selva de Florencia Natural National Park, in the central Colombian Andes, is one of the country's 56 national protected areas, declared in 2005. Receiving more than 7,000 mm of rainfall a year, this intact cloud forest, only 1019 ha in area, is essential for water regulation. More than 60,000 people rely on the water it provides, and it also has high levels of biodiversity, including endangered species of the Podocarpaceae and Lauraceae families and the greatest concentration of frogs in the country.



Selva de Florencia Natural National Park. Photo: Julián Infante.



Cloud forest: Julián Infante.

As rain falls year-round, there are no marked dry periods, which is a comparative advantage for the provision of drinking water, agricultural production and the development of hydroelectric projects. In 2002, the Miel I power plant, with an installed capacity of 396 MW, began production; 13 other sites have also been identified.

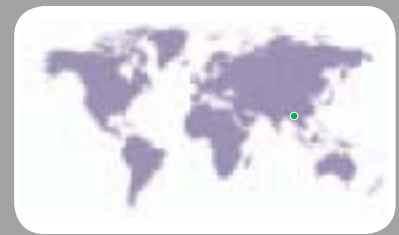
The mountain forests of the Colombian Andes are under continual pressure from the expansion of small-scale agriculture, mainly for subsistence, and urban sprawl; for example, Bogotá is growing at 5.5% per annum. However, for Selva de Florencia, at least 20 years of constructive interaction between academia, civil society organizations and communities, coupled with National Park designation, have led to clear conservation objectives and management plans that reconcile the interests of conservation with the development of the region's economy.

The challenge remains for government agencies to capitalize on the benefits from conservation – such as environmental goods and services, transfers and compensation for natural resources use – and to distribute resources equitably. To ensure the protection of mountain forests and the environmental services that they offer, it is necessary for mountain people to be able to meet their basic needs in a sustainable manner. This requires the development and implementation of policies that lead to comprehensive land planning and to strategies for the delivery of environmental services in this area, as well as in other mountain forest areas in Colombia.

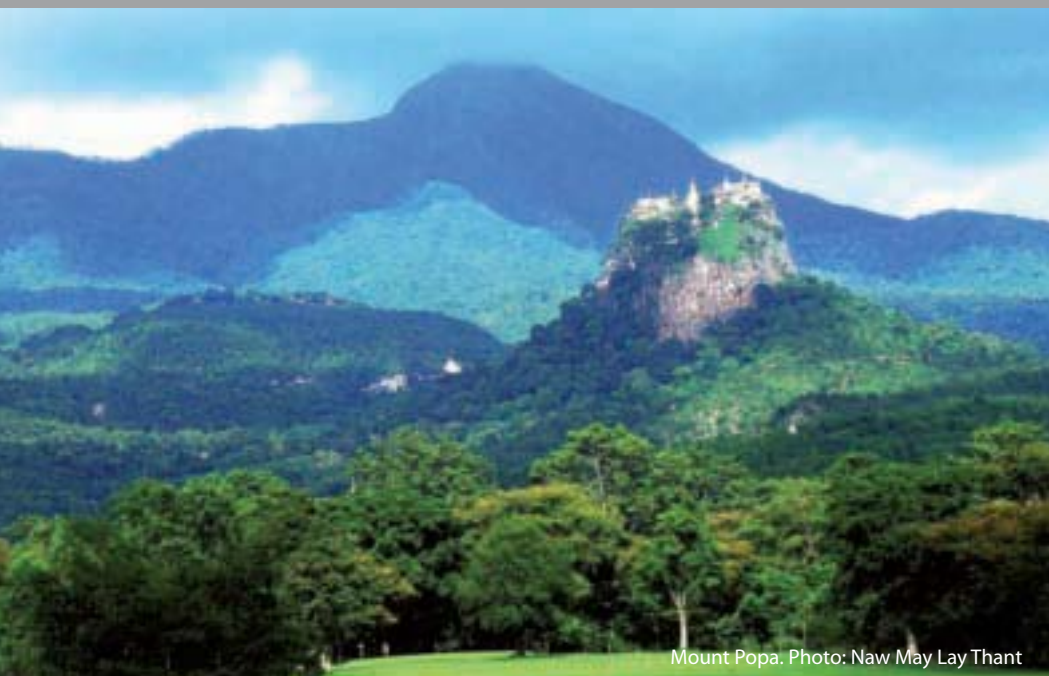
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Popa Mountain Park: An oasis on the dry plains of Myanmar



Mount Popa (1518 m) is an extinct volcano in central Myanmar. Around it, dry, open country extends for more than 100 km in every direction. Because of its height, the mountain receives heavy rainfall and therefore its climate and vegetation are quite distinct from those of the surrounding country.



Mount Popa. Photo: Naw May Lay Thant

Farm at the foot of Mount Popa.
Photo: Naw May Lay Thant



The forest types include thorn forest, deciduous forest, and semi-evergreen forest in the volcanic crater, providing habitat for one of Southeast Asia's rarest endemic species, Phayre's leaf monkey (*Trachypithecus phayrei*). The mountain is also famous for its herbal plants. In 1902, Mount Popa was legally notified as forest reserve. However, during and after World War II, with the breakdown of law and order, local people gradually encroached into the reserve for farming. From 1995 to 1984, the Forest Department, the United Nations Development Programme (UNDP) and the Food and Agriculture Organization of the United Nations (FAO) undertook reforestation programmes, which have been successful – and once-depleted natural springs have been restored. In 1989, Popa Mountain Park (176 km²) was declared to conserve wildlife and to protect the catchment of Kyet-mauk-taung reservoir, used since 1967 mainly for irrigation.

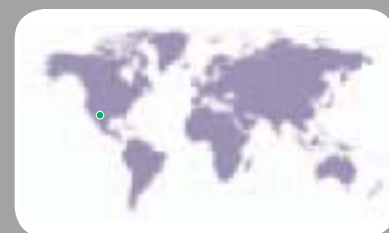
Generally, water resources are very limited in central Myanmar. Most streams are rain-fed and, even after heavy rain, some only flow for a few hours due to relatively low rainfall and sandy soils. Access to groundwater is difficult because most aquifers are comprised of thick layers of sand and clay, with high concentrations of magnesium salt. However, people around Mount Popa can utilize its almost 100 permanent natural springs, which occur on all sides of the mountain and are the main source for Kyet-mauk-taung reservoir. The nearest town of Kyauk-pa-daung, 10 km away, also receives regular water supplies from the springs.

As Mount Popa can be seen from every direction from at least 40 km, indigenous knowledge recognizes it as a weather forecast post. Whenever fog shrouds the mountain, local people realize that rain is likely, and they prepare their farms to catch rain in time.

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The proposed Mavavi Area for Protection of Flora and Fauna, Sonora, Mexico



The Sierra Madre Occidental includes many 'sky islands', mountain ranges varying in altitude from 1,880 to 2,646 m. The water that falls on these mountains feeds the San Pedro River, shared between Mexico and the USA, and most of the rivers of the state of Sonora in Mexico. The Sonora River supplies a significant part of the water used for agricultural, domestic, industrial, and recreational purposes in the state, including 34 towns and Hermosillo, Sonora's capital city.



Rio Bavispe, Mexico, Photo: Sergio Avila

Sierra de los Ajos, Ajos Bavispe Forest Reserve and Wildlife Refuge.
Photo: Angeles Mendoza Sammet



In 1936, the Mexican government established the Ajos-Bavispe Forest Reserve and Wildlife Refuge to protect five sky islands because of their high biodiversity: their juniper, oak, pine, and arroyo forests provide habitat for a wide range of mammals, butterflies and, particularly, birds. Until the mid-1990s, the Refuge did not have management; wood harvesting and grazing were widespread. The Refuge has large copper and other mineral deposits whose exploitation, sometimes illegally done in the Refuge, caused air and water pollution, which have affected the forests and their species, as well as water quality.

In 2002, Mexico's National Commission of Natural Protected Areas and the Secretariat of the Environment and Natural Resources proposed to the Federal Government that the Ajos-Bavispe Refuge and other well-preserved forest and grassland patches in the region should become the Mavavi Area for Protection of Flora and Fauna. While the proposal has not yet been approved, it is of international interest because of the area's border location and its hydrologic relevance for wildlife and people in both Mexico and the USA. In 1988, the USA created a 70 km Riparian National Conservation Area along the upper San Pedro River. This recognizes that this riparian system, located in the Sonoran and Chihuahuan deserts, is a key habitat for more than 400 resident and migratory bird species, almost half of the USA's bird species. Yet the conservation of biodiversity is only one reason to create Mavavi: its forests sustain socio-economic development on both sides of the international border.

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A full-page background image showing a mountain landscape. In the foreground, a winding asphalt road curves through a green valley. The middle ground features steep, forested slopes with patches of green grass and dense evergreen trees. In the background, rugged mountain peaks are partially covered in snow under a clear blue sky.

3

Protection against natural hazards

Protection against natural hazards

Lalisa Alemayehu Duguma and Georg Gratzner

Mountain areas are often exposed to natural hazards – such as erosion, mudflows, rockfalls, avalanches, landslides, debris flows and floods – which can damage settlements, transport and recreational infrastructure and, unfortunately, cause losses of life. Mountain forests play crucial roles in both active and passive protection against natural hazards.

Active and passive protection

In active protection, forest trees act as physical obstacles or barriers that impede downslope mass movements such as rockfalls, landslides, debris flows, and avalanches. Tree roots also stabilize the soil and prevent the occurrence of landslides and erosion. Mountain slopes covered by forests remain stable for longer than open land and other vegetation types; for example, only 5% of slope failures leading to erosion occurred in mountain forests in Western Austria, but 35% in open pastures. Forests in the source zones of avalanches and debris flows also reduce the risk of such hazards by stabilizing the movement of snow and debris. The role of forests in minimizing the formation of snow avalanches is also enhanced by their canopies, as they intercept a considerable amount of snow. This reduces the formation of large snow masses and prevents the formation of large homogeneous snowfields in which large avalanches can start. For example, in the mountainous maritime climate of Oregon, USA, forest canopies intercept about 60% of the snowfall.

In passive protection, mountain forests play significant roles mainly in blocking the movement of solid materials - snow, soil, debris or rock - reducing the impact of the hazards on settlements and infrastructure below. Nonetheless, forests are only very effective if the size and scale of the transported material is small to medium, and energy levels are low; material that is large and/or moving with high energy can destroy forests and cause severe damage below.

The need for cost-efficient protection

Protection is one of the most fundamental functions of forests, making it possible for people to settle in mountain valleys. In the Alps, this function was first recognized in local regulations from the 12th century, and national legislation from the late 19th century. Today, the main role of 20% of Austria's forests is protection against natural hazards. In Bavaria, Germany, 63% of the forests have a protective function against soil erosion, and 42% against avalanches. The importance of this function is immense, particularly because of the cost of building structures to control or mitigate such hazards. For example, in the Swiss Alps, the cost of installing technical measures that would achieve similar protection to forests would be 5–20 times more than maintaining forest. If these

forests were to disappear, the cost of ensuring protection against avalanches using permanent avalanche defense structures would be about US\$111 billion. Thus, the natural protection measures provided by forests are gaining growing attention mostly due to: first, the multiple services and functions they provide; second, the relatively minimal cost they require, compared to mechanical defense structures; and third, the aesthetic values of the forests.

In tropical and subtropical mountains, the protective functions of mountain forests against erosion and landslides are very significant where there are high levels of rainfall; and mechanical measures to minimize the impacts of natural hazards are typically lacking. However, in these parts of the world, such roles of mountain forests are threatened by the clearing of the forests for agricultural expansion, and timber harvesting for both subsistence and commercial purposes, often to the last accessible points in the mountains. As a result, the frequency and scale of natural hazards are increasing. For example, mountain areas in Uganda are frequently affected by landslides which kill hundreds of people and destroy important infrastructure.

Although mountain forests, in both industrialised and developing countries, have important protective functions, they are often not able to provide these functions when extreme events occur. For example, mountain forests can protect against shallow landslides, but not against deep landslides caused by the tectonic movements or earthquakes that characterize many mountain areas. They may withstand moderate storms but not extreme events such as the 'stand replacing disturbances' which cause windthrows and stem breakages. Similarly, forests can protect against erosion and landslides under average rainfall intensities, but not against mass movements resulting from major storm events, especially at the end of the rainy season when the soils are saturated.

Key characteristics for protection

Overall, the effectiveness of mountain forests for protection against natural hazards depends on the type and area of forest cover, the developmental stage of the forest, and the type, scale and duration of the hazard. To provide sufficient protection, a forest must have a diverse species composition, sufficient natural regeneration, and an optimal structure. Forests which are dominated by one



species and old forests without regeneration have poor protective functions. In the Alps, major silvicultural challenges with regard to the protective functions of mountain forests are poor regeneration, a low proportion of medium-aged trees, insufficient instability, and exposure to natural disturbances such as windthrow. Other policy-related challenges with a significant influence on mountain forests are the poor implementation of regulations that favour the proper utilization and management of mountain forests, and conflicting land use patterns (e.g. hunting and grazing vs. the protective functions of the forests in most of the Alpine countries). Similar challenges exist in other mountain areas.

Challenges from climate change

Climate change is likely to have serious impacts on the protective functions of mountain forests, as climate significantly influences the phenology, distribution and physiology of plants, and changes in climatic variables result in changes in the distribution of plant species. For example, surface temperatures in the Alps increased by 1.5 °C over the last century, almost double the global average. Though it is difficult to forecast future climates in mountain areas, the continuation of this trend could increase glacial melt and

destabilize permafrost, increasing the level of hazards such as floods, landslides, and rockfalls that could damage or even destroy forests. A continuing temperature rise could also create favourable conditions for forest damaging organisms, such as bark beetles, that can destroy mountain forests or at least change their structure, diminishing their protective functions. If, as projected, very wet winters and dry summers occur, forest fires may become more frequent, severely damaging forests. In the western United States, the fire season from 1987 to 2003 was 78 days longer than from 1970 to 1986; the number of fires larger than 400 ha increased by four times, and the burned area by six times. Such trends clearly have consequences for the hydrology and protective functions of these forests.

Even though climate change may generally appear to have negative impacts on the protective functions of forests, it may also have a positive impact as the trees in many mountain areas are migrating upwards, so that the areal coverage of forests may increase. Such changes may, however, be offset by the anticipated higher frequency of events causing natural hazards, including high winds and heavy snow- and rainfalls.

Post-disaster reconstruction in Pakistan using a watershed management approach



On 8 October 2005, a major earthquake struck northeast Pakistan, affecting 3-4 million people, killing over 80,000, and causing significant land destabilization. Major landslides and thousands of landslips affected about 10% of arable land, forests and rangelands. Downstream, rocks and debris blocked water channels, roads and paths. Flash floods and mudslides destroyed agricultural land and fruit tree plantations.



Meeting of the Watershed Management Committee, Danna Galli Watershed, Muzaffarabad District. Photo: Thomas Hofer



Landslide, Shohall Mazullah Watershed, Mansehra District, triggered by the 8 October 2005 earthquake. Photo: Paolo Ceci/FAO

The Government of Pakistan established the Earthquake Reconstruction and Rehabilitation Authority which, with the Food and Agriculture Organization of the United Nations, executed a multi-sectoral project, funded by the Swedish International Development Agency, to implement the livelihood component of the rehabilitation plan. The control of hydrogeological hazards through collaborative watershed management at the village level was a key activity, implemented in 17 watersheds in close collaboration with the District Forest Offices and the International Centre for Integrated Mountain Development. In each watershed, the project comprised: watershed delineation; damage, hazard and resource mapping; Participatory Rural Appraisal; establishment of a Watershed Management Committee; participatory preparation of an integrated watershed management plan; implementation of prioritised activities; capacity building. Forestry activities received priority attention, including bioengineering interventions, forest regeneration, and establishment of tree nurseries and fruit tree orchards.

Institutional innovations were introduced and tested. Traditionally, District Forest Offices (DFOs) planned and implemented forestry-related interventions. Through Watershed Management Committees, communities now plan and prioritise their activities; DFOs provide support in implementation. The Forest Department has endorsed this participatory approach and considers it as key to success for projects aimed at restoring natural resources and livelihoods.

Though the July 2010 floods again created significant damage in the region, communities supported by the project were well prepared to cope. Flood damage in the project watersheds was comparatively low because of the protective function of the introduced forests and trees. Through the participatory approach, the project has generated significant community ownership and capacity. The communities have gained confidence in their own ideas and skills, and feel ownership of the positive changes in their environment and livelihoods. Through the watershed management committees, they are now organized and have a voice to request technical assistance and support from line agencies and donors.

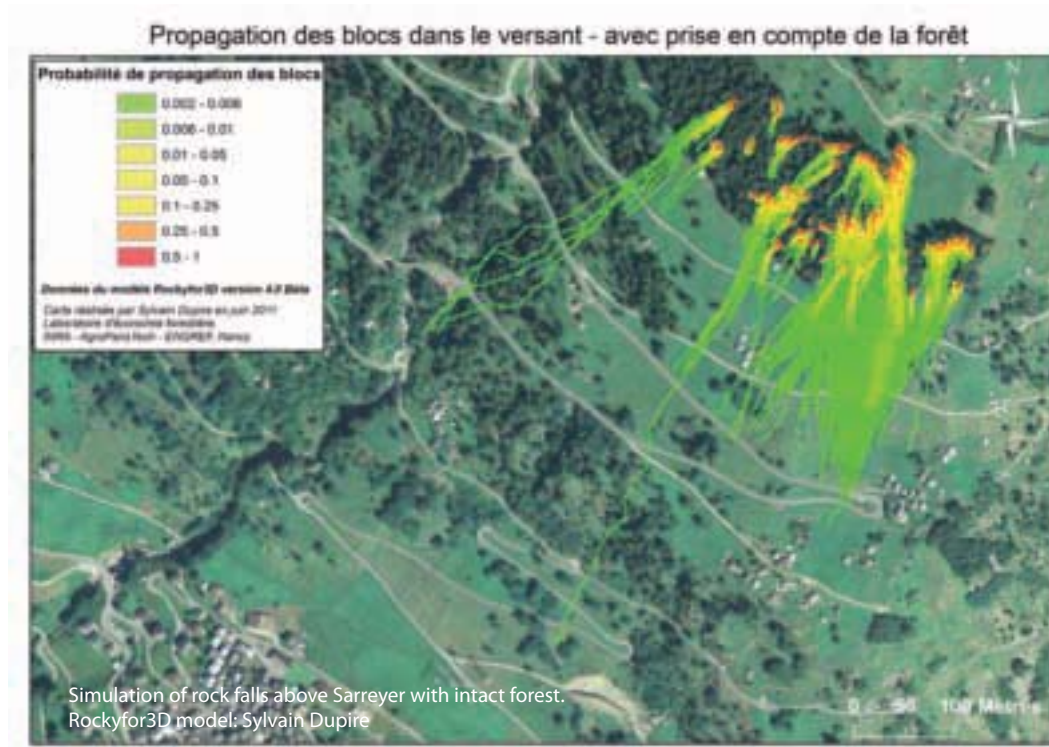
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The 'Sheltering Forest' of Sarreyer, Bagnes, Switzerland



People in the Alps understand that forests have always sheltered their villages. Yet forest administrators often find it difficult to convince them to undertake pre-emptive interventions to maintain or strengthen the protective effect of stands of trees. To change this situation, scientists and administrators have worked together for 15 years to better understand forest dynamics, define the ideal structure of sheltering forests, and inform local people about the need to work towards the goal of maintaining them – even though it may take at least 30 years to achieve the desired result.



Looking down landslide path to Sarreyer.
Photo: Roland Métral

Scientists and administrators from France, Italy and Switzerland are carrying out a pilot project of this kind in the forest of Sarreyer. This forest covers only 27 hectares, but is divided into 80 parcels, divided among 60 private landowners. After a century without maintenance, large trees (diameter over 60 cm) are unstable. If they collapsed, the boulders they would dislodge would cause considerable damage to houses. Modelling (Rockyfor 3D from Cemagref, Grenoble) and field research have shown that trees with a diameter of at least 24 cm can slow down and even stop falling boulders of 1m³; for any given diameter, broad-leaved trees are more effective than coniferous trees; stumps and deadwood increase soil stability and the protective effect of the forests; and dense forests act as green barriers.

Following an information session chaired by the mayor of Bagnes, almost all owners agreed to interventions implemented jointly by the local authorities and forest wardens. Openings were made in the forests, especially where trees were near collapse, so that the increased light increased the foliage on branches. This eliminated unstable trees and increased soil stability, particularly in transportation corridors. While the work is expensive, the long-term costs are less, and the results are just as effective as protective work by civil engineers. Sarreyer is now much safer for the next 30 years. Nevertheless, had this work been done 50 years earlier, it would have taken half as long, and been more effective.

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Agroforestry interventions to reduce soil erosion in the northern Ethiopian highlands



The northern Ethiopian highlands are severely affected by soil erosion. As a result, farmers often experience food shortages. Soil erosion is mainly addressed using physical measures such as terraces and cut-off drains, rather than biological control measures. However, as these physical measures aggravate the acute land shortage problem, farmers tend not to adopt and apply such physical interventions – so soil erosion continues.



Gully erosion in the Gelda watershed. Photo: Belayneh Ayele Anteneh



Eucalyptus woodlots in the Gelda watershed. Photo: Belayneh Ayele Anteneh

In the Gelda watershed, there is a long tradition of retaining trees on farms, even though the main aim is to supply fuelwood, construction wood, shade and animal fodder. The most common on-farm tree species include *Albizia gummifera*, *Albizia lahai*, *Ficus vasta*, *Ficus sur*, *Croton macrostachyus*, *Cordia africana* and *Vernonia amygdalina*. On average, there are about 16 scattered trees per hectare on the farms. Eucalyptus woodlots are also becoming popular, with an average holding of 200 m² per household. A comparison of farms with and without agroforestry interventions showed that the rate of rill erosion in the part of the watershed without agroforestry was around five times higher than with agroforestry. The interventions more than halved annual erosion rates: from 41m³/ha – which is a remarkable amount of soil considering the severe land degradation in the area – to 19m³/ha.

Despite such impressive contributions of scattered on-farm trees in reducing soil erosion, the future of such practices is in jeopardy due to lack of regeneration, which is mainly hampered by free grazing and the destruction of seedlings during ploughing. This leaves only old trees on the farms. If these die off, farms may become bare, enhancing the vicious cycle of aggravated soil erosion, food shortage and poverty. To avoid such an undesirable future, farmers should be assisted and encouraged to retain trees on their farms, by planting and protecting tree seedlings and by managing existing trees properly, particularly on slopes.

Authors

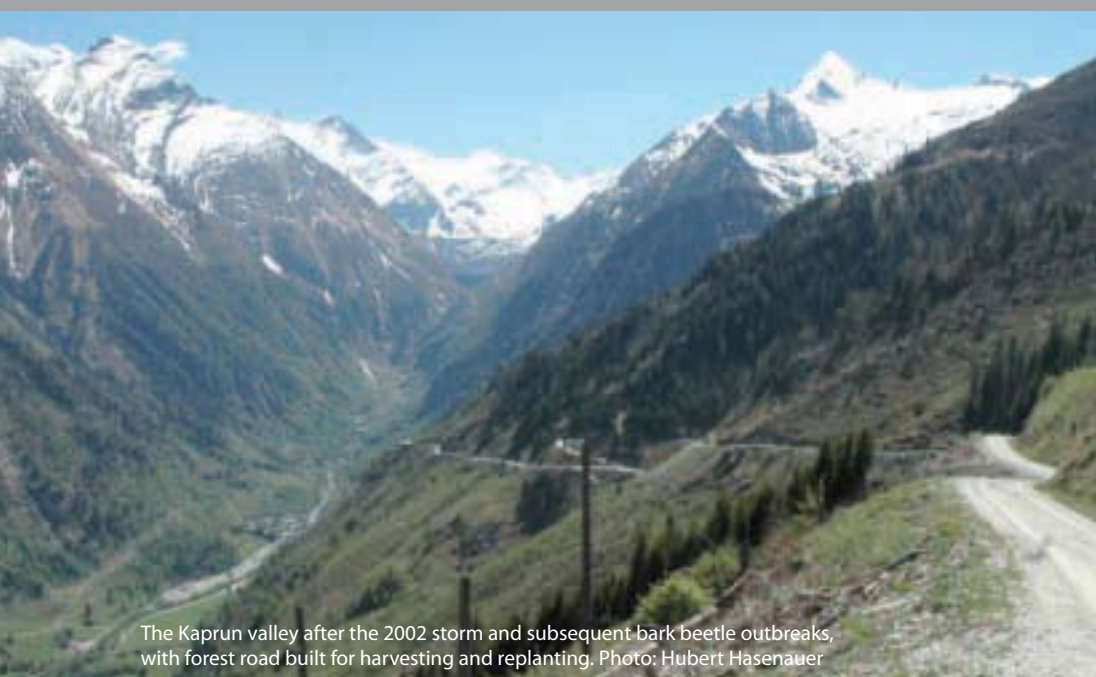
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The effects of a major storm on the protective function of forests in the Kaprun valley, Austrian Alps



On 14-16 November 2002, the storm 'Uschi' damaged two million m³ of timber across southern Germany and western Austria. This was equivalent to twice the usual annual harvest for the region. Winter 2002/2003 was exceptionally mild, with a below-average snow pack, and was followed by a hot dry summer in 2003. The result was a large bark beetle outbreak which became a major regional problem.

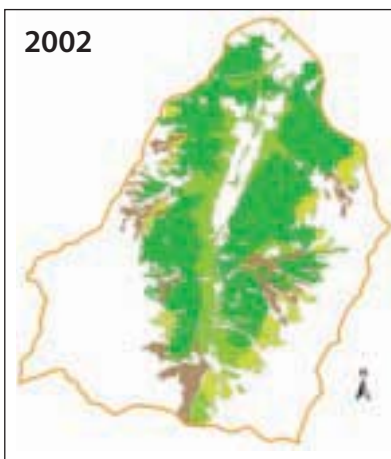


The Kaprun valley after the 2002 storm and subsequent bark beetle outbreaks, with forest road built for harvesting and replanting. Photo: Hubert Hasenauer

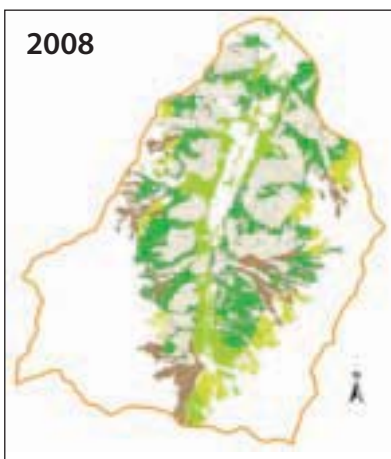
One area severely affected by the storm was the Kaprun valley, with steep slopes mainly covered by Norway spruce (*Picea abies* L. Karst). At the end of the valley is the year-round ski area on the Kitzsteinhorn glacier. During high season, about 10,000 people travel through the valley every day to reach the ski lifts. Thus, any change in the stability of the forests which affects the accessibility of the glacier strongly influences the local tourist economy.

Before the storm, forests covered 1496 ha. The storm destroyed 266 ha (18%) of forests, and damaged single trees and groups of trees, adding 12.5 ha of loss in forest area. As there was no road access and winter was approaching, no harvesting was done until spring 2003. In 2003, a further 141 ha (9.5%) of forests were damaged by additional windthrow and the increasing impact of a severe bark beetle outbreak, which continued. By 2008, 702 ha (47%) of the forest had been lost.

Across the catchment as a whole, the loss of forest cover from 2002 to 2008 led to an increase in annual runoff of about 8% - an additional 3.5 million m³ - significantly affecting the forests' protective function. Consequently, more than 150,000 trees were planted in 2003 and 2004, maintenance roads were constructed, and a wildlife management programme was established, to regain and ensure the protective function of the devastated forests.



Forest cover in the Kaprun watershed, 2002 and 2008. Each colour represents a different tree species. Most losses are of spruce forests (dark green)
Maps: Hubert Hasenauer



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4

Values of biodiversity

Values of biodiversity

Lalisa Alemayehu Duguma, Georg Gratzer, and Martin F. Price

Mountains are global centres of biodiversity; 25 of the 34 global biodiversity hotspots are wholly or partially in mountains. They play a crucial role in harbouring a significant number of plant and animal species that are either endemic, i.e. occurring nowhere else, or threatened. Consequently, mountains are foci of local and global conservation efforts. A third of the world's protected areas are located in mountains; they cover 16% of mountain land.

The high levels of biodiversity in mountains do not derive only from their remoteness and the resulting lower human pressures in terms of intensity of land use. Other factors include high climatic variability along altitudinal gradients and on slopes with different orientations, high heterogeneity of rocks and soils, and diverse disturbance regimes. In combination, these factors mean that mountains provide a multitude of habitats for different species. They also play a crucial role as corridors and refuge areas, particularly as climates change, thus acting as species pumps over evolutionary time scales, so that lowland biodiversity hotspots also tend to develop around mountains.

Realizing benefits, recognizing challenges

Among the different types of mountain forests, cloud forests are critical in terms of both high levels of endemism and the threats they face. In the Peruvian Andes, a third of the endemic mammals, birds and frogs are confined to cloud forests which are therefore important gene pools. This is also true for domesticated agricultural crops; these forests harbour particularly high proportions of wild relatives of crops including potatoes (*Solanum sp.*), tomatoes (*Lycopersicon esculentum*), avocado (*Persea americana*), beans (*Phaseolus sp.*), cucumber (*Solanum muricatum*), and pepper (*Capsicum sp.*). Yet these forests are more susceptible to threats than other types of forest, as their survival depends particularly on water filtered from fog and clouds by their leaves and stems. The large-scale felling of the trees removes these filters so that the forests cannot re-establish.

Generally, the conversion of mountain forests to agricultural land is the main cause of deforestation. Many biodiversity conservation efforts focus on this trend, often with negative effects on the livelihoods of mountain people. However, productive land use does not necessarily contradict the conservation of biodiversity. At moderate levels, land uses such as grazing enhance diversity; a mosaic of moderate-intensity forest and agricultural land uses enhances biodiversity at the landscape scale. Such diversity is important for local land users. For example, people living around Mount Cameroon strongly value biodiversity, linked not only to the usefulness of different sites but also to intangible values such as the forests' aesthetic and spiritual values and tranquility.

Supporting livelihoods

A high level of diversity in mountain forests acts as an insurance against different pressures and changes, particularly when the type and direction of the changes are unknown. Land use by smallholders is often based on high biodiversity, particularly in homegarden systems, such as the Chagga homegardens around Mount Kilimanjaro, which contain 520 vascular plant species, including over 400 non-cultivated plants. Most of these are forest species, and the multilayered structure of these homegardens resembles natural tropical montane forests. This is in stark contrast to the very limited biodiversity in large plantations consisting of one species, which are found in many mountain areas and are increasing in area, mostly in Asia and Europe – a trend that is expected to continue.

Mountain forests are important sources of wood, feed, food and other economically important non-timber forest products. People living in and around mountains rely on their forests for, construction wood and farm utensils, especially in many developing countries, where remarkable numbers of species have one or many specific uses. These forests are also important sources of wild edible plants and animal products, such as honey and bush meat, consumed by many local people, and of traditional medicines where access to medical infrastructure is poor or absent. Thus, many mountain people consider their forests as 'safety nets' providing consumables, feed, medicines and income, especially during the seasons when farm harvests are not enough to sustain families, or in years when crops fail.

Opportunities for realizing economic and cultural values

Many high-value products grow naturally in mountain forests. For example, Arabica coffee (*Coffea arabica*), one of Ethiopia's most important commodities, accounting for around one-third of annual exports, grows in the country's afro-montane forests. Most high-quality timber from central African countries originates from mountain forests. African montane forests are also sources of important medicinal plants such as *Prunus africana*, whose bark is highly demanded internationally to treat prostate diseases.



The biodiversity of mountain forests is important not only for its intrinsic, conservation, livelihood and direct economic values, but also as a component of attractive landscapes, which are an important basis for income generation from tourism, and as habitat for animals and birds which are hunted, generating considerable income as long as populations are maintained at sustainable levels. Forest animals and birds, often living in sacred forests that local people considered as the dwelling areas of 'spirits' and hence respect, also have a strong cultural significance. For example, in the Cameroon Highlands, python (*Python sebae*), leopard (*Panther pardus*), and civet (*Civettictis civetta*) skins are used decoratively and in ceremonies, and Bannerman's Turaco feathers (*Tauraco bannermani*) and porcupine (*Atherurus africanus*) quills are signs of honour given by the local ruler, the Fon.

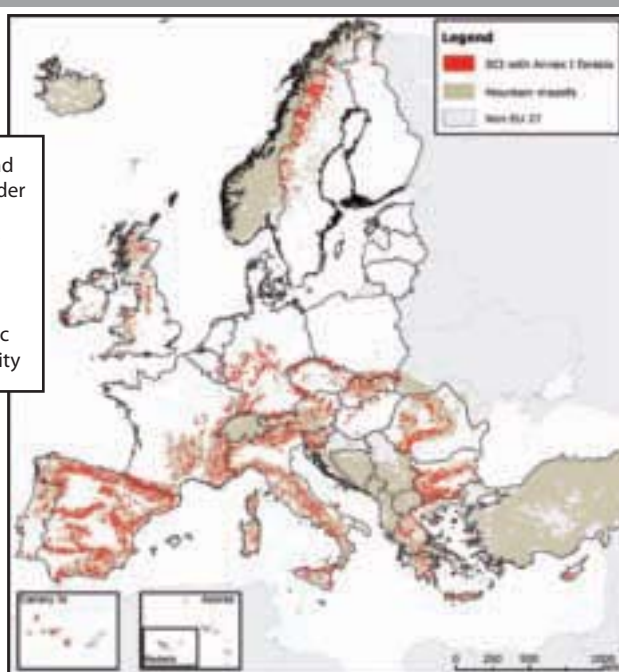
The high endemism of mountains and their forests

Mountain areas and their forests have high degrees of endemism. The Eastern Arc Mountains of Tanzania and Kenya are home to 96 endemic vertebrate species and at least 800 endemic vascular plants; the Tanzanian part of this mountain chain provides habitat for 30–40% of the country's fauna and flora species. The Tropical Andes are home to about 45,000 plant species (of which 20,000 are endemic) and 3,389 vertebrate species, half of which are endemic. In Ethiopia, two-thirds of endemic mammal species and 15 of the 26 endemic bird species live in the mountains. Half of Switzerland's species are found in the mountain forests, which comprise around 80% of the country's forest cover.

Natura 2000 and the European Union's mountain forests



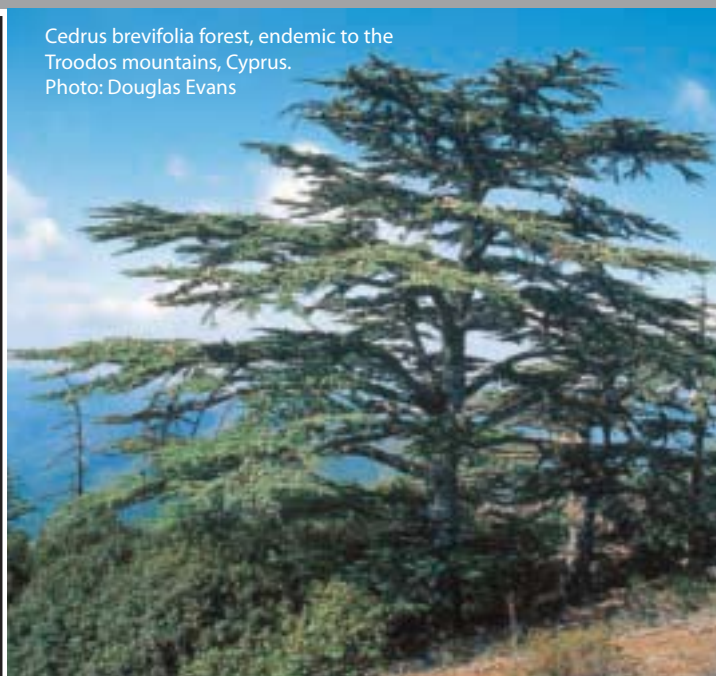
Natura 2000 is probably the world's largest protected area network: its 26,000 sites cover 18% of the European Union's (EU) terrestrial area. The sites are designated according to the EU's principal instruments for nature conservation: the 1979 Directive on Wild Birds and the 1992 Directive on Flora, Fauna and Habitats (Habitats Directive).



Mountains (grey) and sites designated under the EU Habitats Directive for at least one Annex I forest habitat type (red).

Map: European Topic Centre for Biodiversity

Cedrus brevifolia forest, endemic to the Troodos mountains, Cyprus.
Photo: Douglas Evans



Negotiations between the European Commission and the EU's Member States have resulted in a list (Annex I) of 231 habitat types – including 81 forest habitats – to be protected under the Habitats Directive. Both directives also have lists of species to protect, including many from mountain forests. At the end of 2010, 5,513 sites with forest habitats listed in Annex I covered 24% (299,359 km²) of the EU's mountains. This is a higher proportion than for the EU as a whole because mountains usually have low human population densities, so that many habitats and species which have become rare elsewhere survive, and there is less political opposition to the creation of protected areas. In many countries, therefore, Natura 2000 is largely based on existing protected areas, which are often biased towards the mountains; for instance, all but one of France's national parks are in the mountains.

Eighty of the 81 Annex I forest habitat types occur in mountain areas. Although many have only a small proportion of their distribution here, 24 of these habitat types are only found in mountains, and a further 22 have 90-99% of their sites and/or area in mountains. While the sites are distributed throughout the EU, most Annex I mountain forest habitat types occur only in southern Europe, often with limited distributions. Annex I mountain forest habitat types in central and northern Europe tend to have much wider distributions.

Although Natura 2000 is considered to be largely complete, it will only be of value if the sites are appropriately managed. Although some are strict nature reserves, most are likely to be exploited, and the European Commission has therefore published guidelines for the management of forested sites.

Authors

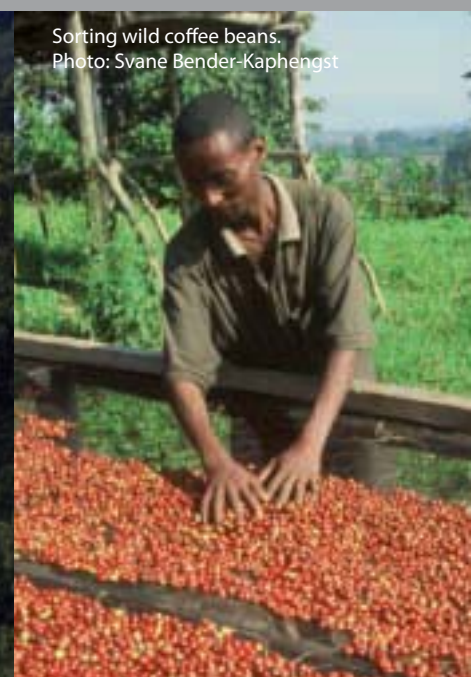
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The wild coffee forests of Ethiopia

The Kafa Biosphere Reserve of southwest Ethiopia ranges from 900 to almost 4,000 metres above sea level. Its diverse habitats include evergreen mountain forests and grasslands and, most exceptionally, Afromontane cloud forests, home to about 5,000 varieties of wild *Coffea arabica*. This is an invaluable genetic resource, given that about 90% of the coffee drunk worldwide is Arabica coffee.



Afromontane cloud forests, Kafa Biosphere Reserve. Photo: Svane Bender-Kaphengst



Sorting wild coffee beans.
Photo: Svane Bender-Kaphengst

In the forests, giant trees, lianas, epiphytes and ferns form dense vegetation that is home to many plants and animals, mostly endemic, including lions, leopards, monkeys, bush pigs, antelopes, and about 260 bird species. Local people are highly dependent on the forests, harvesting wild-growing coffee cherries, lianas, commercially-valuable spices, and honey from wild bees for their own consumption and local sale.

From 1988 to 2008, 43% of the wild coffee forests were lost due to resettlement and migration, timber extraction, forest grazing, and conversion to agricultural land. In response, German private and public partners and NGOs, including the German Nature and Biodiversity Conservation Union (NABU), began an integrative approach to improve coffee quality and marketing, support participatory forest management and family planning, and establish the 760,000 ha Kafa Biosphere Reserve, designated by the United Nations Educational, Scientific and Cultural Organization (UNESCO) in 2010. Both politicians and locals recognised the opportunity to foster regional development by selling wild coffee labelled with the Biosphere Reserve's brand; it is now exported internationally.

NABU has initiated a project on climate protection and preservation of primary forests – including large-scale reforestation with native tree species and participatory forest management – funded by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety within the International Climate Protection Initiative. Fast-growing community forests and wood-saving stoves are being introduced. The tourist infrastructure is being developed, by training rangers and guides and providing micro credits to local people. Thus, living standards are expected to markedly improve – which will benefit the long-term conservation of the forests. From 2002 to 2010, the deforestation rate was only 5%.

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Natural Regeneration in the Mountain Forests of Ecuador



For centuries, people in the Ecuadorian Andes have used naturally-reproduced seedlings to provide food, medicine, forage, firewood, fences and protective barriers in cultivated areas. This natural regeneration supplied local needs until the 1970s, when the government and NGOs began reforestation programmes, to facilitate plantations of native species. In addition, forestry schools and natural resource projects focused on tree species for timber. This detracted from the value of natural regeneration in agroforestry to meet aims other than producing trees that are suitable for use as timber.



The Casillas Castro family and their agroforestry system. Photo: Robert Yaguache



Agroforestry system with chilca and infiltration channels. Photo: Robert Yaguache

Today, the use of plants produced in nurseries has largely replaced the practice of using natural regeneration. However, many communities continue the practice at a small scale. If fire, agriculture and grazing are eliminated through agreements with the land owners, natural regeneration is possible in all ecosystems, and also contributes to biodiversity conservation and decreasing pressure on forests. Recent research in the province of Cotopaxi has shown many benefits of natural regeneration which, unlike nurseries, costs nothing and does not require professionals because rural families collect, transport and manage seedlings.

There are other benefits of natural regeneration. First, grasses, bushes and trees can regenerate to form secondary forests. At an altitude of 2400 m, these can grow to a height of about 1.9 m in 10 years, allowing organic material to accumulate, thus facilitating the temporary retention of water and regulating its flow. These forests also contain many valuable non-timber forest products. Second, many naturally-regenerating tree species can grow, on average, 20 cm per year. In fallow areas where these species grow freely, they can be protected to form a forest-pasture combination and for timber. Third, bands of naturally regenerated vegetation – established with seedlings collected near roads and in fallow areas, thickets, and forests – across slopes and around fields provide protection from winds and freezing temperatures. The improved growing conditions allow the cultivation of grass which can be used to feed guinea pigs, contributing to food security. Finally, up to 80% of family energy demands can be met by pruning naturally regenerated trees.

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Evaluating the role of biodiversity for sustainable management of Kyrgyzstan's walnut-fruit forests



Walnut-fruit forests, found only in Southern Kyrgyzstan, represent a valuable hotspot of biodiversity and are significant for local livelihoods. Particularly since the collapse of the Soviet Union, these forests have experienced great pressures due to economic recession and increased human impacts. Their management must urgently address the resulting challenges related to the conservation of biodiversity, socio-economic efficiency, and local livelihoods.



Walnut fruit forests. Photo: Z Sarymsakov



Field assessment of the impacts of management strategies.
Photo: Gulnaz Jalilova

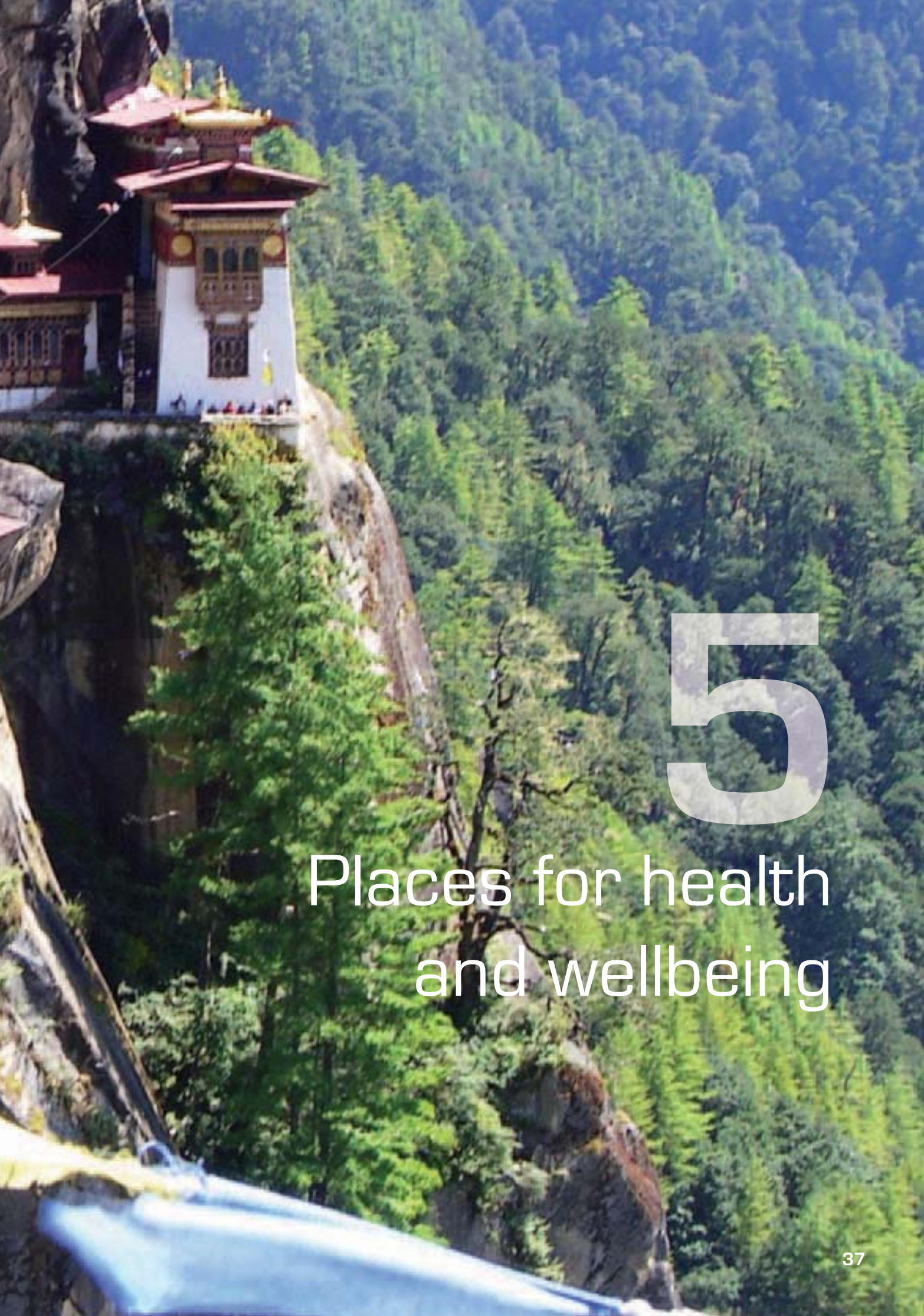
Recent policy options have suggested that local people could meet their long-term demands by incorporating biodiversity conservation in management practices. To design appropriate measures requires knowledge about people's perceptions towards biodiversity and conservation activities. A study on this topic showed that local people are aware of the concept, but perceive it differently depending on the benefits gained from the forests, and on their profession. The study found that people generally have positive intentions for biodiversity conservation, and believe that large state subsidies for income generation, poverty reduction, and public support may help to conserve biodiversity in the long term. However, the study also showed that local people, managers and regional planners need to better understand the importance of functional diversity in establishing a sound conservation and sustainable use strategy, as well as income-generating activities.

To provide a framework for evaluating action plans, and allow improved cooperation in conserving and utilizing forest resources, six workshops at regional and local (leshoz) levels were undertaken to develop criteria and indicators (C&I) to assess sustainable forest management strategies. Stakeholders selected 7 criteria and 45 indicators, and evaluated different management strategies based on their preferences. For various stakeholder groups, biodiversity conservation was the least preferred criterion. In elaborating different management options, the forest tenure system, controlled cattle grazing, and mechanisms to address firewood consumption were found to be the most conflicting indicators. In addition, the involvement of local stakeholders in decision-making and biodiversity conservation was stimulated by the C&I process. These findings therefore provide a fundamental basis for developing a new vision for the sustainable management of these unique forests.

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5

Places for health
and wellbeing

Places for health and wellbeing

Robert Mc Morran and Martin F. Price

Mountain forests play key roles in the physical and mental health and wellbeing of people around the world. They provide medicines for mountain people, and medicinal and aromatic plants to global markets, supporting mountain economies. Mountain forests also provide many opportunities for recreation and tourism. In many developing countries, they are of great cultural and spiritual importance, often being given protected status.

Sources of medicinal and aromatic plants

Mountain forests are sources of not only wood products and edible species, but also medicinal and aromatic plants (MAPs) which support the health of mountain people, and have important cultural and symbolic values. Many mountain communities depend directly on MAPs for income, particularly as timber is only occasionally available for trade, and fuelwood only achieves significant returns on or near busy trekking routes or market centres. More widely, MAPs are critical to many mountain economies; in many regions, the sustainable production of these plants and other non-timber forest products may bring greater income from mountain forests than timber. For example, MAPs traded in national and international markets annually contribute over US\$10 million to Nepal's economy.

Key challenges in dealing with MAPs include the lack of stable pricing, environmental impacts of increasingly commercialised harvesting often leading to the extinction of the species in the wild, and the inequitable distribution of benefits. MAP trading is a 'buyer's market': collectors are usually paid only a fraction of the prices generated further up the supply chain. High-value MAPs from mountain forests are commonly exported: for example, most from Nepal are exported and processed in India. Global market demand is increasing, and overexploitation often results. Many MAPs originate in remote areas from habitats whose conservation is of international importance, and many are designated by governments as protected areas. The resulting restrictions on resource use and associated economic activity frequently have negative consequences for mountain communities. Consequently, the development of integrated approaches to the sustainable extraction of MAPs which consider both conservation and sustainable exploitation is essential.

Lack of knowledge regarding the ecosystems where MAPs grow, and their relative importance in different mountain communities, is a key challenge in developing strategies for their sustainable management. Establishing sustainable harvesting levels requires assessment of MAP resources, harvesting levels and techniques, and potential employment and income. Overexploited MAPs may require restorative conservation measures, monitored harvesting quotas, or cultivation. Partnerships between local

collectors and enterprises and more powerful market actors, and the establishment of processing facilities close to product sources to add value before export are important for developing more equitable supply chains. Despite shifts in many mountain regions towards community management of forest resources, local groups extracting MAPs often remain marginal to policy development. Both local and regional institutions could play important roles in supporting local enterprises and ensuring more sustainable management of MAPs.

A global playground

Tourism and recreation contribute significantly to the economies of mountain regions around the world, and provide critical sources of employment and income that can bring greater economic benefit than the harvesting of timber or non-timber forest products. Mountain forests are a key element of the attractiveness of mountain regions, and their recreational uses are projected to grow rapidly. The increasing trend of escape to the mountains has been facilitated by technological developments, including Global Positioning Systems, off-road vehicles, and mobile phones. Visitors to mountain forests enjoy diverse activities, including walks, trekking, camping, snow sports, mountain biking, fishing, hunting, nature-based tourism, horse riding, and photography. Recreation in mountain forests can have considerable physical and mental health benefits. Yet these uses can represent a double-edged sword: growth in visitor numbers often results in unsustainable levels of resource exploitation, increased air and water pollution, damage to habitats through changes in land use changes, and disturbance to animals.

Developing sustainable tourism and recreation in mountain forests requires knowledge of levels of recreational use, visitors' experiences and attitudes, and associated impacts. Zonation-based approaches to visitor management can facilitate different types or intensities of recreation. Experiences in mountain forests can lead to greater environmental awareness among visitors, particularly where well-planned interpretation communicates the diverse values of the forests. Various types of nature-based 'ecotourism' also represent powerful opportunities for capitalising on emerging markets, while potentially minimising the impacts of visitors on forest ecosystems in the longer term. Nevertheless, as tourism-based economies



are vulnerable to global trends and often provide mainly seasonal employment, it is essential for mountain people to maintain other livelihood sources.

Sacred mountain forests

In mountain regions around the world, areas of mountain forest or whole landscapes are considered as sacred and are protected, often with restrictions of extractive uses of flora and fauna restricted. Sacred forests also represent sanctuaries for worship and religious ceremonies. While cultural and religious values are associated with many forest types, mountain forests are often associated with particularly strong spiritual values, as these are integrated with those of the wider mountain setting.

The level of protection or resource use restrictions depends on the scale of the sacred forest. Smaller groves are often accorded strict protection from extractive uses, including official government

designation; the protection of larger sacred landscapes may be facilitated through social norms which foster careful use, rather than a complete ban on extractive uses. Frequently, complex sets of myths and beliefs act as guidelines to facilitate sustainable human-ecosystem interactions and protect biodiversity. In eastern Bhutan, for example, Ridam, a long-standing practice founded in Buddhist beliefs, prohibits entry to and use of a sacred forest from mid-August to mid-October. This protects young animals and plants during the monsoon growing season, and provides socio-economic benefits through focusing community attention on important agricultural activities. Such traditional ecological knowledge is commonly intricately integrated with spiritual beliefs and practices and contributes to protecting ecosystem complexity, often through fostering the development of landscape mosaics.

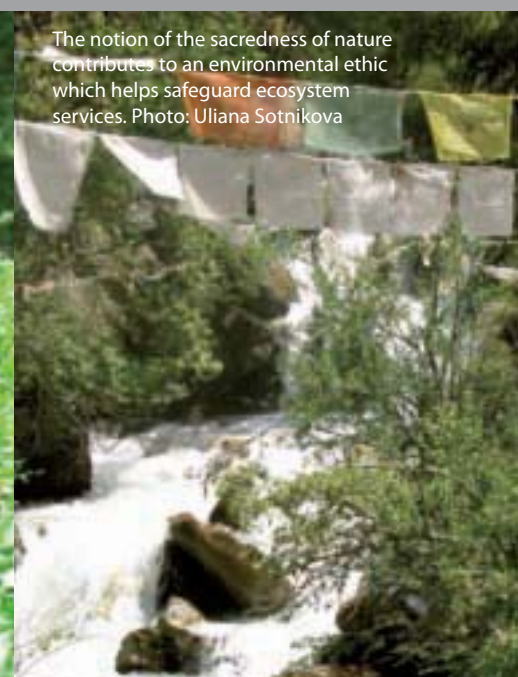
Applying participatory approaches for ecosystem management in the Kailash Sacred Landscape, China, India and Nepal



The Kailash Sacred Landscape (KSL) was delineated in 2009 in a rugged, remote trans-boundary area which is highly diverse and culturally and ecologically rich. Over a million people live within the 31,000 km² KSL, almost all at relatively lower altitudes on the wetter, southern slopes and foothills in India and Nepal.



Local communities rely heavily on forests. Photo: Uliana Sotnikova



The notion of the sacredness of nature contributes to an environmental ethic which helps safeguard ecosystem services. Photo: Uliana Sotnikova

They are heavily dependent on natural resources; their environmental ethic, based on sacred values and religious practices, regards people as part of nature. Yet, given the harsh environment, poor accessibility, and limited livelihood options, a cycle of poverty and resource exploitation has accelerated environmental degradation and biodiversity loss.

As local people consider nature as a power that sustains them, they prescribe obligations towards nature in the form of customs and consequent values and attitudes. At the community level, sacred forests are a prominent mechanism of forest conservation, being offered to the deities, and thus becoming restricted use zones. The motivation behind keeping these patches intact can partly be attributed to the resulting ecosystem functions, including soil conservation, watershed maintenance, and provision of timber and non-timber forest products. When degradation becomes evident or increases rapidly, forest or grazing patches are offered to deities to ensure conservation. In recent years, such practices have increased, particularly in areas where grazing pressure is high or where disputes occur between villages. This notion of sacredness has played an important role in conserving both floral and faunal diversity.

Policy support and enabling policy environments are essential to promote, enable and support such local resource management efforts and approaches. Thus, partners from China, India, and Nepal have established the KSL Conservation Initiative. It is based on a vision of adapting and applying ecosystem management approaches that recognize the vital role of communities and traditional customary arrangements to achieve long-term conservation goals and facilitate community empowerment, as an adaptation strategy addressing both climate change and regional and local economic development.

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Non-intervention and visitor management in Fulufjället National Park, Sweden



Fulufjället National Park was established in 2002, with the objective of preserving 38,483 ha in the southern Swedish mountains, including distinctive forests and other highly vulnerable natural features, in an essentially unspoilt state. Wilderness species include brown bear, lynx, gyrfalcon, and Siberian jay, which is sensitive to clear-felling and therefore finds a haven in this wilderness.



Brown bear. Photo: Orsolya Haarberg



Interpretation site in Göljan Valley.
Photo: Vitantonio Dell'Orto/exuviaphoto.com

According to the park management plan, extractive operations, reindeer grazing and other activities which could damage soils and vegetation are forbidden. In certain areas, non-intervention is a fundamental management tool: an integral part of the overall conservation strategy and visitor management. Non-intervention management is supported by clear zonation, a highly effective method of protecting key natural features and processes, yet also providing a range of opportunities for informal recreation and the appreciation of nature.

The park includes four zones, of which the largest is Zone 1, covering 23,000 ha of unfragmented wilderness – free from roads, snowmobiling, hunting, fishing, and reindeer grazing. The zonation was developed through public consultation with the local residents, and clearly separates non-intervention areas from those where traditional activities such as lake fishing or snowmobiling are allowed. The path towards the establishment of the national park, and thereby the reduction of human impacts, involved compromises. For example, the possibility of hunting birds in Zone 1 was banned; instead, some hunting groups were offered alternative hunting grounds outside the national park.

As part of the non-intervention management approach, the national park uses the remnants of a natural disturbance event in Göljan Valley as a unique interpretation site. During the 1997 'hundred-year flood', flash floods felled an estimated 10,000 m³ of trees in this valley. At the time, this was a nature reserve, and its managers decided to leave the large amount of timber untouched after the dramatic erosion that followed. Today the site, covered in naturally decaying dead wood, is one of the Park's main attractions, equipped with interpretation boards for visitors to learn about natural processes.

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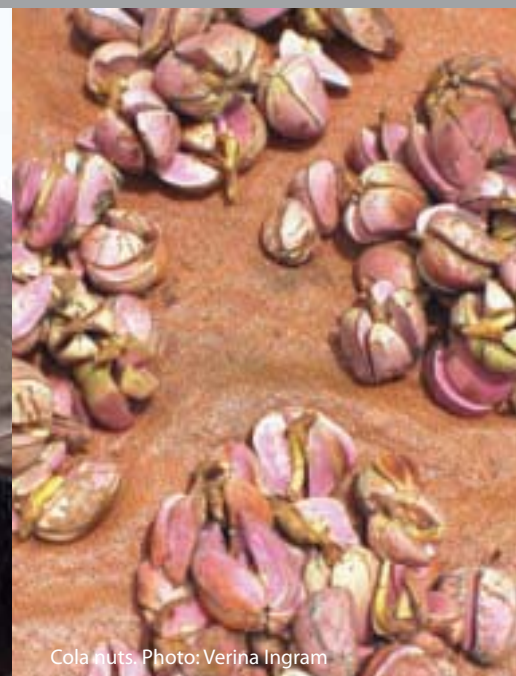
Non-timber forest products from the cloud forests of the Cameroon Highlands



The cloud forests of the Cameroon Highlands are rich in biodiversity, with many endemic species. In the last 50 years, over 50% of their area has been lost and degraded. The largest remaining block is the Kilum Ijim forest surrounding Mt. Oku (3011m), which still contributes significantly to the livelihoods of around 100,000 people.



Traditional meeting house in Bamenda, Northwest Cameroon, made of bamboo and raffia and roofed with local grass. Photo: Verina Ingram



Cola nuts. Photo: Verina Ingram

Products harvested for trade, in small local markets, include palm wine and 30 other products made from Raffia palms, bamboo, grasses for thatching and hives, herbs and spices. The barks, seeds and leaves of at least 77 plant and 40 tree species have medicinal uses; at least 30 tree species are prized for carving. A few products have value chains that now, and in the past, have extended across Africa and internationally, though all have experienced bust and boom cycles. These include *Prunus africana* bark and *Voacanga africana* fruits for medicine; cola nuts (*Cola nitida* and *C. anomala*) and honey for food; and resins such as wild rubber (*Funtamia elastica*). Though most people depend on fuelwood for energy, cultivated eucalyptus is now the main source, rather than the cloud forests.

As large forest animals are extinct, primates and large carnivores are highly threatened, and bats and smaller rodents are hunted. For example, the endemic, endangered Oku rat (*Lamottemys okuensis*) and Oku mouse shrew (*Myosorex okuensis*) are sold in empty sardine tins as "Oku sardines". Despite the loss of fauna, birds and animals continue to have a strong cultural significance. Equally, guides and local experts gain income through small-scale ecotourism and regular research visits, linked to the many endemic species.

Traditional authorities continue to regulate access to and use of forest products, and maintain shrines and sacred forest areas; conservation projects have sought to combine traditional rules with formal community forest management. However, as customary institutions are losing influence and official enforcement is lacking, the use of many forest products is unregulated or subject to corruption, making the sustainable use and management of the cloud forests more challenging.

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Forest Therapy in Korea

Rapid urbanization and industrialization have improved certain aspects of life, but have also caused costly environmental and chronic diseases and stress-related illnesses. Korea's population is ageing: over 7% are over 65, and people are becoming concerned about longevity and healthy life in old age. Given wide acceptance that forests can reduce stress, anger, and aggressiveness caused by modern society and also strengthen the immune system, interest in these benefits is growing.



Baekdu-daegan Forest Therapy Complex. Photo: Korea Forest Service.



Meditation in San-eum Recreational Forest.
Photo: Korea Forest Service

Forests cover 64% of Korea, mostly in the mountains. In 1988, a 'recreational forest' system was introduced to provide places for recreation and relaxation. By late 2010, 38 national recreational forests had been established, as well as 146 places for 'forest bathing', i.e., spending a short time in the forest.

In 2009, to meet increasing demand for the healing benefits of forests, Korea Forest Service initiated a pilot project on forest therapy in San-eum Recreational Forest, which is surrounded by mountains about 1,000 m high. This drew on studies about the benefits of forest bathing and other activities in forests for people suffering from depression and hypertension. Each day, 2,000 people are admitted; facilities and programmes include a forest healing centre, a water pool for therapy, forest healing trails, and Taeguk Zen and meditation programmes.

Although visitors may only stay for two nights, the pilot project has shown that their stay in the forest helps to increase alpha brain waves, which are usually produced when people feel relaxed and blood pressure level is stable. Another recreational forest has consequently been modified for people who need to stay longer for healing purposes. The project will be extended to other national forests that could offer an excellent natural environment or amenities.

Significant economic benefits are expected from protecting the human resource while reducing health care costs by preventing diseases. Korea Forest Service is therefore planning to invest more into research and the development of forest therapy, to train forest healing guides, and to improve therapy programmes based on scientific research.

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A photograph of a mountain landscape. In the foreground, a wooden roof with a dormer window is visible. The background shows a steep, rocky mountain slope under a clear blue sky. A large, semi-transparent number '6' is overlaid on the right side of the image.

6

Sources of wood

Sources of wood

Lalisa Alemayehu Duguma, Walter Sekot and Georg Gratzner

Wood is a basic product of mountain forests; it can be divided into wood for household uses and timber for sale. Even though mountain forests have slow growth rates and thus a relatively low biomass production potential, they provide timber and fuelwood for most households in mountain areas and many in adjacent lowlands. This is especially true in developing countries, where alternative construction materials and energy sources are rarely available.

At least 650 million people live in the mountains of developing countries and, for most, woody biomass is a major source of energy, though crop residues and animal dung may also be important. In both Africa and Asia, wood is the dominant energy source, providing, for example, more than 80% of the total energy requirement in Nepal and Bhutan. People living at high altitudes require more wood for cooking and heating than those living at the lower altitudes. This is associated with differences in both climate and atmospheric pressure: at high altitudes, temperatures are lower, thus requiring more energy for cooking and heating, and water boils at a lower temperature, thus increasing cooking times. For example, in the Himalaya, people living at altitudes above 2000 m use nearly three times more firewood per person than those living below 500 m.

Timber sales in domestic markets are economically important, particularly in developing countries. The current global increase in urban populations in these countries has opened large domestic markets for construction timber from forests and plantations, as alternative sources of construction materials are often absent. For example, about 3 million cubic metres of industrial roundwood are produced annually in Ethiopia and Uganda; all of this is consumed domestically, and much comes from high-altitude areas. In Uganda, around 240,000 cubic metres of timber are traded locally each year, 90% produced through small-scale pit sawing. This local timber market is estimated to have an annual value of around US\$75 million. In Indonesia, around 17 million cubic metres of illegally produced roundwood a year are traded in domestic markets. All of these examples show huge local demands for wood.

Forests are also important sources of wood for international timber trade, i.e., as an export commodity. For example, Africa and Asia produced around 43 and 164 million tonnes, respectively, of industrial roundwood in 2005, mostly for global markets. A significant amount of the wood produced in Africa comes from mid- to high-altitude forests where high-value timber species grow. In the global timber trade, forests provide two critical sources of income. First, they are sources of direct export revenues. Unfortunately, there are no clear estimates of the amounts extracted from mountain forests. Second, forests can be sources of revenues from logging concessions. Again, data relating specifically to mountain forests are limited, but concessions in these forests

are probably less common because topography and difficulties of access make harvesting and transport expensive.

Besides being sources of wood for the local and international timber markets, mountain forests are important sources of wood for carving industries which generate large domestic incomes. For example, wood carving businesses in Kenya are worth US\$30 million per year. From the island of Bali, Indonesia, the annual export of wood carving products is estimated to be worth US\$100 million; in India, the annual value of such products is estimated at US\$65 million. Again, much of the wood used for carving comes from mountain forests.

Even though information about timber production from mountain forests is not available at a global level, these forests are crucial sources of wood, especially in an increasingly urbanized world, where the global timber trade is expanding rapidly, both legally and illegally. Given the economic benefits which can be derived from timber sales in a global market, both the move away from sustainable small-scale harvesting practices towards larger-scale mechanised techniques and the expansion of illegal logging, especially in tropical and subtropical countries, are clear but unwelcome trends. Hence, there is a need to consider how to sustainably use mountain forests in order to gain long-term economic benefits and distribute these benefits equitably, while ensuring the proper conservation of the biodiversity and other ecosystem services which are also key values of these forests. This requires strong and specific research efforts on the role of mountain forests in global timber production, and clear policies which foster the sustainable use of these forests for multiple benefits.



Hochschwab, Austria. Photo: Gerhard Glatzel

The contrasting economics of mountain and lowland forestry in Austria

Data on the production economics of mountain forests as compared to lowland forests are scarce. However, data from Austria show that mountainous settings affect the profitability of forestry as well as the competitiveness of timber production. To begin with, the resource basis is different in mountain areas: compared to lowland forests, mountain forests have 97% of the growing stock and 80% of the annual growth, as well as more than six times more forests older than 140 years. This comparatively high share of old stands is an indication of over-maturity and potential abandonment: often, these stands are not actively managed and unlikely to be harvested. The annual allowable cut is only 86% that in lowland forests, and the adverse terrain means that harvesting is 21% more expensive. The forest road density is 76% of that in lowland forests, whereas the costs of road maintenance are typically higher. Thus, on average, mountain forestry is less profitable. Depending on the interest rate, the capitalized value of timber production varies considerably, with the profit in mountain regions being only 57% of the profit of lowland regions. However, other conditions also determine profitability and competitiveness. For instance, the average profit of mountain forestry is more than five times higher than for a lowland region

with a very dry climate and low productivity in the dominant pine and oak stands.

Non-timber products and forest services can be more significant in mountain forestry than in lowland forestry. For example, although the absolute levels of input and output per hectare of hunting area are lower, the relative economic significance is higher. Typically, the hunting area in mountain regions comprises also pastures and scrub as well as forests.

Despite the adverse conditions, the productivity of family labour on mountain farms, which often include areas of forest, is significantly higher than on lowland farms. On average, mountain farms benefit from economies of scale, as farmers manage a larger area and are more experienced and better equipped. They manage their forests in a more professional way, whereas the small woodlots in other regions often just provide an opportunity for actively spending some leisure time. Thus, in general, forestry is of greater significance for mountain farmers than for lowland farmers. Whereas the contribution to the farm income is still limited, the working income per hour or day which can be achieved in forestry clearly exceeds the working income per hour in agriculture. Hence, forestry may provide a lucrative complement to mountain farming.

Sustainable forest management of mountainous temperate rainforests in British Columbia, Canada



Canada's west coast has some of the world's most productive temperate rainforests. While over 17% of their area is included in protected areas, forest companies harvest significant quantities of industrial wood from publicly-owned forests under long-term forest management licenses. Sustainable forest management plans meet or exceed government requirements to manage forests for diverse economic, social, and environmental values.



Group retention: 25% of original forest retained for long-term structural enrichment. Photo: Bill Beese



The Pileated Woodpecker nests in cavities in dead standing trees. Photo: John Deal

In 1998, a major forest company decided to replace conventional clearcutting with variable retention, a more ecologically-based approach to harvesting and silviculture, and to increase the conservation of old-growth forests by defining broad management objectives for landscape zones. An adaptive management programme was implemented to monitor operational and ecological outcomes and to provide feedback to management. Despite changes to company ownership and depressed markets, an updated strategy continues to guide planning and practices for an annual harvest of over 5 million cubic metres.

The strategy established three stewardship zones, each with a different management emphasis and goal for retaining stand and landscape structure. The basic principles were to: 1) have a range of emphases on timber production and biodiversity conservation across the zones and 2) use ecosystem characteristics to guide objectives and practices. Strategic land use plans were used to assign management emphases, and different practice targets were applied using a biogeoclimatic ecosystem classification system.

The variable retention approach maintains structural elements of the pre-harvest stand throughout a harvested area, recognizing the importance of structural complexity for forest ecosystem function and biological diversity. Live and dead trees of varying sizes and canopy layers, and large woody debris are retained as habitat for diverse organisms. Various logging systems, using vehicles, cables, or helicopters to move the harvested trees, are used.

Monitoring showed that leaving groups or larger patches of trees is more feasible for logging than leaving dispersed individual trees, and has greater ecological value, helping many types of organisms survive and disperse in re-growth stands. In areas exposed to severe winds, leaving groups of trees next to clearcuts has reduced wind damage.

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Using remote sensing to improve the management of Lebanon's forests

The forests that cover much of Lebanon's mountains experience degradation due to urbanization, pests and diseases, fires, climate change, human neglect, improper management, and clearcutting. Most harvested wood, mainly from broad-leaved species, is used for fuelwood and charcoal, which provide the basis of the livelihoods of many rural communities, being both used locally and exported to larger villages and urban settlements.



Charcoal production. Photo: George Mitri



Forested mountain in North Lebanon.
Photo: George Mitri

Demand is increasing, and overexploitation represents a major threat to the country's forests, intensified by the lack of appropriate management plans, poor implementation of laws, and inadequate public awareness.

To date, Lebanon has had no operational mechanism to monitor forest cover and plan the sustainable use of wood resources at the national level. Detailed and current information about the location and extent of forest fuel types as well as changes in forest cover is required to identify forests where harvesting could both supply wood for charcoal and fuelwood and also deliver conservation benefits. Given the extent and often limited accessibility of forest areas, satellite remote sensing is essential to obtain this information.

Two projects at the Institute of the Environment at the University of Balamand are contributing to this goal. The first, funded by the National Council for Scientific Research, has used satellite data to develop a classification model for fuel type mapping. After validation with field data, the accuracy was above 70%. Such fuel type maps can be used not only to develop forest fire management plans, but also to model the sustainable production of wood. The second project, supported by Planet Action, an initiative of the company SPOT Image, aimed to produce an operational model providing baseline information about forest cover change, to help national and local authorities and community groups develop land degradation and climate change mitigation strategies. The combined use of fuel type maps, forest cover change detection maps, and socio-economic data will allow land management agencies to undertake multi-criteria decision analysis to select priority areas for wood supply and to monitor forest cover at the landscape level.

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New cable yarding technology from the Italian Alps



The pressures of global competition on wood harvesting have resulted in a massive trend toward mechanization. However, for use in mountain forests, the classic system for harvesting, transporting, and processing trees must be modified. Harvesters and forwarders to process and transport trees on steep terrain have been built, but none has really been successful.



Excavator-base processor at a yarder landing. Photo: Raffaele Spinelli



1500 m span tower yarder, processor and biomass recovery operation. Photo: Raffaele Spinelli

To address this problem, many operators have now shifted to mechanized whole-tree harvesting. The trees are felled with chainsaws, transported (yarded) in their entirety and processed at the landing (sorting and processing site). In the Italian Alps, the harvesting cost has decreased from €40/m³ to €28/m³, excluding transportation, and operator productivity has doubled, which may alleviate the chronic shortage of labour. Mechanization also offers a safer and comfortable work environment to the few people still willing to work in the forest, and the extraction of whole trees facilitates the recovery of tops and branches, allowing the development of a cost-effective biomass energy supply. Consequently, about 100 operators have converted to this system, which can bring additional revenue to both logging firms and forest owners.

Whole-tree extraction offers new technical challenges and requires careful tree selection and directional felling, especially when trees have to be transported downhill or over distances of more than 500 m. Some new yarders (winches) have cables more than 1000 m long. They can easily replace helicopters and traditional sled-mounted winches; their operating cost is lower than the former and, unlike the latter, they can work from a downhill station. Some use double carriages which hold the load at two points, so that it does not swing during transport: this allows selection cutting in narrow corridors without damaging the trees along their edges. The new yarders are radio-controlled and often fitted with radio-controlled self-releasing chokers, so that the operator at the landing can operate yarder, carriage, and chokers without leaving his cab. Two people can run an operation, with a productivity of about 100 m³ per day – and high-altitude forests are managed in a more timely way.

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Uses of wood from Iran's Hyrcanian mountain forests



Most of Iran's commercially exploitable forests are in the northern Alborz mountains, close to the Caspian Sea. Their natural vegetation is in distinct zones, with the mixed deciduous Hyrcanian forest at the lowest levels, beech (*Fagus orientalis*) forest in the middle zone; and oak (*Quercus castanefolia*) forests above 1,700 m.



Mechanized logging. Photo: Kambiz Taheri Abkenar



Processed timber.
Photo: Kambiz Taheri Abkenar

The small percentage of softwoods includes cypress (*Cupressus sempervirens*), juniper (*Juniperus polycarpos*), and yew (*Taxus baccata*). As well as wood production, these biologically diverse forests provide many ecosystem services, such as watershed protection.

A large proportion of these luxuriant Hyrcanian forests have been destroyed by illegal cutting and government contractors over the past 30 years, leading to negative impacts such as floods, soil erosion, and loss of biodiversity. In 1995, 1.44 million m³ of wood-based products were legally harvested from these forests. By 2004, legal production had declined by 40 percent, mainly for environmental reasons. More recent statistics are not easily accessible. However, though efforts by the government's Forestry and Range Organization appear to have reduced the amount of illegal cutting, it continues, particularly to provide large amounts of fuelwood which are sold on the black market.

Both the construction and maintenance costs, and the environmental impacts, of forest roads in these mountains are higher than in lowland areas. The expense of construction has increased in recent years, due to higher costs and additional attention to environmental risks. Large machines are used for harvesting and transporting wood in major forestry projects, which produce large logs exported to other parts of Iran for use in the pulp and paper and manufacturing industries. Lower-diameter trees are used for construction, and the production of particleboard and fibreboard. Much of the logging and transportation continues to be done by local contractors in the traditional way, using animals.

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A scenic landscape of rolling hills under a blue sky with scattered white clouds. The hills are covered in dense forests with trees in various shades of green, yellow, and orange, indicating autumn. In the foreground, a small wooden cabin with a dark roof is nestled among the trees on a grassy slope. A wooden fence runs across the bottom of the frame.

7 Managing cultural landscapes

Managing cultural landscapes

Georg Gratzner, Lalisa Alemayehu Duguma and Martin F. Price

As long as people have migrated through mountain areas or decided to live permanently in them, their uses of forests and other parts of mountain landscapes have been interwoven. Forests provide a multitude of services which support and sustain people living in mountain areas. This is particularly important because land suitable for agriculture is rare in mountains: globally, only 2% of the global mountain area is estimated to be of good to very good suitability for agriculture, while this percentage is 22% for non-mountain lands.

Addressing challenges to living in the mountains

Before the advent of agriculture, hunter-gatherers lived permanently in many mountain regions. When people started agriculture in these areas, they first converted the scarce suitable land. The remaining land – which was too steep, with soils that were too shallow, too nutrient-poor, too wet, or too dry – retained its natural vegetation: forest where climate and soils allow trees to grow. Globally, the people living in these remaining larger areas of forests often suffer from higher persistent poverty than people in areas without forests. Such remote forest areas have been called poverty traps. This tendency is explained by a number of sometimes related factors: they have low market access, poor infrastructure, fewer job opportunities, and land tenure is usually weak. In developing countries, most forests are government-owned, making it more difficult for local people to generate income from them. Participation in political processes is usually poor, which amplifies difficulties of gaining access to natural resources and generating income, especially when such areas also possess high biodiversity and conservation values. Protection for biodiversity conservation frequently leads to additional limitations on the use of forests and their resources for the rural poor, often resulting in local win-lose situations between conservation and local people. A final challenge is that remote mountain areas are frequently a refuge for people fleeing conflicts.

To survive in the challenging conditions of mountains around the world, people have developed innovative ways to survive. First, they converted the land suitable for permanent agriculture, thus reducing the area under forests. Where permanent agriculture was not possible, particularly in difficult conditions of upland or frontier agriculture, forests were cleared and burned, providing nutrients which became available to plants. This allowed a few years of cultivation; after the soil nutrients were depleted, the land was abandoned and left to nature. Such shifting cultivation or slash-and-burn systems have been used in mountain regions around the world, only coming under pressure when populations increased and people returned too early for the soil nutrients to be replenished.

Moving nutrients from forests to agriculture

Forests continue to be crucial for human survival in mountains because they provide nutrients for agriculture. Mountain people around the world have developed many ways to convert nutrients stored in the leaves and needles of trees, and in litter, herbs, and grasses, into meat, milk products or crops. They continue to send their livestock into forests to feed on what grows there. As large quantities of nutrients are stored in tree canopies, high above the reach of hungry cattle, yaks, goats, sheep, and llamas, people climb trees and lop branches in order to feed the livestock with leaves. Leaf and needle litter is collected from the forest floor, often mixed with dung, and spread on the fields to improve their fertility and increase harvests. Amounts of biomass harvested for these purposes have been huge: for example, in the mid-19th century, 4,850,000 cubic metres of litter were collected on 370,000 ha in the mountains of Western Austria, increasing the harvest by 1300 - 2000 kg/ha. Mountain forests thus not only produced products such as timber and fuelwood, but also nutrients for agriculture.

Such uses of forests are not a distant past for many mountain areas. In Bhutan, 700 tonnes of phosphorous per year are transferred from the forests to agriculture through grazing and litter collection; compared to 153 tonnes from inorganic fertilizer. Harvests in this mountainous country are only possible because of the transfer of nutrients from the forests. This transfer clearly has consequences for forest ecosystems: soils become impoverished in mineral nutrients and nitrogen, and acidify. When cattle graze in forests at too high a density – or the breed is too heavy – they compact topsoil and reduce water infiltration into soils, leading to increased runoff and higher erosion risks. Trampling by cattle on shallow roots of trees allows fungi to enter, leading to butt rot. Browsing can hinder tree regeneration if the tree species are more palatable than the available herbs and grasses. Particularly when control over use of trees and over the livestock is separated, such effects of grazing can lead, to user conflicts. However, livestock grazing in forests also has positive effects for forest management. It can reduce competing vegetation through browsing and trampling, provide niches for regeneration through exposure of soil, and increase plant species diversity.



Especially in developing countries, the transfer of nutrients from forests into agriculture will continue as long as there are no alternatives for maintaining adequate levels of agricultural production. In industrialised countries, a more recent concern is the harvesting of whole trees and their transport from the forest for processing. The crowns of trees are left outside the forest stands. As most nutrients are stored in needles and leaves as well as fine twigs, this leads to strong depletions of nutrients in the forests.

Potentials of agroforestry

There are many options for reconciling agricultural and forestry land use. Agroforestry systems – combining the cultivation of trees with agricultural crops, or trees with livestock – make use of benefits provided by trees for agriculture. Trees grown with crops pump nutrients from deep in the soil, prevent erosion, decrease respiration losses (which can increase harvests), and provide additional products such as fuelwood, fruits, medicines and timber. Agroforestry systems have a long history in mountain agriculture and are still more widespread than in the lowlands because agro-industrial production systems are less suitable in mountain regions. These systems are now receiving renewed attention because of their comparatively high carbon sequestration, and may have a more positive future in mountain regions than highly industrialised segregated agricultural systems.

The potentials of community-based resource management

Governance and land tenure are key issues in the management of resources, in terms of both their economic role and sustainability. While centralized government control has dominated forest ownership for centuries in developing countries, the percentage of forest land managed by communities in these countries grew from 22% to 27% in the 2000s. Worldwide experiences with the transfer of tenure rights to local communities show that “local communities can be good forest managers”. The ownership of forests is generally not a significant driver of forest degradation; for example, recent analysis of 30 sites in 10 Asian countries showed consistent improvements of forest conditions for community forests. Particularly in Nepal, community forestry is considered to be a successful forest conservation strategy. In recent decades, the focus has shifted from conservation to poverty reduction; and there have been highly positive effects, particularly when representatives of marginalized groups are involved in decision-making. This is not only true for Nepal; throughout Africa, Asia and Latin America, community-managed forests show generally positive contributions to the livelihoods of people or, at least, no declines in livelihood outcomes. Yet governments rarely transfer highly valuable forests to communities. Given that local rules are developed in a participatory way, there is a large potential for improving livelihoods through such transfers.

Forest grazing and tree regeneration in Bhutan



In Bhutan, forest grazing has resulted in major land use conflicts. Forest managers regard this traditional practice as outdated and inappropriate because of supposedly negative ecological and economic impacts, and policies have suggested its abandonment. Yet pastoralist farmers rely on forests for grazing cattle and yaks, and for fodder and animal bedding. Crop production depends on nutrient transfer, as manure, from forests onto agricultural fields. Without this input, agricultural production could not be sustained, given the low level of use of inorganic fertilizers.



Mountains in Bhutan. Photo: Georg Gratzer



Forests remain the major source of fodder for domestic animals. Photo: Georg Gratzer

Forest grazing facilitates tree regeneration on some sites, and has detrimental effects on others. In fir and hemlock-spruce forests, the effects of grazing depend mainly on understory type. While dense bamboo understories can substantially extend regeneration periods after harvesting through competitive exclusion of tree regeneration, cattle and yak grazing reduce competition by bamboos, enabling successful regeneration. Forest grazing can thus be used as a forest management tool on such sites.

After commercial harvests in mixed conifer forests with understories dominated by a mix of palatable and non-palatable herbs, forbs, ferns, bamboos and shrubs, the exclusion of cattle results in lower numbers of tree seedlings in small- and medium-sized openings. Large openings attract high numbers of ungulates, with negative effects on regeneration.

In cool-temperate broadleaf forests, understory type still appears to be a stronger driver of tree regeneration. Grazing has adverse effects on regeneration for palatable species (*Quercus*, *Castanopsis*, *Magnolia*, *Schima*, *Phoebe* spp), most of which are primary timber species; but facilitated the recruitment of non-palatable species (*Daphniphyllum*, *Persea*, *Symplocos* spp.) widely used by local communities. Higher grazing pressure intensifies these effects.

The ecological effects of forest grazing relate to carrying capacities for cattle and yak in different forest types, and the forest and livestock management schemes applied. Forest managers and herders must collaborate in developing site-specific land use management strategies, which must consider forest types, understory conditions, seasonality of grazing, and forest management systems.

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Threats to the integrated forest-grassland system of the Golden Mountains of Altai, Russian Federation



The Golden Mountains have a mix of ecosystems: tundra, steppe, desert, and biologically and culturally rich forests which stretch high into the valleys. These mountains represent an intact biocultural mountain landscape, maintained by the indigenous Altai peoples who consider the landscape as like a living being.



Cattle and horses at communally managed summer farm. Photo: Robert Wild



Larch forest in late September. Photo: Chagat Almashev

Nearly all the area has deep cultural and sacred values and outstanding biodiversity, including snow leopard, Argali sheep, wolf, bear, and important and rare bird and plant species. The traditional integrated land management system comprises a mosaic of high pastures, hay meadows, cereal fields, and forests. In summer, communal transhumance is practiced, with semi-wild horse herds on the highest pastures, and sheep and cattle lower down.

All the forests are federal property. Since its latest revision in 2006, the Forest Code no longer prevents timber extraction in the habitats of endangered species. Most accessible forests are over-exploited; the removal of the best trees and fire are major problems. The extent of illegal cutting depends strongly on the market situation and the level of management by the regional Forest service, which has a limited budget. Financial constraints also reduce management capacity in the protected areas, including three designated in 1988 as a Natural World Heritage Site. Increased illegal activities and limited law enforcement are compounded by lack of experience and rigid management systems – and cultural values are not recognised by the nature conservation authorities.

This is one of the economically poorest areas of the Russian Federation, under severe pressure not only from illegal timber harvesting, but also insecure land tenure, agricultural intensification, poorly controlled tourism, hunting, mining, transport infrastructure, and a natural gas pipeline. Yet local communities also play an active role in development activities, and have also been promoting forest conservation – for instance in the Karakol Valley, one of the most sacred places in Altai and until recently closed to outsiders, where local people have created the Uch Emeck Nature Park. They are also in the process of developing an Altai law on sacred sites.

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Linking forests and farmland: challenges and solutions in the Ethiopian highlands



Over 90% of Ethiopia's people live in the highlands, which also contain 93% of the country's cultivated land. At one time, forests covered about 90% of the highlands. Today, they cover 5.6%, mainly due to forest clearance for agricultural expansion and settlements. Most forests are now confined to inaccessible or legally protected areas – though these still experience significant pressures. As the human population has grown, deforestation has intensified, and the available land is cultivated more frequently, resulting in severe land degradation and hence poor productivity.



Advancing soil erosion on farm land. Photo: Lalisa Duguma



Illegal grazing in Menagesha Suba state forest. Photo: Lalisa Duguma

One example of these trends is the Menagesha Suba area in the central highlands, which includes the Menagesha Suba state forest. When it was officially demarcated in 1984, its area was 9000 ha; it is now 3530 ha. As land degradation has progressed, farmers have explored the use of less favourable land – such as forests, grazing land, and steep slopes – to grow agricultural crops and feed their livestock. As they also require income to buy consumable items for their families, they have encroached on the remnant forests to extract wood for sale. In addition, as the available grazing lands have decreased in area and become degraded, the state forest has been used for illegal grazing, which significantly affects forest regeneration and structure. However, as strict measures are in place against illegal grazing in such protected areas, farmers move their livestock for 2–3 months a year – especially during the dry seasons – to the mountains to forage on grasses and perennial vegetation.

In order to address land degradation and encroachment on the forests, farmers are growing trees for household wood demands, income generation, and fodder production. However, challenges such as shortage of land, lack of appropriate tree seedlings, insecure land tenure, and lack of expertise and knowledge remain. Farmers are also making efforts to improve the productivity of agricultural land using cattle dung, crop residues, and household waste – though only a small proportion of the first two is used for this purpose, as they are highly marketable.

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Lata Village, Nandadevi Biosphere Reserve, Uttarakhand, India



Lata village is the gateway to Nandadevi, India's third highest peak. The women of Lata and its neighbouring village Reni in the Niti valley were at the forefront of the Chipko movement which, in 1974, galvanised opinion to save Himalayan forests from commercial logging. Stressing the need to ensure local control and benefits from forest use and conservation, Chipko became a global inspiration for conservation movements.



Rishiganga hydropower project. Photo: Ashish Kothari



Bhotia woman with morel mushrooms. Photo: Neema Pathak Broome

Yet the resulting conservation policies had negative impacts on these villages. Government bans on commercial felling and the Forest Conservation Act 1980 restricted local access to resources. In 1982, the state government established Nandadevi National Park, cutting off sources of livelihood, such as mountaineering and high-altitude pastoralism. In 1988, the United Nations Educational, Scientific and Cultural Organization (UNESCO) designated 6,407 km², centred on the National Park, as a Biosphere Reserve and, in 1992, part of this as a World Heritage Site. These designations did not entail any further legal restrictions, but local people were hostile to them; in 1988-89, several hundred forcibly entered the National Park in a symbolic move to assert their right of access. More recently, several hydro-power projects have been approved and are under construction, despite protests about ecological and social costs. Lata villagers have stalled one project.

Some recent developments have been more positive. After Lata, other villages, and the NGO 'Alliance for Development' formulated a declaration asserting their rights to control and benefit from tourism and other activities, and their resolve to protect biodiversity, the government opened up a few trekking routes, providing employment for local young people, who also manage the trails. The Forest Department has initiated eco-development projects, using funds from UNESCO for the Biosphere Reserve and compensatory funds from hydro-electricity companies, but with limited benefits so far. In 2011, NGOs, government agencies, and local community organizations began to discuss possibilities of an institutional structure bringing together all stakeholders to formulate and implement integrated conservation and development plans, building on the priorities and knowledge of local people, empowered through their village assemblies.

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8

Climate Change

Climate change

Robert Jandl and Martin F. Price

Given the long lifespan of trees living in mountain forests, the considerable quantities of carbon that they contain, and the other ecosystem services they provide, climate change is a major issue for those concerned with planting, restoring, and managing these forests, as well as forest-dependent communities living in or near them.

As forests have the highest carbon density of all terrestrial ecosystems and as the forest cover on managed land increases with altitude, the carbon pool of mountain forests, both below and above ground, is high. Other mountain ecosystems, such as deserts, grasslands, and alpine tundra, have a much lower carbon density. Mountain forests are often well adapted to harsh climatic conditions and are, despite natural disturbances, stable elements of mountain ranges. As mountain forests hold a vast quantity of carbon, the size of the carbon pool and changes in it are highly relevant for climate change policies. However, when the reporting modalities are confined to actively managed ecosystems, as under the Kyoto Reporting Rules, the role of many mountain forests is not fully recognized because they are not managed.

Changes in mountain forests: natural and planned

Natural forest dynamics are driven particularly by climate factors. Under increasingly favourable climate conditions, the major constraints to forest growth at high altitudes – short growing seasons and low temperatures – are being alleviated and the timberline is moving upwards, at least where the soil and precipitation conditions are suitable and there is little grazing or cutting. Superimposed on this tendency are changes in land use practices. In industrialized countries, including many parts of Europe, North America, and Japan, the active management of mountain pastures is declining for economic or political reasons, and forests are expanding into these areas. The main economic reason is that high-altitude grazing is no longer competitive in an increasingly globalized market; the political reasons are strong public preferences towards ecosystem conservation at the cost of practical forestry. In developing countries, pressures on forests are strong because they provide opportunities for the expansion of agriculture and harvesting of wood for local and commercial use. Nevertheless, in some countries, plantations of fast-growing trees are being established in mountain areas.

Potential positive impacts of climate change

Increases in growth rates can be beneficial for those depending on trees for wood, and both this trend and a higher treeline can

improve protection against natural hazards. Changes in climate can also, in some locations, enrich the diversity of tree species and provide appropriate conditions for certain endangered habitats or species.

Potential negative impacts of climate change

Climate change may have positive outcomes for some species comprising and living in mountain forests, but may lead to the extinction of many others: a process that has already begun, especially in tropical mountains. Such changes affect not only ecosystem services, but also tourist economies related to high levels of biological and landscape diversity. While rising temperatures benefit the growth of trees, they also facilitate the more rapid growth and expansion of populations of pests and disease-causing organisms. This is further exacerbated by the rapid distribution of such organisms through global market streams. Together, these global change processes increase pressures on mountain forests. In regions of extensive forestry, outbreaks of pests and diseases have caused major damage to mountain forests: for instance, millions of hectares of lodgepole pine (*Pinus contorta*) in the Canadian Rocky Mountains have been lost to mountain pine beetle (*Dendroctonus ponderosae*), releasing considerable quantities of carbon and putting forest-dependent communities at risk as outputs decrease. In regions of intensive forestry, monitoring is becoming ever more essential and widespread, and silvicultural costs will increase due to the need for international and national alerting and monitoring programmes to combat insect and disease outbreaks at an early stage.

In regions where precipitation is increasing, wetter conditions will contribute to reduced fire frequency but, at the same time, increased tree cover promotes fire. Regions that are becoming drier – and often warmer – are likely to have a higher risk of wildfires. Both of these trends require better understanding of the processes involved, and more effective monitoring and rapid response. Nevertheless, many fires are started intentionally or accidentally by people, so that climate change is only one of many factors to be considered.

While changes in average temperature and precipitation lead to certain negative impacts, changes likely to result from increased numbers of extreme events are at least as critical. Examples



Forest of Ludikhola watershed, Dolakha, Nepal. Photo: Sanjoob Bhattarai (ANSAB)

include windstorms and heavy rain- and snowfall. Such events will endanger the stability of mountain forests and hence the provision of the ecosystem services they provide.

Contributions to the mitigation of climate change

The role of mountain forests in the mitigation of climate change is rather passive. Their loss would release large amounts of CO₂ into the atmosphere. Their protection, conservation and management are therefore important; and some governments are promoting the establishment of forests in mountain areas as part of their climate change policies or to benefit from carbon credits, often through the United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries (REDD). Active mitigation – the absorption of CO₂ in biomass and soils – is slow because the growth of trees and chemical processes at high altitudes are slow. A second field of mitigation is the substitution of fossil fuels with renewable forms of energy. In this context, mountain forests play a modest role as the trees generally grow slowly. Nevertheless, some species, which are not of great value for timber, can be regarded as reliable sources of biofuel – as can parts of large trees, such as smaller branches, that are not valuable as timber. In the mountains of developing countries, wood remains the principal energy source and is therefore highly important for supporting rural livelihoods. Given growing energy demands, all efforts to increase the efficient use of energy are important, so that key needs are to ensure that fuelwood is used more efficiently and that, wherever possible, other renewable energy sources are used.

Contribution of forests to climate change adaptation

Adaptation to climate change may be reactive or planned. Reactive adaptation includes actions such as changes in harvesting levels and schedules, the removal of downed trees after storms and the use of the resulting wood, and the development of socio-economic support programmes for communities experiencing negative impacts. Planned adaptation implies the redefinition of forestry goals and practices, taking into consideration the risks and uncertainties associated with climate change. Management plans will have to include uncertainty and the increased probability of extreme events, and be regularly updated. Farmers, communities and forestry companies and agencies alike need to identify and plant species or provenances which will grow well and ensure stable and productive forests in the climates of the later decades of the 21st century, contribute to local livelihoods and, in particular, ensure forest cover in areas with an increased risk of erosion, landslides, or other natural hazards. Conservation agencies need new approaches for planning and managing protected areas and corridors, which consider not only biodiversity but also other ecosystem services. For communities, adaptation may include better governance of forest resources, capacity building to monitor and cope with extreme events, increased use of agroforestry practices, and diversification of income sources. At national and global levels, key actions may include the development and implementation of monitoring and reporting systems and tools for vulnerability assessments and adaptation planning, as well as increasing the flexibility of organizational cultures, structures, and forest-related policies before crises arise.

Adaptation to climate change by mountain communities in Vietnam



About two-thirds of Vietnam is upland or mountainous, and mainly forested. These lands have been home to many ethnic minorities for centuries, providing the basis of their livelihoods; they rely heavily on fuelwood and other wild products for food, fodder, medicines, construction materials, and other items. In remote communities in the northern uplands, forest products not only provide subsistence needs, but also contribute 30-40% of total incomes. The forests are also very important for their roles in the national economy, poverty reduction, and environmental protection. However, climate change is likely to change many mountain forests.



House on stilts of the Nung people, one of 30 ethnic minorities in northern Vietnam. Photo: Ho Ngoc Son



A Nung woman in Ba Be district, Bac Kan province preparing wild bamboo shoots for sale. Photo: Ho Ngoc Son

Several recent studies concur that Vietnam is one of the most vulnerable countries to climate change, and that mountainous areas are at high risk of natural hazards and disasters. Therefore, mountain communities, especially ethnic minorities, are more likely to be vulnerable to flooding and other natural disasters, including more frequent forest fires. As climate change is expected to have significant impacts on the capacity of forests to provide vital ecosystem services, this could have far-reaching consequences.

In coping with natural disasters, both timber and non-timber forest products play important roles for mountain people as a source of income, used to compensate for losses from extreme weather events. Therefore, when droughts or floods destroy crops and affect household incomes, forest extraction also increases significantly, acting as a 'natural insurance'. Forest extraction is a safety net for very poor households, and is particularly important for households who are not able to use other risk-management and risk-coping strategies such as off-farm employment, formal credit and insurance and agricultural diversification.

Overall, forest management and policy in Vietnam need to take into account the potential impacts of climate change, which could decrease the capacity of local people to gain livelihoods from the forests. To increase the resilience of local communities to climate change, they need to have secure access to forest products; and economic alternatives need to be developed to reduce pressures on forests.

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Climate influences on forest dynamics in the Patagonian Andes, Argentina



Patagonia's forests are probably experiencing the warmest period of the last millennium; precipitation has also decreased significantly in recent decades. These changes have introduced substantial variations in rates of forest growth and the frequency, magnitude, and spatial scale of natural disturbances at regional scales. Several long-lived tree species living in the region are suitable for reconstructing past disturbances at an annual resolution, making it possible to understand these relationships using long-term series of both climate and disturbance.



Ormiscodes amphimone outbreak in summer 2003, Chorrillo del Salto, Santa Cruz (caterpillars in detail). Photo: Ricardo Villalba

Ormiscodes amphimone

Avalanche paths near El Bolsón, Rio Negro. Photo: Alejandro Casteller

Across the Patagonian Andes, drought events are one of the major factors influencing dynamics of the extensive *Austrocedrus chilensis*, *Nothofagus dombeyi* and *N. pumilio* forests in northern Patagonia. These events have been associated not only with episodic tree mortality but also have triggered forest decline at the regional scale.

Increasing summer temperatures appear to be the major cause for changes in the growth and mortality patterns in southern Patagonia's *N. pumilio* forests during the 20th century. An abrupt increase in mortality rates at the xeric forest-steppe border coincided with more frequent dry-warm events over the last three decades. Higher temperatures have also significantly influenced the frequency, intensity and magnitude of *Ormiscodes amphimone* outbreaks in these forests. Trees affected by this moth exhibited complete defoliation and an abrupt reduction in growth in the years following insect attacks in 1998, 2003, and 2005.

In the upper-elevation *N. pumilio* forests, avalanches are a major forest disturbance. The frequency and intensity of avalanches have been related to regional variations in winter precipitation during the 20th century. In years with large avalanche activity, the atmospheric circulation patterns showed features typically associated with the cold phase of the El Niño-Southern Oscillation.

Climate model simulations suggest that even warmer and drier conditions will prevail over the Patagonian Andes during the 21st century. Consequently, both the number of avalanches and the area affected by forest decline due to drought and insect infestations can be expected to increase in the near future.

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Climate change adaptation and mitigation through community-based sustainable management of forests in Nepal



Nepal's forests are critical to rural livelihoods for energy, compost-based farming, and marketable and subsistence timber and non-timber forest products, and provide critical ecosystem services. Through the introduction of community forestry, local people are organized to protect, manage, and benefit from forests that are otherwise unmanaged and prone to degradation and overuse. This has led to the substantial recovery of Nepal's forests over the last 20 years. Community forests now cover 1.25 million hectares, approximately 21% of Nepal's forest area, benefitting nearly 40% of the population.



General assembly of CFUG in Dolakha district, Nepal. Photo: Shambhu Charnakar



Forest in Kayarkhola watershed, Chitwan, Nepal. Photo: Sanjeeb Bhattarai

In 2009, the Asia Network for Sustainable Agriculture and Bioresources (ANSAB) and partners started a project to design and implement governance and payment systems for community forest management to reduce emissions from deforestation and degradation, through forest conservation, sustainable forest management and carbon stock enhancement (REDD+). The project, implemented in 10,266 ha of forests managed by 105 Community Forest User Groups, has identified drivers of deforestation and forest degradation, trained local communities to measure carbon stocks, and initiated direct and indirect carbon mitigation interventions. These include plantations, fire prevention, controlled grazing, and improved forest management practices, complemented by the adoption of bio-gas and improved cooking stoves and fodder production on private land. In 2011, the carbon stock of these community forests increased by 100,436 tons.

Communities have also developed conservation and adaptation activities with performance-based incentives from a forest carbon trust fund and payment mechanism. Encouraged by these results, ANSAB and international partners, including the United Nations Environment Programme and the Forest Stewardship Council's International Center, have developed a project to bundle forest carbon with other ecosystem services, such as tourism and hydrological services, and certify them at landscape level for enhanced benefits.

These experiences show that community-based, enterprise-oriented forest management is a vital component of local-level climate change adaptation and mitigation. The provision of economic incentives to local stewards helps reverse deforestation, enhances the stock of natural wealth for the sustained flow of ecosystem services, and strengthens the capacity of local communities to adapt to and mitigate climate change.

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Sustainable management of forest soils in the Calcareous Alps of Austria and Bavaria



Many protective forests in the Austrian and Bavarian Alps have regenerated after centuries of intensive utilization for fuelwood and timber for mining and industrial production. In most forests, grazing continued until recently. These activities frequently led to losses of tree species diversity, unfavourable age structures, and soil deterioration. In recent years, disturbances by windthrow and bark beetle infestations have impaired the integrity of these forest ecosystems; such disturbances are likely to increase in frequency and extent as a result of climate change.



Intact mixed mountain forests in the Northern Calcareous Alps. Photo: Klaus Katzensteiner



Using a portable photosynthesis system to measure gas exchange of tree seedlings. Photo: Gisela Pröll

Protective functions are provided best by continuous forest cover with gap regeneration. This is necessary in about two-thirds of the protective forests – but natural regeneration is usually inadequate. To develop a knowledge base to safeguard the functions and services of mountain forests, and understand possible carbon emissions, scientists from universities in Munich and Vienna are working in close collaboration with forest authorities, land owners and local stakeholders in the SicAlp project, funded by the European Regional Development Funds of the European Union, Austrian and Bavarian Ministries, and Austrian provinces.

Results from models and experimental studies on water and energy budgets, erosion and turnover of carbon and nutrients are being combined to quantify and upscale the impacts of disturbances on site conditions. This has shown that organic soils on calcareous bedrock material are extremely vulnerable, and humus disintegration and erosion after disturbances lead to severe losses of forest functions and services. If regeneration fails, the thickness of organic soil layers decreases in average by around two-thirds within a decade, leading to losses by respiration as CO_2 to the atmosphere and as organic carbon by erosion and leaching.

Strategies to replace forests after windthrow and bark beetle infestations must consider both the performance of tree species under extreme site conditions in windthrow areas and their anticipated resilience over their lifetime. Various studies are therefore being done to inform afforestation planning under changing ecological conditions. Sites with different afforestation and stand treatment practices have been established for long-term investigation as benchmark sites for adaptive management.

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9

Proactive ways
forward

Proactive ways forward

Georg Gratzner, Lalisa Alemayehu Duguma, Martin F. Price and Robert Mc Morran

Forests are a critical resource for people living in mountains, as well as many living in rural and urban areas outside the mountains. Mountain forests provide many goods and ecosystem services, and are often of great cultural importance. These vital goods and services are at stake, particularly because of overexploitation and losses of forest land to farming in developing countries on one hand, and decreasing use in industrialised countries on the other hand. In addition, climate change is likely to have many impacts, both short- and long-term, on mountain forests. Global energy problems and mitigation strategies geared towards the substitution of fossil energy with energy from biomass create additional strong pressures. All these factors increase uncertainties for those who depend on these forests for their livelihoods and economic gain – and therefore demand proactive approaches.

Multifunctional futures for mountain forests

As demands for the many functions and services delivered by mountain forests continually increase, so do potentials for conflict between the objectives of forest managers and the various groups and organizations with a stake in forest resources. Approaches to delivering multiple functions from mountain forests have often involved dividing these resources into productive and protective zones. It is increasingly recognized that many forest functions are inextricably linked to forests acting as whole functioning ecosystems, so that the spatial separation of key functions can result in losses of forest ecosystem integrity and long-term forest functionality. Consequently, to balance the protective functions of mountain forests (which often have considerable downstream benefits) against their productive functions (which are often more locally beneficial), and also to take into account the cultural functions, the concept of multifunctionality has been developed.

Applying a multifunctional approach involves identifying forest functions and relevant stakeholders, and the relative values they place on forest resources. This is followed by an ongoing process of stakeholder negotiation, involving local communities in decision-making, to develop stakeholder partnerships, agree long-term objectives for forest management and planning in long-term forest management plans, and implement these plans. The process offers considerable potential for reconciling the often conflicting demands being placed on mountain forests and for balancing short-term demands with the longer-term requirements for stable, productive forest ecosystems. At the policy level, the establishment of legitimate institutions, which enable and oversee local forest management, is critical. Developing multifunctional approaches also often involves providing incentives to landowners and forest managers to ensure that they manage forests to deliver public benefits.

From a silvicultural perspective, techniques such as Continuous Cover Forestry (CCF), which have been developed in industrialised countries, offer considerable potential for taking a systems approach to the management of plantation forests. In practice, CCF commonly involves the conversion of mono-specific plantations to less productive, lower-risk systems dominated by native species, with higher structural diversity and higher ecological resilience. In

many regions, regional, landscape-scale, forest habitat networks are being implemented to combat forest fragmentation by taking an ecosystem approach. This process generally involves identifying areas most suitable for expanding core areas of primary forest and for establishing forest habitat corridors to facilitate the movement and migration of forest species.

Three possible pathways to support mountain people and forests

Increasing human capacities

In the mountains of developing countries, the strong challenges deriving from increasing populations, growing demand for land for food and biofuel production and, often, inappropriate governance mechanisms call for case-specific mitigation strategies, which need to be informed by targeted research. This implies a need for adequate research capacities – in the form of scientists and local experts. Yet research capacities in poor economies are weak: for example, research activities on climate change in developing countries are orders of magnitude below those in industrialised countries. Education at all levels has strongly positive effects on economic growth and people's livelihoods. If research is to induce change and improve livelihoods, a change from linear, top-down knowledge generation models is needed. New approaches to research include participatory and bottom-up processes, including social, cultural and institutional dimensions, with mountain people no longer being seen as "...passive beneficiaries of trickle-down development or technology transfer" but as "knowledgeable, active and centrally involved in both the upstream choice and design of technologies, and their downstream delivery and regulation" (Leach and Scoones, 2006). What is therefore needed is strong support for capacity building in developing countries, complemented by funding strategies that foster holistic research and management strategies.

From poverty traps to the basis of livelihoods

High levels of poverty in remote mountain forest areas result from several factors: low income because of inadequate infrastructure and market access; weak tenure; difficulties in generating income



Mata Atlantica, Brazil. Photo: Olivier Chassot

from forests; and the fact that remote places often attract immigrants. Frequently, property rights to agricultural land are stronger than for forests, a situation which often leads to deforestation. A transfer of authority for forest management to a local level is widely acknowledged as an appropriate solution for providing social and economic benefits from natural resources to local people. Hundreds of millions of hectares of forest worldwide have been handed over from governments to communities. Provided that security of tenure for managed forests is strong, community-based management has a strong potential to both provide income and empower mountain people to actively take part in political processes. Frequently, ecological concerns are voiced when rights of management are conferred to local levels. However, a meta-analysis of 69 community forests showed that the majority (58%) of the forests showed “improved forest condition”. Another study showed that, for 80 community forests in 10 countries, decision-making authority at local levels was positively correlated with carbon levels of forests.

There are a number of reasons why communities can be effective managers: they have better knowledge about resources and their uses and users, and they can apply by-laws and sanctions which are embedded in long-established social systems. This calls for further transfer of user rights to local levels, particularly for the more valuable forest resources which often remain under government control.

Payment for ecosystem services: creating upland – lowland partnerships

The sustainable management of mountain forests provides many long-term benefits to downstream populations. The beneficiaries of the ecosystem services provided by these forests – such as hydrological services, carbon sequestration, recreation, tourism

and biodiversity conservation – generally do not pay for these services. Consequently, over the past decade, in an increasing number of countries, governments, international and national NGOs, and private companies have implemented payment for ecosystem services (PES) schemes which offer incentives to farmers or landowners to manage their forests in ways that ensure the long-term flow of specific ecosystem services: most frequently, carbon sequestration, watershed protection, and biodiversity conservation.

Such payment schemes have to address a number of key challenges. These include defining the beneficiaries of the services that specific areas of forest can provide; identifying the land managers and owners, and the management practices that will achieve cost-effective delivery of the services; agreeing on a rate of payment that will foster these practices; and designing processes to monitor compliance. PES schemes have been developed for various land uses and ecosystems; a further challenge in mountain forests is that returns on investments are typically measured in many years or even decades, given the slow growth rates of trees. However, such schemes can also address more suitable grazing practices, or agroforestry, which can achieve faster results. As noted above, another particular challenge in many mountain areas is security of tenure; if PES schemes are to work, those implementing them on the ground need to know that they will continue to derive benefits.

Governing the social and environmental impacts of afforestation in the eastern African highlands



Afforestation has been promoted throughout the global South as socially and environmentally beneficial. Yet it may also have harmful effects. Each tree species and pattern of management has its unique environmental ‘signature’ and set of trade-offs for different system goals and actors.



Stakeholders meeting to negotiate the location of eucalypts on a mission boundary, Lushoto, Tanzania. Photo: Laura German



Tree water interactions affect the hydrology of valley bottoms, where the main cash crops are grown in Lushoto, Tanzania. Photo: Laura German

Participatory watershed diagnosis in the Ethiopian, Tanzanian and Ugandan highlands identified several concerns related to agroforestry: 1) farmers plant trees near farm boundaries to minimize competition with their own crops, but this enhances competition with neighbours' crops; 2) trees grown near springs grow faster, maximizing individual benefits but undermining collective goods (water for domestic use and irrigation); 3) certain tree species bring significant income to farmers, but their leaf litter enhances runoff and losses (e.g., soil, seed, fertilizer) to farmers downhill; 4) ‘thirsty’ trees, planted in valley bottoms, grow rapidly but contribute to the drying of valley bottoms used for cash crops, and reduce downstream flows.

Each species tends to embody either favourable or negative environmental characteristics, and different levels of economic benefit. Ethnoecological research highlighted trade-offs inherent in tree species selection: species generating the most income tend to exhibit negative environmental impacts; those with multiple (but less lucrative) uses tend to exhibit favourable ecological characteristics. Thus, when choosing species, farmers often opt for economic over ecological goals, and individual over collective interests.

Reducing the social and environmental costs of afforestation requires understanding species' compatibility with specific landscape niches from different stakeholders' perspectives, and encouraging farmers to adopt niche-compatible agroforestry practices. Local people may have a deep knowledge of species compatible with ‘problem niches’, yet forestry extension agencies often promote fast-growing species with more significant trade-offs. Farmers' incentives to maximize income pose another challenge to ‘niche-compatible’ agroforestry. Facilitated negotiations among stakeholders with divergent interests, combined with formal by-laws, can help balance divergent interests while enabling creative but enforceable solutions emanating from the grassroots. The challenge is to upscale these innovations without losing the support enabled through localized consensus-building, and to expand these lessons to govern the social and environmental costs of industrial-scale plantations being promoted in the region.

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Proactive management in Muerzer Oberland Nature Park, Styria, Austria



Muerzer Oberland Nature Park has a long tradition of forestry and hunting, and is highly suitable for outdoor recreation and nature-based tourism. The concept of a Nature Park encourages any type of sustainable land use. Since 2009, representatives of forest owners, park management, hunters, forest administration, nature conservation, communities, the regional development board, and experts on natural hazards have jointly developed a management framework, based on European criteria and indicators of sustainable forest management (SFM).



Forest in Muerzer Oberland Nature Park. Photo: Veronika Wirth



Stakeholder discussion of sustainable forest management practice. Photo: Veronika Wirth

With assistance from BOKU - University of Natural Resources and Life Sciences, Vienna, and the Federal Research and Training Centre for Forest, Natural Hazards and Landscapes, indicators were adapted to the local situation. Several new criteria and indicators were designed to reflect adaptation to climate change, deadwood retention for biodiversity, and management for recreation and tourism.

The project showed the value of the adapted SFM framework for evaluating the current situation, and defining integrated management actions. For example, the inventory led to the identification of a remarkable diversity of lichens in mature forest stands, which provide an opportunity for developing new tourism products and educational programmes. Overall, the main advantages of the adapted framework can be summarized as follows:

- Economically: the process clearly recognized the local value of non-timber products. Visitor monitoring identified only a few high-use areas, and forest management can now focus on these to meet visitor preferences and enhance forest aesthetics. Forest stands where private forest owners may be able to obtain funding or subsidies were identified. Discussions about climate change and related management actions will lead to long-term economic advantages.
- Socially: the process reduced barriers between interest groups, enhanced cooperation between forest and park management, and identified challenges when improving visitor facilities.
- Ecologically: a detailed ecological inventory identified prime habitat to be considered in forest management plans. Recognition of ecosystem services increased, including deadwood: an important issue, as its volume could be reduced significantly if whole-tree harvesting is introduced.

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The need for effective management and participatory development in Algeria's mountain forests



At least a quarter of Algeria's population lives in mountain areas, gaining their livelihoods from agriculture, grazing, and forestry. However, degradation processes have affected forests and agro-ecosystems for decades. From 1955 to 2010, the national forest area decreased from 5 to 3 million hectares.



Cereal and Livestock Smallholder Development Project in the Wilaya of Tiaret.
Photo: ©IFAD/Alessandro Rosati



Land reclamation through reforestation near Ain Beida.
Photo: ©FAO/Franco Mattioli

During the preparation of the 2006 national forestry strategy, various key challenges were identified: clearing of forest areas, linked particularly to demographic growth and forestry concessions; fire, which limits reforestation; grazing pressure, with a four-fold increase in animals over the last 30 years; and soil erosion, which endangers about 12 million hectares, mainly due to deforestation, overgrazing and agriculture, and exacerbated by the climate. All these challenges can be linked to the poverty of increasing numbers of mountain people as well as to issues such as management, land conflicts, and limited local participation.

To address these challenges, the forest administration had developed various initiatives. From 1984, programmes to stem soil erosion were undertaken, particularly in order to stop dams from silting up. However, these programmes were often based on inadequate technical studies or inappropriate for the area selected. Development programmes focusing on water and soil conservation were implemented from the early 1980s, but plans for watershed management were only partly applied, mainly for wood harvesting. Reforestation programmes and a national reforestation plan were developed, but the goals do not appear to have been achieved due to inappropriate techniques and species, and problems in project implementation. Finally, while rural development programmes often included the forest sector, they were often ineffective.

New rural policies stress participatory approaches, but technicians and administrators often view these as a formality, and local people are often not involved in projects. However, some small rural development programmes include awareness-raising and are more successful. A new vision of governance is required, which should: firstly, foster participatory processes including key stakeholders; secondly, reinforce policies and plans for forest conservation, reforestation, and soil and water protection; thirdly, ensure that development considers interactions between agriculture and forestry; and fourthly, make sure that institutions function effectively.

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The BOKU Mountain Forestry Masters Program – capacity-building to manage and conserve cultural landscapes in mountain regions



Education has strongly positive effects on economic growth and people's livelihoods. Human capacity is fundamental for mitigating the effects of global change, especially rapidly changing conditions and large uncertainty. Yet industrialized and developing countries differ greatly in terms of research, and research capacity, including research on global change.



Plant identification in Austria. Photo: Klaus Katzensteiner



Fieldwork in Austria.
Photo: Christina Delaney

Recognizing this disparity and the strong leverage of inputs into mountain regions for poverty alleviation, BOKU - University for Natural Resources and Life Sciences, Vienna, started a Masters Program for Mountain Forestry in 2002. Based on a long tradition in sustainable management of Austria's mountain forests and long experience with research on the sustainable use of mountain forests in many regions worldwide, the curriculum aims to provide a specialised education in managing mountain forest resources in an integrated way and with a global perspective. Students learn to manage mountain forests sustainably, recognising and solving problems in forest management and conservation and integrating multiple user interests. Their interdisciplinary and participatory approaches integrate aspects of engineering, socio-economics, natural sciences and other subject-specific fields.

Over 120 students from 23 countries have graduated; most (60%) from Nepal, Ethiopia, and Bhutan. Possible brain drain is a key issue for studies with a focus on developing countries, particularly when the course is in a developed country. Yet more than 90% of the graduates have returned home and work in natural resource management. The exceptions are mostly European or North American students now working in Europe. Over half the graduates work in governmental organizations related to forest management, often in leading positions. A third are studying for a PhD in forestry-related topics; a few work in National Park management or with environmental protection-related NGOs.

The fact that most of the graduates work in the field for which they were trained indicates the lasting impact of the training. The many students studying for a PhD will contribute considerably to research and training capacities in their countries, most of which still have inadequate manpower to tackle the challenges of sustainably managing the cultural landscapes of mountain areas in a changing world.

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Moving towards action

Martin F. Price, Thomas Kohler and Georg Gratzner

Mountain forests are of global importance as sources of water, vital centres of biodiversity, and settings for tourism and recreation. For people living in mountain areas, they provide sources of livelihood and protection from natural hazards. This last function is also vital at a wider scale, along the many transport routes which cross mountain areas. To ensure the long-term provision of all the many functions of mountain forests, the many concerned stakeholders need to jointly design and implement informed policies and actions.

Actions depend on the context

While mountain forests around the world have many common values, their relative importance varies at many scales, depending not only on the particular type of forest but also on the economic, social, and political framework conditions. These vary considerably between mountain areas, particularly between industrialised and developing countries. Most mountain people live in developing countries and, in most of the world, poverty in mountain areas is higher than in lowlands. As poverty increases, so does the dependence of people on forests. For the rural poor, mountain forests function as a safety net by providing products and critical services at times of shortage and scarcity. In rare cases, they may also offer pathways out of poverty by providing high-value products. Both large-scale industrial logging and the establishment of large plantations for agrofuels, in response to growing energy demands, lead to the displacement of land users who are driven into less productive mountain areas. Increases in food prices, partly also caused by competition for land, affect poverty-stricken mountain communities more, and further increase the pressures on mountain forests for the substitution of products and energy. These changes and increased pressures amplify the baseline challenges of increases in demand for food production and increased population growth, often combined with poor governance, frequently reflected in uncertain land tenure rights.

In contrast, mountain areas in industrialised countries are often characterised by: decreasing human populations; the abandonment of agricultural land onto which forests can expand; underexploitation of forests, especially the less accessible; and increasing emphasis on ecosystem services, such as reliable water supplies, biodiversity, and landscapes for recreation and tourism. Given these significant contrasts, the appropriate responses often diverge; though all need to consider the importance of planning for uncertainty in a rapidly changing world.

Four guiding principles for action

To address these challenges, four guiding principles can be proposed for the protection and sustainable use of mountain forests:

- Measures to protect mountain forests need to be based on enhanced coordination at international and national levels, consider local specificities, and integrate forest issues into broader policies and programmes;
- International policies, e.g., policies on mitigating climate change and managing biodiversity, need to be evaluated in terms of their relevance to mountain forests and their consequences for livelihoods for mountain people;
- Local people are central actors in forest resource use; their needs must be considered in shaping policies and implementing activities which aim at the sustainable use of mountain forests;
- Approaches to sustainably manage and use mountain forests and, where necessary, protect them, must include many perspectives – far wider than the sectoral perspective of professional forestry.

These principles require actions at different levels, and by different groups of stakeholders, as presented below.

Action at the local level

Measures designed to manage mountain forests sustainably will fail unless they meet the needs of local people. However, local communities are not uniform; they differ widely in their economic, social and cultural characteristics, and hence in their influence and power to use local resources. Local communities therefore need to be encouraged to seek equity in the use of mountain forests and the many resources they provide: not only wood, but also many non-timber forest products and opportunities for recreation and tourism. Considering that many mountain forests are comprised of slow-growing trees, these forests should be managed with a longer-term view; it is rarely beneficial for local communities to accept short-term profits based on exploitative schemes offered

by outside agents or firms. A long-term view is also important when considering the possible impacts of climate change on mountain forests. Local communities must also be encouraged to revitalise or establish local institutions with the authority to enforce regulations for the sustainable and equitable use of their forests, and to mitigate local conflicts that might arise regarding their use. They should also be given user rights over high-value products and high-value forests.

Action at the national level

National policies that are either specific to mountain forests or address other sectors relevant to these forests – such as rural land use and development, energy supplies, climate change, water management, or biodiversity conservation – should adopt a long-term view within an overall framework of the sustainable use of natural resources. Such policies should consider the site-specific characteristics of mountain forests and the needs of local mountain communities with regard to mountain forest use. Typically, mountain forests provide a wide range of goods and services for mountain communities as well as many other users, such as industry, tourism, transportation, and urban populations. Highland-lowland interests as well as rural-urban needs must be carefully balanced. Multifunctionality – with a focus on the ecosystem services provided by mountain forests – can be a useful concept to achieve this aim.

A key need is for the political will to implement policies and legislation according to the principles of subsidiarity and decentralisation. Fostering local stewardship and accountability for the management of mountain forests on the basis of secure land tenure and local user rights is an important element of these principles. Alternative sources of energy such as solar power and hydropower, as well as more efficient ways to use energy, especially for cooking and heating, can reduce demands for fuelwood; ways must be found to support such alternatives. In the context of rural development, appropriate government policies can help provide an enabling environment for potential investors willing to create employment opportunities in the processing, industrial and service sectors. This is important in reducing pressure on natural resources, including mountain forests.

Where protective rather than productive uses need to be prioritised for reasons of national or international interest – such as protection of watersheds or conservation of biodiversity – governments should develop and implement equitable approaches to provide incentives to farmers or landowners to manage their forests. This is to ensure that the benefits accrue to the stakeholders who have to limit or change their uses of the forests, to compensate them for loss of opportunities of use and for managing forests for the benefit of the society at large.

Particularly in times of economic crisis, national funding for research and monitoring is reduced drastically; long-term monitoring programmes are often abandoned. Such actions endanger the provision of crucial information to enable informed policy-making. Mountain forests in particular, because of their ecological and social complexity, require intensive, interdisciplinary research and monitoring with adequate funding.

Action at the international level

Numerous international initiatives, research centres and programmes exist within the forest sector, such as the International Union of Forest Research Organizations (IUFRO) and its Special Program for Developing Countries (IUFRO-SPDC), the Centre for

International Forestry Research (CIFOR), the World Agroforestry Centre (ICRAF) and the United Nations Forum on Forests (UNFF). These initiatives and programmes need to be coordinated and to take account of mountain forests and the interests of the stakeholders who depend on them. In any effort on behalf of mountain forests, it is important to consider issues addressed in not only the mountain chapter (13) and the forest chapter (11) but also other chapters of 'Agenda 21' and the final documents of the World Summit on Sustainable Development in 2002, as many of these are indirectly concerned with mountain forests and other resources. These include international efforts to reduce debt and to expand market access for developing countries, implementation of international conventions – such as those on climate change and biodiversity – and financial mechanisms such as the Global Environment Facility (GEF) and the United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries (REDD). Regional cooperation and networking with regard to the sustainable use of mountain forest resources should be encouraged, including, for example, policies regarding timber extraction (concessions), watershed management, and other transboundary issues such as biodiversity conservation and air pollution.

Action by civil society and NGOs

Civil society and NGOs from both mountain and lowland areas can play important roles in creating awareness, lobbying governments and key commercial users – such as the timber and tourism industries – in genuine cooperation with all concerned stakeholders. On the ground in mountain areas, they can demonstrate their commitment and effectiveness in designing, implementing, and providing support for locally appropriate, innovative ways to manage and use mountain forests to provide a variety of compatible outcomes. They can help to foster cooperative institutions of local users and provide support for minorities and for women, who depend most on forest resources in many mountain regions, but lack the support they need to express and safeguard their own interests. Where security of tenure or use of forest resources is weak, NGOs can play key roles in supporting local communities to strengthen the rights of local communities. Civil society and NGOs can also help increase political acceptance of sustainable resource use at regional, national and international levels.

Action by the timber industry and other commercial users

The timber industry and other commercial users, such as water and tourism companies, have key roles to play in developing approaches for sustainable forest management. Such approaches should be based on the principles of multifunctionality and of compensating local communities for their stewardship, and also consider long-term trends, such as climate change. Recognising that basic economic principles and shareholder value will remain important aspects of logging and other commercial operations, the timber industry should give higher priority to the accreditation of sustainable forest management and do more to support product labels. To achieve long-term sustainability, the various industries benefiting from mountain forests have a responsibility to help forge active partnerships with other stakeholders, especially mountain communities. These industries should be invited to consider innovative ways to finance complementary efforts that avoid or mitigate adverse environmental and social impacts that result from their activities, to develop an internationally binding code of conduct for the sustainable use of mountain forests, and to train their staff to make their operations more sustainable.

Action by the scientific and research communities

There is need to gain better understanding of mountain forests. First of all, this applies to forest ecology and silviculture. The main characteristics and functions of many plant and animal species in mountain forest ecosystems are still largely unknown, especially in tropical mountains. Likewise, understanding of the impacts of environmental stress, including air pollution and the effects of climate change, require long-term research and monitoring. Second, research should be targeted on the economic and socio-cultural aspects of the management and use of forest resources, including economic and societal valuation of mountain forests and the services they provide, and analysis of the effects of different land use systems on watersheds. Third, greater understanding is needed of the many locally developed land-use systems, especially those linking agriculture with forest resources (e.g., shifting cultivation, agroforestry). These systems provide valuable experience both in the local context and further afield. Fourth, in an era of increasing uncertainty, research is needed to understand which existing approaches and institutions can be utilised to provide resilience, and where new approaches and institutions are needed.

In the process of developing alternatives for the sustainable use of mountain forests, scientists should join forces with important stakeholder groups such as local experts and users, the timber and other industries, and forest authorities. Scientists must use their knowledge to educate and train forestry staff and practitioners about the many functions of mountain forests and the diverse groups that depend on them. They must become partners in collaborative research and learning processes, rather than continuing with extractive “science-push” research approaches. Finally, they must communicate their key findings more effectively to policy-makers, donors, and the general public – especially young people – in order to ensure informed decision-making and public support for the sustainable use of mountain forests.

From 2011 to 2012 and beyond

This report is a contribution to the International Year of Forests, 2011, whose aim is “to raise awareness and strengthen the sustainable management, conservation, and sustainable development of all types of forests for the benefit of current and future generations”. The report also looks forward to the ‘Rio + 20’ United Nations Conference on Sustainable Development in 2012. The two themes of the Conference are a green economy in the context of sustainable development and poverty eradication; and the institutional framework for sustainable development. As this report makes clear, mountain forests contribute to these two themes in many ways; yet there are still many challenges ahead in order to ensure that these forests are managed sustainably for the benefit of present and future generations of both hundreds of millions of mountain people and billions of other people around the world who depend on these key resources.





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Introductory text: Robert Mc Morran, Martin F. Price (UHI)

2. Sources of fresh water

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Moving towards action

Martin F. Price (UHI), Thomas Kohler (Centre for Development and Environment, University of Berne, Switzerland), Georg Gratzer (Institute of Forest Ecology, Department of Forest and Soil Sciences, BOKU) - with reference to: Price MF, Kohler T, Wachs T (eds.) (2000) Mountains of the World: Mountain Forests and Sustainable Development. Mountain Agenda, Centre for Development and Environment (CDE), Institute of Geography, University of Berne, Switzerland.



A quarter of world's forests are in mountain areas. These forests typically have high biodiversity, and provide many goods and services for people both in the mountains and the lowlands, often far away. Mountain forests are important as sources of wood, as well as other products such as medical herbs. When managed well, they are also vital for ensuring reliable supplies of high-quality water and for protection against natural hazards such as avalanches, landslides and floods. They are also the setting for tourism and many recreational activities. This publication, a contribution to the International Year of Forests, presents the many values of mountain forests, outlines current challenges for their management, and proposes recommendations for their sustainable management.

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