

Mountains of the World – Ecosystem Services in a Time of Global and Climate Change

Seizing Opportunities – Meeting Challenges





Thangthangka, Bhutan

Mountains of the World – Ecosystem Services in a Time of Global and Climate Change

Seizing Opportunities – Meeting Challenges

Framework paper prepared for the Mountain Initiative of the Government of Nepal
by ICIMOD and the Government of Nepal, Ministry of Environment
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Message from the Minister



Minister for Environment

Government of Nepal

Ministry of Environment
Singhdurbar
Kathmandu, Nepal

Message

This publication on **Mountains of the World – Their Resources in a Time of Global and Climate Change: Seizing Opportunities – Meeting Challenges** provides background information and a framework for discussing mountain issues in the context of the current climate change dialogue. It synthesizes the state of current knowledge and provides an overview of the evolution and status of the global Mountain Agenda from the time it was agreed upon during the Rio Earth Summit in 1992 to the United Nations Framework Convention on Climate Change (UNFCCC) processes. It also critically assesses the past and current global commitments on sustainable mountain development and helps provide a new direction and framework to push the Mountain Agenda forward in the context of global climate and other changes. I consider that it provides a good setting for enhanced cooperation among Mountain countries in dealing with climate change.

The Ministry of Environment of the Government of Nepal, in collaboration with its development partners, is hosting an International Ministerial Conference of Mountain Countries on Climate Change as an initial step for the Mountain Initiative. The Conference is expected to provide a platform to address the concerns and interests of Mountain countries, identify upstream-downstream linkages, and explore sustainable mountain development opportunities to adapt to and benefit from the climate change negotiation process and other initiatives. The Mountain Initiative steered by the Ministry of Environment, Government of Nepal, with the technical backstopping of the International Centre for Integrated Mountain Development (ICIMOD), will help to address the issues, concerns and impacts of climate change on mountains across the globe – the source of water and livelihood resources for billions of people.

The paper will be discussed at the International Expert Consultation organized jointly by the Ministry of Environment and ICIMOD to facilitate and provide support to the International Ministerial Conference of Mountain Countries on Climate Change. The paper is intended to serve as a framework and basis for the concerned stakeholders, civil society organizations, researchers, development partners, policy and decision makers, and international agencies working on issues related to climate change in mountain regions. The paper will also be useful in other international debates including the upcoming Rio +20 dialogue. I hope it will provide a good reference to build up regional and global collaboration and co-operation on the sustainable management of mountain ecosystem services.

On behalf of the Government of Nepal, I would like to thank the author, reviewers and others who have contributed to bringing this paper into its present form. Finally, I commend the technical support of ICIMOD in highlighting the need to promote the Mountain Agenda more succinctly.

8 September 2010
Kathmandu

T. P. Sharma
Thakur Prasad Sharma

Foreword

The potential impacts of climate change are becoming increasingly evident in mountain environments. Not only are mountain regions with their fragile ecosystems particularly vulnerable to anthropogenic emissions of greenhouse gases; there are indications that changes in temperature and other factors are taking place at a greater pace at higher altitudes than in the lowlands. Mountain social, economic and ecological systems are being affected, including the water and other resources on which billions of people in mountains and areas downstream depend. Although mountain people have contributed very little to global greenhouse gas emissions, they are the first among the vulnerable communities bearing the brunt of the impacts. Mountain areas cover about a quarter of the Earth's land; they provide essential ecosystem services and are water towers for billions of people living in downstream slopes, valleys, and plains. Although Agenda 21 and the UN Framework Convention on Climate Change (UNFCCC), adopted in 1992, provide a basis for addressing a multitude of issues and promoting sustainable mountain development, the mountain agenda has not yet been addressed adequately by the UNFCCC climate deliberations and associated processes to reflect the need to improve and maintain mountain ecosystem services, and the livelihoods that depend on them.

Recognising the urgent need for action, the Prime Minister of Nepal called on the mountain countries and stakeholders during the 15th session of the Conference of the Parties (COP 15) to UNFCCC in Copenhagen to come together to form a common platform and ensure that mountain concerns get due attention in the climate change deliberations. The positive actions from the global community must address the vulnerable status of mountain ecosystems and afford protection to the lives and livelihoods of mountain people. To reach this goal, the Government of Nepal proposed to initiate a 'Mountain Alliance Initiative (MAI) for Climate Change Adaptation in Mountainous Regions'. The Initiative provides a framework within which mountain countries, in collaboration with specialised global and regional mountain agencies, can work for greater recognition of the fragility of mountain systems in view of global climate change, advocate based on state-of-the-art knowledge, and support mountain people more effectively in their struggle to adapt to the new challenges, while at the same time enabling them to benefit from emerging opportunities.

The Government of Nepal is moving this agenda forward with the technical and backstopping support of the International Centre for Integrated Mountain Development (ICIMOD), which is providing advice and research-based knowledge based on its long experience of working on sustainable mountain development agenda in the Hindu Kush Himalayan region over the last 26 years.

The present paper has been prepared jointly by ICIMOD and the Government of Nepal to serve as a rationale and framework for the Mountain Initiative. It describes the context in which the Initiative is being set, elaborates the specific vulnerability contexts and situation of mountain people and their social-ecological systems, highlights the importance of mountain ecosystem goods and services for mountain people as well as downstream communities, and also explores the opportunities that are created by climate change. In order to achieve the goal of sustainable mountain development, the paper calls for all to develop a common vision and strong voice to advocate the case for mountain people and ecosystems. For this, improved networking among all mountainous states and key stakeholders will be necessary.

We believe that the paper will be a valuable source of information to support efforts to contribute to and advocate for regional and global approaches to address the critical challenges posed by climate and global change in the mountains.



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Shyok river, Khapalu valley, Pakistan

1 Introduction and Rationale

Mountain areas cover 24% of the world's land surface (UNEP-WCMC 2002) and are home to 12% of the global human population (Huddleston and Ataman 2003), with a further 14% living in their immediate vicinity (Meybeck et al. 2001). All of the world's major rivers originate in mountains and more than half of the world's mountain areas play a vital role in supplying water to downstream regions (Viviroli et al. 2007). Mountain areas are repositories of biological and cultural diversity and provide vital services with a tangible economic value – such as water, power, tourism, minerals, medicinal plants, and fibres – to mountain communities and, even more important, to often heavily populated downstream areas. Mountains also influence the climates of their surrounding regions and serve as important carbon sinks.

However, mountain environments are highly fragile, and people living in mountain areas are exposed to a system of environmental and non-environmental stressors which are interlinked and have serious repercussions on mountain people's livelihoods. These stressors include processes of socioeconomic development and growing populations, which linked to increasing demand and globalisation increase the pressure on water, land, and other natural resources and services. In this context, climate change acts as an additional stressor which can multiply existing development deficits and reverse progress in mountain areas (UNDP 2010) and may limit mountain people's inherent capacity to cope and adapt. Mountain people, who have contributed the least to global greenhouse gas (GHG) emissions, are expected to be among those who will be the worst affected by adverse impacts of climate change. In order to achieve equitable development, the international community needs to support policies that compensate mountain communities for the value of the ecosystem services provided by mountain systems, and that help them benefit from emerging opportunities. A special effort is needed to raise awareness of the fragility of mountain social-ecological systems in view of global climate change, and to lobby more effectively, particularly in the context of the United Nations Framework Convention on Climate Change (UNFCCC) and associated processes, for the main causers of climate change to support the people of mountain areas. In this context, greater access to funding mechanisms for climate change adaptation is required, geared particularly towards the needs of fragile mountain social-ecological systems. Mountainous countries in the developed world can serve as important resource centres providing knowledge, technology, and expertise to mountain areas in developing countries.



This paper describes the high vulnerability of mountain social-ecological systems, elaborates the importance of mountain ecosystem goods and services for mountain people and downstream communities, and explores the opportunities that are also created by climate change, especially for mountain economic development. The paper concludes with recommendations on the urgent need for global collaboration and lobbying in order to achieve resilient mountain social-ecological systems.

2 From Rio to Copenhagen

The Rio Earth Summit Set the Stage for the Mountain Agenda

With the inclusion of Chapter 13 – ‘Managing Fragile Ecosystems: Sustainable Mountain Development’ – into Agenda 21 in 1992 at the United Nations Conference on Environment and Development (UNCED), or ‘Earth Summit’, in Rio de Janeiro, the importance of mountain social-ecological systems was acknowledged for the first time on a global scale. Chapter 13 of Agenda 21 focuses on two programme areas: a) generating and strengthening knowledge about the ecology and sustainable development of mountain ecosystems; and b) promoting integrated watershed development and livelihood opportunities. The Food and Agriculture Organization (FAO) of the UN was given the role of Task Manager for Chapter 13 with a mandate to facilitate and report on the implementation of these two programme areas. In 1994, FAO convened a task force including NGOs (non-government organisations), development organisations, and UN agencies to coordinate the implementation of Chapter 13. During the decade following the Earth Summit, many specific initiatives by governments, international institutions, NGOs and scientific organisations emerged from Chapter 13. One important initiative was the establishment of the Mountain Forum in 1995: a global network for information exchange, mutual support, and advocacy towards equitable and ecologically sustainable mountain development and conservation. Yet, over the years, it became more and more apparent that Chapter 13 – although being a good starting point – did not adequately address many key issues related to sustainable mountain development, including water resources; biological diversity; cultural diversity and heritage; adequate infrastructure development for mountain people (access to health services, markets, and so on); appropriate recognition and valuation of services and benefits deriving from mountains; the importance of mountains for people’s livelihoods; and the recreational and spiritual significance of mountains (Sonesson and Messerli 2002).

In 1998, the United Nations General Assembly designated 2002 as the International Year of Mountains (IYM) through a resolution which was supported by 130 States. It also agreed to the request made by the Kyrgyz Republic to host a ‘Bishkek Global Mountain Summit’ in the same year. The International Year of Mountains was an excellent occasion to raise awareness about the importance of mountains to life at a global scale, and to promote action. With the Year, the Mountain Agenda gained new momentum and many new initiatives materialised, including the Adelboden Group out of which the SARD-M (Sustainable Agriculture and Rural Development in Mountains) project emerged, GLOCHAMORE (Global Change in Mountain Regions), and the Mountain Research Initiative (MRI). Also in 2002, the Mountain Partnership was launched at the World Summit on Sustainable Development in Johannesburg to promote and facilitate closer collaboration between governments, civil society, intergovernment organisations, and the private sector toward achieving sustainable mountain development.

Key Achievements and Limitations Following the Rio Earth Summit

The institutions, research and development projects, conferences, workshops, and others which developed from Chapter 13 and the International Year of Mountains effectively raised awareness of the importance of mountain systems, and some of them initiated or supported successful interventions promoting sustainable mountain development. Nevertheless, despite all these vital initiatives and the UN General Assembly regularly restating the importance of mountain areas, mountain systems have never received the expected attention in the international development agenda. Other priorities tended to dominate the sustainable development agenda such as the Millennium Development Goals (MDGs) and the Poverty Reduction Strategy Papers (PRSP), which were largely implemented as national schemes, not considering specific eco-regions such as mountains.

Today, with global climate change and the expected impacts on mountain people and ecosystems, as well as on the goods and services they provide to more than half of mankind, mountains are gaining a new importance from



Kibber village, Spiti, India

national, regional, and global perspectives. However, the concrete measures and policy proposals proposed in the frame of United Nations Framework Convention on Climate Change (UNFCCC) still lack a mountain perspective, largely because of substantial knowledge gaps from the scientific point of view and an uncoordinated approach by the countries that are most affected by climate change in their mountains.

What is New Since the Rio Earth Summit?

In Chapter 13, mountain systems across the world were treated uniformly; no distinction was made regarding their socio-cultural and economic roles, which vary significantly from one region to another. In mountains in tropical and subtropical zones – in contrast to most mountains in the developed world – populations are generally growing and mountain systems remain centres of livelihoods for hundreds of millions of people (Nogues-Bravo et al. 2006). Climate change in general, and related changes in precipitation patterns and the frequency of extreme events in particular, are expected to directly affect crop yields and livestock and have immediate repercussions on the livelihoods of mountain people. Hence, climate change places mountain systems in developing countries and their growing socioeconomic vulnerability at the centre of attention. In addition, growing demands for water and hydroenergy and other ecosystem services deriving from mountains have led to recognition of the need for more integrated visions addressing upstream-downstream interdependencies, as well as integrated basin-wide management approaches. In addition, the urgency of adaptation to climate change has redefined the globalising development agenda in terms of calling for eco-region specific development agendas. Finally, mountain systems have suddenly gained global attention because of receding glaciers and growing glacial lakes, which create new vulnerabilities and are, at the same time, the most spectacular indicators of climate change. Creating a more solid knowledge base on the under-researched cryosphere of developing countries will not only serve mountain systems and their people; it will also create highly relevant indicators to assess the efficiency of global greenhouse gas emission reduction measures.



Makalu, Nepal

3 Mountain Systems and Climate Change

Increasing Vulnerabilities

It is widely recognised that mountain regions include many of the world's most sensitive ecosystems. They are particularly vulnerable as a result of their high relief, steep slopes, shallow soils, adverse climatic conditions, and geological variability (Sonesson and Messerli 2002). Mountain ecosystems and people are subject to a variety of drivers of change including globalisation; economic policies; and increasing pressure on land and mountain resources due to economic growth and changes in population and lifestyle. Global climate change acts as an additional stressor which is expected to exacerbate the impacts of other drivers of change. Although we acknowledge the importance of these other drivers, and that their impacts on mountain social-ecological systems may currently be even more severe than those from climate change, it would go beyond the scope of this paper to analyse them in detail. In this context, we recognise further that the exact impacts of climate change on mountain systems, and the interlinkages with other drivers of change, are not yet well understood, and that there are large knowledge gaps which need to be addressed.

Regardless of the high degree of uncertainty, it is clear that the biophysical fragility of mountain ecosystems has direct consequences for the socioeconomic vulnerability of mountain people, estimated at 720 million or 12% of the world's total population. Nearly 90% of the mountain population – 663 million people – live in developing or transition countries (Huddleston and Ataman 2003); of these, half live in the Asia-Pacific region and one-third in China. Although 30% of all mountain people are urban, the vast majority live in rural settings (Hassan et al. 2005)¹. Mountain areas are ethno-culturally very diverse, with a high diversity of languages and culture. The proportion of indigenous peoples is also high. These people often guard a vast body of traditional ecological knowledge on how to sustainably manage the land in a challenging mountain environment. Their traditional land management practices (e.g., trenching, terracing, and irrigation systems) are still crucial today for low-intensity production systems at high altitudes (UNEP-WCMC 2002).

Fragility and vulnerability to climate and other drivers of change, along with growing scarcity of freshwater and energy as a basis for economic growth, have created not only new challenges but also new opportunities and possibilities for mountain regions and mountain people. Examples for emerging opportunities include a growing demand for high-value mountain niche products, including tourism, in the lowlands; hydropower generation for local and possibly also regional use; payments for ecosystem services; and potential for carbon sequestration to name just a few.

Biophysical Fragility

Temperature

Mountain regions have experienced above-average warming in the 20th Century (IPCC 2007a,b), which has significant implications for mountain environments and environmental processes. In the Himalayas, for example, progressive warming at higher altitudes has been three times greater than the global average (Eriksson et al. 2009; Xu et al. 2009). Predictions for the 21st Century indicate that temperatures will continue to increase disproportionately in mountain areas. The greatest temperature rise under the four IPCC Special Reports on Emissions

¹ These numbers have been estimated using the UNEP-WCMC definition of mountains which categorises mountains into six classes, including areas starting from 300 m above sea level that exhibit steep slopes and have a wide range of elevation in a small area. All areas above 2,500 m are considered as mountains.

Scenarios (SRES) is expected in high- and medium-latitude mountains, including the high-latitude mountains of Asia, North America, and Europe and mid-latitude mountains of Asia. The high-latitude mountains of Asia are expected to experience the greatest changes in temperature, whereas tropical and mid-latitude mountains in Africa and South America are expected to warm less (Nogues-Bravo et al. 2006). The average warming projected in mountain areas across the globe by 2055 ranges from 2.1°C to 3.2°C, depending on the emissions scenario (Nogues-Bravo et al. 2006). This is two to three times greater than recorded during the 20th Century (Pepin and Seidl 2005).

Cryosphere

The most noticeable impact of climate change in mountains is the recession of glaciers. According to a recent publication by United Nations Environment Programme (UNEP) and the World Glacier Monitoring Service (WGMS): “The ongoing trend of global and rapid, if not accelerating, glacier shrinkage on the century timescale is of non-periodic nature and may lead to the deglaciation of large parts of many mountain ranges in the coming decades” (UNEP WGMS 2008). In the European Alps, for example, the Alpine glacier cover is estimated to have diminished by about 35% between 1850 and the 1970s, and by a further 22% by 2000 (UNEP WGMS 2008). In the Canadian Rockies, glaciers lost at least 25% of their volume during the 20th Century (Luckman and Kavanagh 2000). In the Himalayas, glaciers appear to have receded relatively faster than the global average (Dyurgerov and Meier 2005). The rate of retreat for the Gangotri Glacier over the last three decades has been more than three times the rate during the preceding 200 years (Srivastava 2003). Most glaciers studied in Nepal are also undergoing rapid deglaciation (Seko et al. 1998; Kadota et al. 2000; Fujita et al. 2001; and others). In the last half century, 82.2% of the glaciers in western China have retreated (Liu et al. 2006; Kang et al. 2010). On the Tibetan Plateau, the glacial area has decreased by 4.5% over the last twenty years and by 7% over the last forty years (CNCCC 2007). One exception is the Karakorum, where some high altitude glaciers have been found to be advancing (Hewitt 2005). In South America, the Northern Patagonian Ice Field lost about 3.4% or 140 km² of its area between 1942 and 2001 and in Africa, 85% of the total ice volume of the plateau glaciers of Mount Kilimanjaro disappeared between 1912 and 2000 (Thompson et al. 2009). Other consistent trends are that the degradation of permafrost is accelerating, with the active layer becoming thicker due to surface warming, and that most snow and ice caps across the world are shrinking at increased rates. These alterations in the cryosphere are already leading to changes in land surface characteristics and drainage systems and are very likely to have significant repercussions on water availability for mountain and downstream communities (Stern et al. 2006).

Hydrology

With global warming, it is likely that the hydrological cycle in mountain areas will intensify, changing the frequency and intensity of floods and droughts (Beniston 2005). The discharge regime may also change as a result of the expected shifts in the species composition of mountain ecosystems. Moreover, with continuing melting of glaciers and snow and ice cover, the supply of water to vast landmasses and billions of people may no longer be guaranteed, leading to severe water stress and potential conflicts. In Asia, for example, changes in perennial snow and glacial melt induced by climate change could affect half a billion people in the Himalayan region and a quarter of a billion people in China, who all depend to some extent on meltwater from the mountains for their water supply (Stern et al. 2006). Nevertheless, it should be recognised that as a result of the interlinkages between the climatic and non-climatic drivers influencing the world’s freshwater resources, as well as the high uncertainty regarding changes in precipitation patterns and other parameters influencing the hydrological cycle in mountains, it is extremely difficult to predict what changes will occur.

Biodiversity

As a result of the steep terrain, the compression of climatic zones, and landscape fragmentation, mountain ecosystems are characterised by a high biological richness in terms of both species diversity and endemism (IPCC 2007a,b; Körner 2009). Mountain systems support about half of the world’s biological diversity and nearly half of

the world's biodiversity hotspots (Hassan et al. 2005). Of the world's total acreage of land-based protected areas, some 27.6% is situated in mountains (Kollmair et al. 2005). However, mountain species are very sensitive to climate warming because they are adapted to specific altitudinal zones and microclimatic conditions (Hassan et al. 2005, IPCC 2007a,b). With rising temperatures, upward shifts of vegetation belts to higher elevations and northward advances in the geographical ranges of species in the northern hemisphere are expected. Changes in the species composition of communities are also likely (Nogues-Bravo et al. 2006). These processes should not only be regarded as negative, however, they may also bring new opportunities. Because temperatures decrease with altitude, mountain species are in the privileged position of being able to migrate upwards into cooler areas, whereas lowland species usually have no other option than to adapt to higher temperatures which is much more difficult (Körner 2009). Thus, mountains can serve as refuges for species which can no longer be grown in the lowlands and which need to climb to cooler areas (Singh et al. 2010). However, some mountain species are likely to become losers. These include large territorial animals, late successional plant species, species with small, restricted populations, and species confined to summits (Körner 2009).

Extreme events and natural hazards

Mountains are typically exposed to multiple hazards (Kohler and Maselli 2009). With climate change, it has been predicted that the frequency and magnitude of extreme events, including floods, windstorms, and droughts, will increase (IPCC 2007a,b). This is expected to have significant implications for fragile mountain ecosystems as well as for mountain livelihoods and infrastructure. For example, it is expected that the intensity of precipitation events will increase, especially in the tropics and at higher latitudes where an increase in overall precipitation is expected. More intensive precipitation events could trigger flash floods and landslides in mountainous terrain. Conversely, it has also been predicted that the risk of droughts in most subtropical and mid-latitude regions will be greater in the future. What is more, continuing glacier recession increases the danger of glacial lake outburst floods (GLOFs). In the Hindu Kush-Himalayan region, there are about 204 critical glacial lakes that have a potential for breaching (Ives et al. 2010).





Kulekhani, Nepal

Socioeconomic Vulnerability

Determining factors of socioeconomic vulnerability to climate and other drivers of change

Mountain people and their livelihoods are particularly vulnerable to climate and other drivers of change (UNEP-WCMC 2002). The underlying causes of vulnerability include disproportionate poverty rates, high prevalence of food insecurity and poor health, high dependency on natural resources, marginalisation, and limited livelihood diversity. These factors, which are described in more detail below, are the driving forces of mountain people's vulnerability, and are expected to be further aggravated by climate change.

Climate change and economic development

Experts believe that the impacts of climate change on economic development will be unevenly distributed around the globe (Sanderson and Islam 2009). The relationship between climate change and economic development depends on a particular region or country's extent of vulnerability to the impacts of climate change, as well as the opportunities the factors of change provide for policy actions towards alleviating climate change vulnerability, particularly through adaptation measures. Mountains, in general, are considered highly vulnerable, and knowledge about the impacts of climate change on economic development is lacking. However, to sustain and enable current economic development in the mountains, it will be crucial to address the issue of climate change and its relationship with economic development through adaptation measures. Climate change is threatening sustainable development, especially poverty alleviation, in the mountains since a single extreme event such as a flood can wipe out major livelihood resources such as standing crops, stored food and seeds, and fertile land. The mountain poor will face more serious impacts in future due to the likelihood of more and more frequent occurrences of extreme events, and their economic development prospects are increasingly facing risks.

Poverty and marginalisation

In the developing world, mountain communities generally tend to suffer disproportionately from poverty and lower levels of development than those in lowland areas. The prevalence of poor and vulnerable people increases with elevation (Hassan et al. 2005, Huddleston and Ataman 2003). A recent study in Nepal has shown that poverty inequality between mountain communities and those living in other areas is currently increasing (ICIMOD 2010). Globalisation tends to further reinforce differences between highlands and lowlands (Royal Swedish Academy of Sciences 2002). Mountain poverty has to be understood in the light of several mountain-specific constraints which intensify the prevalence of poverty. These include fragility of ecosystems; remoteness; poor accessibility and marginalisation of mountain communities from the mainstream; lack of equity in terms of access to basic facilities such as health care, education, and physical infrastructure, as well as to markets, political power, and representation; lack of employment opportunities; and proneness to natural disasters (Jodha 1992; ICIMOD 2010). In this context, climate change acts as another stressor which may limit the capacity of mountain communities to cope or adapt to new and often more stringent environmental conditions. Climate change may thus further increase existing inequalities between highland and lowland communities.

Nutrition and health

Mountain people are highly susceptible to food insecurity. Around 40% of mountain people living in developing and transition countries have been estimated to be vulnerable to food insecurity; of these, about half are likely to be chronically hungry² (Huddleston and Ataman 2003). Malnutrition is also prevalent among mountain people, who often lack a balanced diet providing sufficient micronutrients. Furthermore, respiratory infections exacerbated by harsh climate and exposure to smoke from heating and cooking are common among mountain people (Huddleston and Ataman 2003). Maternal and infant mortality rates are also above average for mountain populations due to limited access to

² For these estimates, two indicators have been used to measure vulnerability: one looking at the proportion of people living in areas where cereal production does not exceed 200 kg per person, and one focusing on low to medium bovine density.

primary health-care and sanitation facilities, as well as food deficiencies (FAO 2008). Food insecurity could grow more acute with climate change, and the health status of mountain people – especially those with low adaptive capacity such as the elderly, children, pregnant women, and the chronically sick – may worsen. Crop failure as a result of water shortages and more frequent natural disasters, and the spread of crop and livestock pests and vector-borne diseases to higher altitudes with rising temperatures may further challenge the wellbeing of mountain communities.

Natural resource dependency

Overall, 78% of the land surface in the world's mountain areas has been classified by the FAO as not suitable or only marginally suitable for agriculture. Nevertheless, the vast majority of rural mountain people engage in some form of agricultural activity and are thus highly dependent on natural resources (Huddleston and Ataman 2003). Intensive mixed farming systems are the most common form of agriculture at lower altitudes in the highlands. However, due to environmental constraints such as unfavourable climatic conditions, poor-quality or shallow soils, and sloping terrain, productivity is generally low and harvest output is not competitive in the global market (Huddleston and Ataman 2003). At higher altitudes, where mountain environments are harsh and suitability for agriculture is restricted, pastoralism is the most common livelihood strategy. Pastoral systems, however, are becoming increasingly vulnerable due to population growth and the resulting increasing pressures on the land, the impacts of more frequent and severe droughts, and the breakdown of traditional trade routes and patterns of exchange (Huddleston and Ataman 2003). Climate change may further reduce the competitiveness of agriculture-based mountain livelihood systems, although it may also provide new opportunities such as longer growing seasons for certain crops or the possibility of growing crops at higher altitudes. This, however, may again result in increased pressure on already stressed fragile landscapes.

Changing livelihood options

The livelihood options of mountain communities besides agriculture are often restricted, mainly due to the poor accessibility of the areas in which they live. However, there are new opportunities emerging which may gain in importance as alternative livelihood strategies in the future.

Tourism is a major livelihood strategy in mountain areas in both the developed and the developing world. Especially in the developing world, tourism is a major source of foreign exchange and is one of the few factors that stabilises mountain populations and deters people from migrating. Like agriculture, the tourism industry is highly sensitive to changes in environmental conditions. It depends on pristine landscapes, high biological diversity, and well-managed protected areas, which serve as important tourist destinations, and, in the case of winter tourism, on reliable snow cover. Temperature rises as a result of climate change, and the increase of extreme events, already challenge the tourism industry in developing and developed countries. Over the past years, winter resorts in the developed world have made heavy investments into adapting to higher temperatures, and it is expected that in the future particularly those situated at lower altitudes will no longer be competitive (IPCC 2007a,b). On the other hand, with rising temperatures, cool mountain resorts in the subtropics and tropics may increase in popularity and provide important new livelihood options as summer destinations for people who wish to escape the heat in the lowlands.

Out-migration, especially of young household members, has also become a vital livelihood strategy which reduces the dependence of mountain communities on natural resources. Migration provides important connections between upland and lowland areas, and financial as well as social remittances are becoming increasingly important for the development of mountain areas (Hoermann and Kollmair 2009). However, migration can place significant burdens on those left behind, especially women, children, and the elderly (Hoermann et al. 2010). With increasing environmental stress, the number of migrants may increase. Yet there is great uncertainty regarding the numbers of expected environmental migrants both from and to mountain regions (Guzman et al. 2010). The current phenomenon of migration of upland populations to lowland plains and urban centres is a manifestation of the existence of unequal economic opportunities and access to services between mountains and plains. Poor rural households always seek better livelihood opportunities. It can very well be argued that if we can create more economic opportunities in the mountains, the current migration pattern can be changed.

Upstream-downstream Linkages: Mountains are Vital Providers of Resources and Services

Mountains support many different ecosystems and provide key resources and services for human activities well beyond their natural boundaries (Beniston 2005). Whereas most of the goods and services provided by mountains have their origin in the headwaters, the consumers of these goods and services are mostly in the lowlands. Highland and lowland systems are thus highly interdependent in terms of ecology and economy as well as in social and political terms. Mountain communities with their traditional ecological knowledge contribute significantly to the quality and the sustainable management of these goods and services. However, they are rarely compensated fairly for the services they provide to downstream communities. The goods and services provided by mountain ecosystems can be divided into three major groups: provisioning services; regulating and supporting services; and cultural services (Hassan et al. 2005; UNEP WCMC 2002).

Provisioning services: Water as a key resource

Probably the most important good provided by mountains is water. Mountains are often referred to as ‘water towers’ for the world’s lowlands (Viviroli 2007; UNEP-WCMC 2002). Mountains store a vast amount of water in glaciers, snow, and ice; as well as in soil, groundwater, and lakes. Almost all the world’s major rivers, as well as many minor ones, originate in mountains (Messerli and Ives 1997) and, according to Viviroli et al. (2007), over 50% of the Earth’s mountain areas are vital for supplying water to adjacent lowlands for drinking and agriculture, to generate electricity, and for industry.

Besides water, mountains feature high biological and agricultural diversity including food, fibre, and medicinal plants. Many important crops (e.g., maize, potatoes, barley, sorghum, tomatoes, and apples) and domestic

mammals (e.g., sheep, goats, domestic yak, llama, and alpaca) originated in mountain areas (UNEP-WCMC 2002). High-value mountain products such as medicinal plants and nutraceuticals, precious fibres such as cashmere or alpaca wool, and mountain-specific crops are in great demand in downstream and global markets. Mountain forests provide timber, fuel, forage, and non-timber forest products for mountain and downstream economies. Thus the genetic diversity remaining in mountains represents an important resource in a changing world with a growing population.



Regulating and supporting services

Apart from providing important resources to mountain and downstream communities, mountain ecosystems are of vital importance for maintaining and supporting a healthy and safe environment and climate. For example, they play a vital role in water purification and water retention in the form of groundwater, ice, and snow, as well as in lakes and streams. Mountain ranges are also responsible for atmospheric and climate regulation, modulating the climate well beyond their geographical boundaries. Mountain soils are important storage reservoirs for water and

carbon as well as nutrients for soil fertility. Mountain forests (28% of the world's forests are situated in mountains) are highly relevant for protection against natural hazards, ensuring slope stability and preventing or reducing erosion, landslides, and avalanches. Moreover, mountain forests, especially in the tropics, have high genetic diversity and serve as wildlife habitats. Together with highland wetlands, mountain forests play a significant role in biospheric carbon storage (IPCC 2007a,b).

Cultural and recreational services

Mountain areas are home to a high diversity of cultures. Until now, many of these cultures have maintained a rich traditional agricultural knowledge that commonly promotes sustainable production systems. These lifestyles are severely threatened, however (Sonesson and Messerli 2002). For many of these cultures, mountains play an important spiritual role: they are living forces, sources of power, and symbols of the sacred (Bernbaum 1997). In addition, as mentioned above, mountains and many aspects of their people's cultures are attractive for tourism as well as for many recreational activities.

Implications of Environmental Change for Mountain and Downstream Communities

As a result of the strong highland-lowland linkages, particularly the fact that mountain ecosystem provisioning services mainly benefit lowland populations (Hassan et al. 2005), the consequences of unsustainable management of mountain resources, and the impacts of climate change on mountain ecosystem goods and services, reach far beyond mountain areas. What is more, due to the high fragility of mountain systems, their ecosystems take longer to regenerate from environmental stress than lowland ecosystems and can more easily deteriorate irreversibly.

The weakening of mountain ecosystem services due to climate change and other drivers of change will affect the lives and livelihoods of hundreds of millions of people in mountains and a much higher number in downstream communities (Viviroli et al. 2003). This is particularly true in the case of water. It has been estimated that the reduction of water supplies during the dry season associated with increasing glacier retreat and loss of mountain snow will affect up to one-sixth of the world's population (over one billion people), predominantly in the Indian sub-continent, parts of China (over a quarter of a billion people), and the Andes (up to 50 million people) (Stern et al. 2006). In the Hindu Kush-Himalayan region, seven of Asia's largest rivers are fed by meltwater from mountain glaciers. The Ganges alone provides water to about 500 million people (Stern et al. 2006).

Decreasing flows of water from mountains will be inextricably linked to a decline in agricultural productivity, with serious implications for the food security of mountain and downstream communities. Increasing water stress could lead to conflicts, especially in arid and semi-arid areas which are highly dependent on mountain water. Furthermore, with increasing water shortages, water quality may decline and the risk of spread of water-borne diseases may increase. Similarly, increases in air temperature have been linked to the expansion of diseases such as malaria to higher altitudes in both Africa and Latin America.

Mountain Systems as Global Early Warning Systems

Mountain systems, particularly the cryosphere, serve as important early warning systems for global climate change impacts. Because of their high sensitivity, environmental changes become visible earlier or are more pronounced in mountains than in the lowlands. Data on higher temperatures in mountains resulting from increasing concentrations of greenhouse gases and aerosols in the atmosphere – for example as a result of the impact of black carbon and the brown cloud over Asia on the Himalayas (Ramanathan et al. 2007) – could help in understanding changes in climate parameters and assessing the efficiency of global mitigation efforts. In terms of biodiversity, mountains offer an early biological indication of change (Körner 2009). Reducing the knowledge gaps with regard to changes of different climatic parameters in mountain systems will thus help the international community to understand better global climate change and the consequences of the associated changes.



Thimphu, Bhutan

4 Emerging Opportunities

Seizing Opportunities

As described extensively in this document, different drivers of change, particularly climate change, are increasing stresses on mountain social-ecological systems and require targeted efforts to enable the resilience of these systems to be strengthened. Equally, growing awareness of the importance of mountain ecosystem goods and services calls for the specific attention of the global community and creates new opportunities for mountain people which should be seized. The emerging opportunities for sustainable development in mountains include the increasing demands for mountains as places for recreation, for high-value mountain products, and for freshwater as a scarce resource, as well as the recognition of the potential of mountains for carbon sequestration, as a refuge for species which can no longer survive or be grown in the lowlands (Singh et al. 2010), and for the generation of hydropower. The financial and social remittances from labour migration flowing back to mountain areas offer further opportunities



Inle lake, Shan state, Myanmar

Rewards for Mountain Ecosystem Services

Mountain people, through their still predominantly sustainable land management practices, provide a number of positive externalities (non-market side effects of an economic activity) including (agro-) biodiversity conservation; carbon sequestration and climate mitigation; soil protection and preservation; water/watershed management; protection from and prevention of natural hazards (e.g., avalanches, floods); and preservation of cultural and natural landscapes for recreation (FAO 2009). So far, there are only a few examples of mountain people

being rewarded for such services, in part because there is a lack of public awareness and a lack of valuation of the importance of mountain ecosystem services and of the people serving as stewards for these services. Payment for environmental services (PES)³ schemes are one way to reward mountain communities for the vital services they provide. At the same time, such schemes provide incentives to prevent the deterioration of mountain natural resources and the environment, which will help make them more resilient to future climate change. Such schemes should therefore be promoted at a global scale in order to make mountain social-ecological systems more resilient in view of climate change.

³ PES schemes consist of a payment of direct compensation for the maintenance or provision of an environmental service by the users to the providers of the service (Hassan et al. 2005, p703).

Framework Conditions Conducive for Promoting Sustainable Mountain Development

Today, for the first time since the Rio Earth Summit, we are experiencing an emergence of awareness of the importance of mountain systems for the sustainability of mountain ecosystem goods and services. In addition, both the conviction that adaptation calls for tailored packages that are specific to different eco-regions, and the availability of potential investment funds that help to mobilise the required resources for adaptation and mitigation initiatives, are further attracting global attention to mountain systems. The Adaptation Fund of the Kyoto Protocol, for example, includes a specific clause to favour project or programme proposals submitted by developing countries which include fragile mountain ecosystems that are particularly vulnerable to the adverse effects of climate change (Adaptation Fund Board 2010). REDD (reducing emissions from deforestation and degradation) or REDD-plus (enhancement of carbon stocks) are other important mechanisms under the United Nations Framework Convention on Climate Change (UNFCCC) which offer incentives for developing countries to reduce emissions from forested lands and invest in low-carbon paths to sustainable development (UN-REDD Programme 2010). Given that 28% of the world's forests are situated in mountain areas (IPCC 2007a,b), mountains bear a huge potential for carbon storage and sequestration and are therefore in a privileged position to attract such funds for climate change mitigation.

From this point of view, climate change is an opportunity for mountain ecosystems and people. Regardless of the lack of information on detailed impact scenarios, it is clear that mountain systems will be essential building blocks for long-term sustainable global development. The question is whether the countries whose territories contain a substantial part of, or an entire, mountain system have the capacity to take up the challenge to collaborate in order to benefit from these emerging opportunities.





Khumbu, Nepal

5 A Call for Action!

Mainstreaming Climate Change

It is realised that without the support and awareness of civil society, including NGOs (non-government organisations), civil society organisations (CSOs), the private sector, universities, and other research institutions, it will not be possible to achieve resilient mountain social-ecological systems. It is, therefore, essential that these institutions assume responsibility for sensitising policy makers, planners, and decision-makers at all levels, as well as the public, about the importance of the goods and services provided by mountain systems, as well as about their disproportionate vulnerability and the emerging opportunities. Mountains should be recognised as hotspots of climate and other global changes, and policy makers should be motivated to take action and place a special emphasis on the conservation of mountain social-ecological systems, to fund research in order to reduce existing knowledge gaps, and to respond to the specific needs of communities dwelling in these fragile systems in this time of rapidly changing climatic and socioeconomic circumstances. Local and regional authorities play a crucial role in this context, since mountain areas usually do not cover entire countries.

Need for Mountain-specific Policies

Despite differences between mountain areas across the world in terms of the needs and challenges, particularly between those situated in developed and in developing countries, the fundamental challenges of mountain areas such as high fragility, loss of biodiversity, physical isolation, and political marginalisation are largely common and highly related. National policies often do not adequately consider or directly address the special conditions and challenges that mountain regions and their inhabitants face. Effective mountain-specific policies need to be designed not only at the local or country level but beyond, as these challenges are independent of national boundaries. In many countries, policies currently mostly favour lowland areas and largely ignore the disproportionate vulnerability of mountain social-ecological systems. As a result of the strong highland-lowland linkages described above, this could have negative repercussions on both mountain systems and lowland communities, as they are highly dependent on services and goods deriving from the mountains.

Need to Address Knowledge Gaps and for International Cooperation

There is still a high degree of uncertainty about climate change impacts on mountain systems. Especially in the developing world, the density of hydro-meteorological stations is extremely low, resulting in a serious lack of data. This is especially pronounced at high altitude and in remote areas. What is more, existing regional climate change models are still too crude to predict the impacts of climate change at regional or even local levels. It is therefore effectively impossible at present to predict with any certainty the many impacts of climate change on mountain systems. Given the importance of mountain goods and services, it is in the interest of both upstream and downstream communities to lessen the existing knowledge gaps. Comprehensive networks of climatic and hydrological monitoring stations are needed in mountain areas across the world, together with research in the fields of impacts, vulnerability, and adaptation to climate change. Sharing of research experience and data, and international level transfer of knowledge (especially in the fields of meteorology, water and glaciers, forests, energy sources, migration and conflict), are crucial for meeting the challenges mountain systems currently face from climate and other drivers of change, and achieving resilient mountain social-ecological systems. As most climate change issues are transboundary in nature, it will be essential to establish or reinforce international research partnerships, and develop international mechanisms on knowledge and data transfer.

Strengthening Existing Initiatives

In order to achieve an optimal impact, greater effort should be put into existing initiatives, and they should be linked effectively. At a global level, such initiatives include the Convention on Desertification; the Convention on Biological Diversity's (CBD) Programme of Work on Mountain Biological Diversity, which specifically addresses "the fragility of mountain ecosystems and species and their vulnerability to human and natural disturbances, in particular to land-use change and global climate change (such as the retreat of glaciers and increased areas of desertification)" (CBD 2010); the CBD's Programme of Work on Protected Areas, which promotes protected areas as being a strategy for both mitigation and adaptation to climate change and states that protected areas provide opportunities for research including for adaptive measures to cope with climate change; and UNFCCC REDD. Regional initiatives, including the Alpine Convention which has led to an Action Plan on Climate Change in the Alps, the Carpathian Convention, and non-legal frameworks and efforts such as the Balkans and Caucasus processes being led by UNEP, should also be strengthened and might serve as examples for other regions.

The Mountain Partnership hosted by FAO could gain new importance in linking these various global initiatives and making the learning available to all stakeholders. Regional information networks are increasingly needed to serve as learning and awareness creation platforms between researchers, civil society, and government institutions and to support targeted education and training. Mountain countries and regions need to develop mountain specific adaptation and mitigation policies, institutions, knowhow, and capacities to overcome the challenges posed by climate change and thereby maintain the pace and spread of economic development. This is the goal of the Mountain Initiative.

Sharing of Good Practices and Capacity Building

With regard to adaptation to and mitigation of climate change, while funds to implement interventions are necessary, knowledge about successful mechanisms and up-to-date technology may be even more relevant. In this context, developed mountain states, who often already have the benefit of long experience at their disposal, as well as greater financial means to test and implement such mechanisms, could play crucial roles in providing knowledge and expertise to, and building the capacities of, developing mountain states. Furthermore, traditional knowledge on coping and adaptive mechanisms to environmental change needs to be better understood. Overall, good practices of climate change adaptation and mitigation – both modern and traditional – need to be documented and disseminated through training and education initiatives that are tailored to the needs of mountain environments and people.

The Way Forward: An Initiative for Enhancing Resilient Mountain Systems

Mountain systems across the world, which are largely situated in subtropical and tropical zones, have contributed the least to global greenhouse gas emissions. Yet they are at the receiving end of the adverse effects of climate change, and thus urgently need to be supported in their struggle to adapt to the challenges, and enabled to benefit from emerging opportunities. In order to achieve environmental justice and develop resilient mountain social-ecological systems, developing countries with a high proportion of fragile mountainous territory need to be compensated and rewarded for their services by the Annex 1 Parties of the United Nations Framework Convention on Climate Change (UNFCCC). In order to achieve this goal, developing countries with mountain systems need to accept the challenge and collaborate with each other in order to have a strong common voice and to be in a position to defend their interests. For this, the promotion of a strong network of developing mountainous states and all concerned stakeholders will be indispensable.



Jiaju Zangzhai, Sichuan, China

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About ICIMOD

The International Centre for Integrated Mountain Development, ICIMOD, is a regional knowledge development and learning centre serving the eight regional member countries of the Hindu Kush-Himalayas – Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan – and based in Kathmandu, Nepal. Globalisation and climate change have an increasing influence on the stability of fragile mountain ecosystems and the livelihoods of mountain people. ICIMOD aims to assist mountain people to understand these changes, adapt to them, and make the most of new opportunities, while addressing upstream-downstream issues. We support regional transboundary programmes through partnership with regional partner institutions, facilitate the exchange of experience, and serve as a regional knowledge hub. We strengthen networking among regional and global centres of excellence. Overall, we are working to develop an economically and environmentally sound mountain ecosystem to improve the living standards of mountain populations and to sustain vital ecosystem services for the billions of people living downstream – now, and for the future.





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