Long-term Environmental Observations in Mountain Biosphere Reserves: Recommendations From the EU GLOCHAMORE Project

GLOCHAMORE (GLObal CHAnge in MOuntain REgions), a joint project of UNESCO–MAB and the Mountain Research Initiative (MRI) (Becker and Bugmann 2001) is funded under the European Union (EU) Sixth Framework program 'Sustainable Development, Global Change and Ecosystems' to develop and implement a strategy to detect signals of global environmental change in mountain environments across a network of observation sites in selected UNESCO–MAB Biosphere Reserves (MBRs; see the map of MBRs published in *MRD* vol 25 no 3, August 2005, p 283). Following the MAB Biosphere Reserves Integrating Monitoring concept (Lass and Reusswig 2002), these observations will involve both natural and socioeconomic systems (Lee and Schaaf 2004). The present article presents the recommendations of natural scientists and MBR managers based on a workshop held in Vienna, Austria, 9–10 May 2004, entitled "Long-term Monitoring and Analysis of Indicators of Environmental Change in Mountain Regions."

The scope of the recommendations

The recommendations concern 1) **cryospheric indicators** related to snow cover, glaciers, permafrost, and solifluction processes; 2) **indicators for freshwater ecosystems**, their sediment record, and for watershed hydrology; and 3) **indicators for terrestrial ecosystems**, particularly plant communities and soil invertebrates. In view of resource limitations, 3 levels of observation are proposed:

- Essential (minimum level of funds available),
- Improved (medium level of funds), and
- Optimum (funding levels satisfy maximum scientific requirements).

Global change drivers and impacts in high mountain regions

Glaciers and permafrost react sensitively to changes in atmospheric temperature because of their proximity to the melting point. Warming during the 20th century, and its pronounced effects in the glacial and periglacial belts of mountains (Haeberli and Beniston 1998), indicates an accelerating rate of change globally. If sustained, this may result, for example, in the disappearance of smaller mountain glaciers and the deep thaw of perennially frozen ground (eg Sonesson and Messerli 2002; Watson and Haeberli 2004).

Alpine environments react sensitively to climate change, and models (eg Walker et al 2001) forecast large reductions in the extent of alpine environments, up to 80% in the Himalayas (Alcamo 1994) and 100% in the Australian Snowy Mountains (Pickering et al 2004). The main drivers of change in alpine environments are climate, land use, and N deposition (Sala et al 2001; Walker et al 2001). Ecosystem changes are likely to affect water yield and quality, and soil stability, factors which can evidently impact on local dwellers' livelihoods.

The selection of indicators

The indicators were selected on the basis of their conceptual relevance, feasibility of implementation, response variability, and ease of interpretation and utility (Kurtz et al 2001; Grabherr and Pauli 2004).

The essential set of variables enables the detection of abiotic and biotic changes triggered by climate change, pollution, or land use change. Their measurement allows basic comparisons across MBRs and provides a fundamental input for complex studies. If requirements—be it with respect to selecting the essential variables or in relation to sampling design (eg number of sampling units, frequency)—are not met, inferences that can be made will be limited.

An improved set of variables allows a refined definition and understanding of the system studied and enables the elucidation of certain responses by phenomena and organisms to global change. Such a dataset requires more complex analytical techniques and expert knowledge than the essential one.

An optimum set of parameters allows integration across systems (atmosphere, cryosphere, hydrosphere, terrestrial ecosystems). Such a comprehensive dataset enables the analysis of the impacts of global change on biotic and abiotic interactions such as biodiversity, food webs, or on energy and element budgets.

General data requirements

Common to the studies concerned is the need for background data on atmospheric variables that determine climate and weather (Table 1). In addition, ancillary data such as terrain data (digital elevation models) and remotely sensed imagery are required. In combination with geographical information systems, such data form a basis for spatial integration.

TABLE 1 Recommended features and their sampling frequency and methods for the recording of atmospheric, snow, glacier, and permafrost properties in UNESCO-MAB Mountain Biosphere Reserves. C, cryosphere; H, hydrosphere; T, terrestrial ecosystems

Variable/Indicator	Essential	Improved	Optimum	Sampling frequency
ATMOSPHERE				
Air temperature	✓ (C, T)			Continuously
Precipitation	✓ (C, H, T)			Continuously
Atmospheric deposition (wet and dry)		✓ (H, T)		Annually
Precipitation chemistry			✓ (H, T)	Per event
Distribution of precipitation in catchment			✓ (C, H, T)	Continuously
SNOW				
Depth (snow stakes)	✓			Daily
Snow water equivalent		✓		Twice daily
Snow cover extent (satellite image)		✓		Weekly
Density		✓		Daily
Snow pack			✓	Weekly
GLACIERS				
Mass balance (at selected stakes/snow pit)		✓	✓	Annually to seasonally
Length and area (remote sensing data)	✓	✓	✓	Multi-annually
Bed geometry, flow **(radio-echo sounding)** **(velocity measurements)**			✓	 Once Annually to seasonally
Runoff (gauge station in catchment basin)		✓		Daily
PERMAFROST				
Permafrost occurrence	✓			Multi-annually (model)
Temperature of shallow ground (miniature temperature datalogging)		✓	✓	Continuously
Temperature of deep ground			✓	Multi-annually
Slope deformation			✓	Multi-annually to annually
Temperature of rock, coarse and fine material (miniature temperature datalogging)			✓	Continuously

Special data requirements

CRYOSPHERE

Snow, ice, and perennially frozen ground have contrasting indicator values for detecting environmental change, and differing functions in ecosystems. Cryospheric changes are being recorded as part of global climate-related observing systems (Haeberli et al 2002; Harris et al 2003).

Snow

The measurement of snow depth is an essential requirement in a long-term study to detect changing patterns in snow distribution and in corresponding changes in permafrost distribution, vegetation, and meltwater yield.

Most ground-based snow recording networks with daily measurements operate near settlements, roads or railways for avalanche or road condition forecasting. Weekly or monthly snow cover data (depth and water equivalent) are available from regions where hydropower generation, agriculture or water supply are of importance. Few remote mountain areas have automatic measurements of snow depth and long-term (>50 years) datasets are rare. Remote sensing is used in some areas to map snow cover. However, as such maps use modeled latitudinal and altitudinal gradients, they require field verification.

Glaciers

Glaciers are reliable indicators of integrated long-term climatic changes. The observations made by the Global Terrestrial Network on Glaciers (Haeberli et al 2000) include regular data on glacier changes (volume, length) by using a combination of field measurements, remote sensing, and modeling. Glacier mass changes at the regional level are recorded by using index stakes, combined with repeat field mapping, repeat stereo photogrammetry, or air-borne laser scanning (Kaser et al 2003).

The World Glacier Monitoring Service (WGMS, http://www.geo.unizh.ch/wgms/) collects detailed data on mass balance changes from 15 glaciers worldwide, and about 60 glaciers are being observed at a lesser intensity for regional signals. The distribution of the observed glaciers is uneven among climate zones and mountain ranges. The GLOCHAMORE project offers an opportunity to rectify this by including in the WGMS network all MBRs with major glaciers (eg Gurgler Hauptkamm, Austria, and Huascarán, Peru).

Permafrost

Climate-induced changes deep in the perennially frozen alpine slopes and rock walls have a large time lag because of the slow diffusion of heat at depth, and the thawing of permafrost continues long after the surface soil and rocks have defrosted. Mountain permafrost is often only a few degrees below zero, and as a result, reacts sensitively to warming. The response, however, is difficult to predict as it depends on surface cover (especially snow depth and duration), the nature of the substratum (eg bedrock, coarse debris, or soil) and on ground ice contents. A first result of permafrost thaw is the increased surface instability of mountain slopes (Harris et al 2001; Noetzli et al 2003; Gruber et al 2004). A Global Terrestrial Network for Permafrost (GTN-P) of the Global Climate Observing System (GCOS; Burgess et al 2000) is collecting data on permafrost, including a series of 7 100-m-deep boreholes in bedrock along a latitudinal transect across Europe (Harris et al 2001).

Recommendations

In GLOCHAMORE we propose a basic protocol applied across the relevant MBRs, with the option to collect additional data for scientific and local management needs. Data requirements for cryospheric variables are listed in Table 1.

MOUNTAIN WATERS

Water links and integrates landscape and catchment elements and is a crucial resource for ecosystems and human societies. Freshwater systems are sensitive to a range of global change impacts, such as climate warming, deposition of nutrients and pollutants, increase in UV radiation and CO_2.

Lakes

Lakes, at the bottom of catchments, integrate all inputs. This is important for understanding the cumulative impact of upslope processes (Psenner 2002; Burt 2003). Lake-bottom deposits enable one to make inferences about the resilience, vulnerability, adaptation, or recovery of biotic and abiotic components of aquatic systems in relation to disturbances (eg rapid climate change, changes in catchment vegetation, human impact, acidification) at a range of timescales that go well beyond available long-term studies. Moreover, sediment studies enable the establishment of baseline conditions (eg for weathering rates, atmospheric pollution, trophic status)—a prerequisite for management scenarios and monitoring. The combination of measured data and historical records provides a powerful instrument for studying global change impacts in an integrative manner (terrestrial and aquatic processes) at the catchment scale. For these reasons, sediment studies should form part of the GLOCHAMORE approach.

Watercourses

Streams and rivers, unlike lakes, are highly dynamic and respond rapidly to changes in the hydrological cycle. Numerous hydrological stations measure discharge and water quality at the catchment outlets, providing information about their overall chemical budgets. There is a good knowledge of the biology of rivers and of benthic invertebrates, macro-algae and protozoa, and information on biofilms (eg Battin et al 2001) in alpine streams is increasing rapidly. All these make watercourses amenable to indicating global change impacts in mountain catchments.

Detailed methodology is available (eg MOLAR Water Chemistry Group 1999) for physico-chemical parameters (eg atmospheric deposition, water chemistry, meteorology) and biota (eg plankton, macroinvertebrates, bacteria) in mountain lakes (Wathne et al 1995; Wathne and Hansen 1997; Patrick and Flower 1999; Battarbee et al 2002; Battarbee et al 2003) and streams (Brittain and Milner 2001).

Recommendations

As an essential set, we suggest the recording of precipitation, discharge at the catchment (or lake) outlet, water temperature, pH, conductivity, and epilithic diatoms in lakes and water courses (Table 2). Pilot studies should decide whether a single representative catchment can be found for a MBR, or whether the study of more than one catchment is required.

TERRESTRIAL ECOSYSTEMS

The literature on the methodology of studying changes in species and

TABLE 2 Recommended features and their sampling frequency for the recording of physical, chemical, and biological properties in water courses and water bodies in UNESCO-MAB Mountain Biosphere Reserves.

Variable/Indicator	Essential	Improved	Optimum	Sampling frequency
WATER COURSES: Physics				
Discharge at the catchment outlet	✓			Continuously
Temperature	✓			Continuously
Turbidity		✓		Continuously
Suspended solids		✓		Selected periods
Suspended solid budget			✓	Continuously
Bedload			✓	Selected periods (flood)
WATER COURSES: Chemistry				
pH, conductivity	✓			Selected periods
Water chemistry		✓		Selected periods
Output budget			✓	With discharge
WATER COURSES: Biology				
Epilithic diatoms	✓			Annually
Benthic algae		✓		Annually
Macrophytes		✓		Annually
Benthic invertebrates		✓		Selected periods
Fish: species, status, abundance			✓	As desired
WATER BODIES: Physics				
Water temperature at the outlet	✓			Continuously
Temperature profile, at center of lake		✓		Seasonally/monthly
Temperature profile with thermistor chain			✓	Continuously
WATER BODIES: Chemistry				
pH, conductivity at the outlet	✓			Annually
Water chemistry at the outlet		✓		Annually
Water chemistry profile at center of lake			✓	Seasonally/monthly
WATER BODIES: Biology				
Epilithic diatoms	✓			Annually
Littoral benthic invertebrates		✓		Selected periods
Plankton tows			✓	Bi-weekly
Fish: species, status, abundance			✓	As desired
Palaeolimnology			✓	One-off

TABLE 3 Recommended features and their sampling frequency to be recorded in terrestrial ecosystems in UNESCO-MAB Mountain Biosphere Reserves.

Variable/Indicator	Feature	Essential	Improved	Optimum	Sampling frequency
LANDSCAPE, RESERVE					
Repeat imagery (fixed point photography)	Vegetation, land cover type (qualitative, +/-)	✓			Periodically, selected features
Satellite imagery without ground truthing	Land cover type, treeline (quantitative, ca 20% error margin in land cover type change analysis)	✓			Periodically
Maps (with ground truthing)	Land cover, land use, vegetation, remoteness			✓	Periodically
PLOT-BASED					
Species list	Species present, alien species, Nitrogen (N) indicators, crop and synanthropic species (qualitative)	✓?	✓		Periodically, in selected localities
Species cover/abundance	Natural vegetation, alien species, naturalized species			✓	Periodically
Ground cover type	Vegetation (vascular, bryophyte, lichen, rock, bare soil)		✓		Periodically
PLOTLESS					
Bryophyte N concentration	Atmospheric N deposition		✓		Periodically
Dung count	Vertebrate grazer density		✓		Periodically
Some invertebrate groups	Higher taxa			✓	Periodically

populations of plants and animals is extensive (eg Elzinga et al 2001). Well-established systematic long-term observation studies, such as GLORIA for alpine environments (Pauli et al 2004), or the UK Environmental Change Network (Brooker and Turner 2004) contain elements of a broadly applicable scheme. The generic criteria and indicators developed by the Centre for International Forestry Research (Prabhu et al 1999) for sustainable forest management seem readily adaptable to the needs of long-term observations in montane forests in MBRs. The combination of methods developed in GLORIA, with methods available for soils and soil-dwelling invertebrates (eg Kaufmann 2004) and for forest ecosystems, offers a methodological basis for studying long-term responses of terrestrial ecosystems to climate change in MBRs. The study of invertebrates can greatly improve our understanding of the nature and functioning of the trophic web. However, their inclusion requires careful evaluation of available expertise and budget constraints (Kaufmann 2004).

Recommendations

Vegetation and land use maps at the MBR-scale (Table 3) are essential. At the improved level, qualitative and some quantitative information on features indicating climate, pollution and land use impacts is required. At the optimum level, detailed ecological studies on changes in species cover/abundance and ecosystem functioning are the target.

Conclusions and outlook

The proposed network of MBRs includes countries with different economic capacities and cultural traditions. In addition to economic and logistic considerations, such as financial support from the local government and the availability of local expertise in the host country, successful implementation necessitates that decisions observe local cultural heritage.

From the outset, sufficient attention should be paid to the details of hypothesis formulation, survey design (eg *ad hoc* sampling versus proper probability sampling), data quality, and statistical power (Legg and Nagy 2005). An essential criterion is that the resources allocated to a study are adequate and a mechanism is in place to ensure that a sufficiently high standard is maintained, ie the capability to reject a false null hypothesis with reasonable power (eg Peterman 1990). If resources are limited to such an extent that the estimated power is inadequate, then it is necessary to decide whether to proceed or to abandon the study altogether, as there is little point in financing a program that cannot reject a null hypothesis that is false (Manley 1992).

It is essential for all the proposed studies that the ultimate aim is not only the detection of change *per se* but rather the detection of changes which indicate departures in the state(s) of the system(s) studied—and other connected systems—large enough to yield new qualities. For example, the change in the glacier mass balance becomes of major interest once it is related to the anthropogenic system, eg water supply, or through hazards resulting from permafrost thaw or glacier lake outbursts. Equally, while from the point of view of biodiversity, changes in species composition in some research plots above the treeline are important, for ecosystem functioning we need to understand how changes in vegetation structure affect soil stability and processes, and hydrological properties which, in a cumulative manner, affect resource use by humans.

Cause and impact are becoming increasingly difficult to separate as natural systems are being increasingly altered by the accumulated results of human activities (Orr 2004). There is a strong need to develop interdisciplinary approaches that combine social and natural sciences to understand the nature–society system and its responses to change (Parr et al 2003). The impacts of global change cannot be studied without a collaborative approach by the various disciplines of the natural sciences on the one hand, and most importantly, without full integration between the natural sciences and the socioeconomic disciplines, on the other. Integration, which includes end users such as MBR managers, is required to ensure that the scientific data collected find application in assisting management decisions. GLOCHAMORE has a work group on social monitoring of global change in mountain regions, the work of which has been reported recently (Price 2004).

Monitoring of human impacts, combined with long-term studies of natural systems, offers a start in the direction of integrated studies. Through monitoring one can design a scheme to target indicators that are driven by human action, and MBR managers can set threshold values (eg for sustainability), which can be met by management. However, a fully integrated manner of studying the nature–society system will entail finding common denominators and coining a new language understandable to both the natural and social sciences. The GLOCHAMORE project strives to support such progress. An integrated approach to the long-term study of the complex interactions of natural and societal (socioeconomic) drivers and impacts of global change in mountain regions was discussed at the GLOCHAMORE open science conference in October 2005.

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Addressing Climate Change Through Development Cooperation
Climate Change Issues in the Field of Natural Resource Management, Livelihoods, and Food Security

DEZA
DDC
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COSUDE

The Swiss Agency for Development and Cooperation (SDC) recently prepared a short orientation paper, entitled Addressing Climate Change Through Development Cooperation, *with a focus on natural resource management, livelihoods, and food security. This document illustrates how the issue of climate change can be addressed and integrated into the work of an agency. In SDC's programs, special emphasis is given to two important areas—adaptation and mitigation—as well as to the linkages between policy levels and concrete development work.*

SDC's position is based on the recognition that climate change is one of the greatest global environmental threats. It can dramatically affect the economy, infrastructure, natural resources and local livelihoods in developing countries. Depending on their specific site characteristics, developing countries are confronted with steadily changing conditions as well as increasingly extreme climatic events such as droughts, hurricanes, and heavy rainfall that will increase the risk of so-called natural disasters.

These circumstances will affect *inter alia* food production, infrastructure, water supply, biodiversity, natural ecosystems, and human health. Developing countries will suffer disproportionately from the negative impacts of climate change. In addition, processes of development will be retarded, and new sources of social conflict will arise as a consequence of increasingly adverse climatic conditions. Therefore it is necessary to define actions aimed at reducing the vulnerability of poorer social groups and allowing them to participate equitably in the new opportunities offered by global climate change policy. It is in this area that development cooperation finds a specific niche where it can address a global concern through activities at the local level.

The Swiss Agency for Development and Cooperation (SDC) recognizes climate change as a threat to sustainable development in developing countries. Additionally, its Global Environmental Program (GEP) is aimed at *supporting developing countries in their efforts to implement the UN Conventions concerned with the global environment*. Along these general lines, SDC's approach to climate change proposes that programs and projects supported by SDC in the fields of food security, natural resource management, and local livelihoods should integrate, to the extent possible and in a complementary manner, measures that address one or more of the following objectives:

- *Adaptation*: Understand and reduce the impacts of climate change on livelihoods among the poor, with special consideration given to extreme events, natural disasters, resource availability, biodiversity loss, and reduction of carrying capacity for food production;
- *Mitigation*: Promote equitable participation of the rural poor including small-scale farmers, with a focus on gender issues, to allow them to take advantage of opportunities emerging from the implementation of the mitigation strategy, with special regard to their need to increase capacity to participate in the flexible mechanisms;
- *Sustainable Development*: Ensure that the implementation of mitigation and adaptation projects promotes sustainable development in poor rural areas.

Reducing vulnerability to climate change, especially to extreme events, is closely related to humanitarian aid, and more concretely to managing and reducing the impacts of so-called natural disasters. This link is clearly defined in the objectives of the SDC's *Advocacy Guidelines*, as well as in Article 7 of the Swiss Federal Law concerning International Development Cooperation and Humanitarian Aid of 1976.

Due to the evolving policy context at the international level, this work is seen as a permanent learning process, starting with an understanding of the relationship between climate change impacts, sustainable development, and risk management. Such a process-oriented approach includes development of methodological approaches, technologies available for local communities, and the support of pilot experiences. Implementation of the proposed approach to climate change will take account of the specific characteristics of partner countries in different regions, including Africa, Eastern Europe, Asia and Latin America.

SDC's actions in the field of climate change with regard to natural resource management, livelihoods, and food security take place at two levels:

- *Coordination level*: information exchange and clearing desk, through the **Natural Resource and Environment Section**; and
- *Operational level*: mainstreaming climate change issues in operational work through SDC's **Geographical Divisions**.

Specific actions in the area of ***mitigation***:

- Support *capacity building* in Clean Development Mechanism (CDM) projects;
- Promote technology transfer and technology development, especially in the fields of renewable energy and energy efficiency, and ensure that they contribute to sustainable development, food security, and poverty alleviation;
- Support and document emission reduction efforts in the land use, land use change, and forestry (LULUCF) sector and make sure that they contribute to sustainable development and poverty alleviation.

Specific actions in the area of ***adaptation***:

- Support efforts to understand vulnerability to climate change at the local level;
- Promote the design and use of tools for vulnerability assessment at the local level;
- Support *adaptation programs* in countries where expected impacts of climate change and vulnerability are high;
- Support *capacity building* in the areas of vulnerability assessment and planning for adaptation.

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Climate Change in the Himalaya

Views of Mountain Forum Members Voiced on the Mountain Forum Global Discussion List

In November 2004, news was flashed around the globe that a delegation of environmentalists would present a petition (Climate Justice Programme 2004) to the United Nations Educational, Scientific and Cultural Organization (UNESCO) to place the Sagarmatha National Park (SNP) World Heritage Site on UNESCO's List of World Heritage in Danger, citing melting snow and glacier ice as the primary threat. This development, brought to the attention of Mountain Forum by Ms Salima Khatoon of the Mountain Forum Secretariat, was hotly debated in the Mountain Forum's global discussion list (mf-global@mtnforum.org). Several members of Mountain Forum also participated in this spontaneous discussion.

An overview of the debate

Dr Thomas Schaaf of UNESCO clarified that SNP was already a World Heritage Site under the World Heritage Convention, and that Qomolangma (the Chinese side of Mount Everest) was nominated as a Biosphere Reserve on 29 October 2004, and was now part of the World Network of Biosphere Reserves under the UNESCO Man and the Biosphere (MAB) Program. UNESCO services both world heritage sites and biosphere reserves.

Prof Jack D Ives, while appreciative of the drive to enlist SNP on UNESCO's List of World Heritage in Danger, expressed concerns that this may deflect attention from equally important challenges to the integrity of SNP, such as inefficient park management. He noted that carefully researched studies, such as those of the Imja Lake, researched in detail since the early 1980s, had altogether escaped the notice of most of the current group of environmentalists and filmmakers, and advised that a methodological scholarly approach (such as collection, replication and archiving of photographic images as a basis for the study of glacier and lake change) was needed instead of another "overdramatized rush for consulting contracts."

Dr Lorenzo Cappon of the EV-K2-CNR Committee, an organization that has been working at the Pyramid Observatory located in Lobuche at the heart of SNP for over 15 years, regards the petition as confusing and counterproductive, as it is not based on updated documentation and information and therefore does not describe the actual situation. He agreed with Professor Jack Ives that by focusing on one single problem, the petition runs the risk of obscuring more immediate and equally important problems facing the region. Furthermore, he criticized it for being a 'top-down' initiative that did not involve or request the viewpoints of local stakeholders. He sees it as yet another example of mismanagement of a serious environmental problem, based on incomplete or out-of-date information and proposing unilateral interventions and "solutions." According to Article 11.4 of the UNESCO World Heritage Convention, the criteria for adding a World Heritage site to the danger list require description of "serious and specific" threats to a heritage site. Dr Cappon finally stated that "In the case of Everest, we cannot limit our call for protection to an isolated fear, without drawing in the multi-faceted influences a natural environment is faced with," at the same time criticizing the petition for having left EV-K2-CNR's list of publications almost entirely unreferenced in the petition.

Mr Phuntsho Namgyel, PhD candidate at the University of Reading, UK, voiced the opinion that he was unable to piece together a case for the petition at a time when Russia too was signing the Kyoto Protocol and the latter was well on its way to becoming an international instrument for dealing with climate change. He wondered if the impact of climate change on a heritage site such as SNP was advanced for reasons of self-interest in order to add this site to the danger list. Moreover, he expressed concerns over what the implications would be for the national government and local communities if SNP was placed on UNESCO's List of World Heritage in Danger.

Mr KN Vajpai of Prakriti, Dehradun, India, warned that not only a natural heritage site such as SNP, but also planet Earth itself may well be needed to be placed on the List of World Heritage in Danger with respect to the universe.

Mr Roger Payne, Sports and Development Director of the International Mountaineering and Climbing Federation (UIAA), mentioned the UIAA's expedition in 2002 to Island Peak (a low neighbor of Everest), when the film *Meltdown* was shot for UNEP to promote World Environment Day during the International Year of Mountains 2002. The expedition found a glacial lake 2.5 km long, 500 m wide and 100 m deep, whereas there had been no lake in the area in 1953 when Island Peak was first climbed.

Dr Javier Corripio of the Swiss Federal Institute of Technology referred to an article in the online edition of *The Guardian* newspaper dated 24 September 2004 (Watts 2004). The article talked about a detailed study carried out by researchers from the Academy of Sciences on China's glaciers (which are said to account for 15% of the planet's ice). This study claimed that the highest ice fields would not last another 100 years. Dr Corripio noted that these findings were based on a simplistic linear extrapolation of the ice volume lost during the last 25 years, without considering topography, elevation, precipitation, or the general energy balance of high-altitude glaciers: "This is the equivalent of saying 'If I can run 1 km in 4 minutes, I can run 180 km in 12 hours.'"

Mr Gehendra Gurung, Director of the Annapurna Conservation Area Project, Nepal, called attention to the related phenomenon of glacier slides. In August 2003, a huge mass of glacier slid down to the mouth of Madi Khola River, which is fed by the lower glaciers of the south face of Annapurna II, damming it for hours. When the glacier and the water suddenly burst, the flood, lasting 6 hours, destroyed human life, land, forest, livestock, property, and infrastructure. While glacial lakes develop gradually and close monitoring makes it possible to predict floods, glacier slides are difficult to monitor and predict. They are more likely to occur without warning in steep parts of the Himalaya.

Mr Vimal Khawas of the Centre for Development Alternatives, Ahmedabad, India, noted that observations by geo-scientists have detected various rates of glacial retreat in different parts of the Himalaya. While the Zemu Glacier in North Sikkim has been retreating 8 m per year, the Kangchenjhau Glacier, also in North Sikkim, is behaving differently. He further stated that local measures such as checking deforestation and overgrazing in high-altitude areas may not be sufficient to check glacial melting, as glacial retreat is a global problem requiring global action.

Mr Mingma Sherpa of World Wildlife Fund USA recalled that the residents of Khumbu have seen little support since the famous glacial lake outburst flood of 1985 that drew the world's attention to this phenomenon in SNP.

Mr Rajiv Rawat, PhD Candidate in Geography at York University, Toronto, Canada, noted that with the intensification of natural resource use and the spread of urban sprawl into hill and mountain areas, more local research and activism at national and global levels is required. While the encroachment of industrialization onto hill and mountain areas is nothing new, he expressed his fear that the world is set to experience a far greater extractive process than ever before, particularly as China and India experience rapid growth on the Western model of high consumption and high pollution.

Mr Remi Chandran, Project Assistant at the Environment and Sustainable Development Programme (ESD) of the United Nations University, suggested that Clean Development Mechanisms (CDMs) would be a good way to address impacts of climate change on fragile mountain ecosystems. The Memorandum of Understanding signed between the Asia Carbon International B.V. and The Energy and Resources Institute (TERI) in New Delhi was a significant step toward enhancing Asia's participation in CDMs, entailing cooperation in the areas of stakeholder capacity building, establishment of a CDM Projects Portfolio, consolidation of the global carbon market, and other areas of cooperation focusing on mitigating climate change.

Ms Mandira Shrestha, Water Resources Specialist at the International Centre for Integrated Mountain Development (ICIMOD), Nepal, pointed to the transboundary nature of some glacial lake outburst floods. In April 2000, about 300 million m^3 of debris, soil, and ice dammed the Yigonzangba River (a tributary of the Yarlanzambo, also called the Brahmaputra). Despite mitigating measures taken by the government of Tibet, the dam burst on 10 June 2000, resulting in a total economic loss estimated at USD 22.9 million and rendering over 50,000 people homeless downstream in Arunachal Pradesh, India. Because of the transboundary nature of glaciers, cooperation is required between the countries affected in terms of data sharing, monitoring of potentially hazardous glacial lakes, establishment of early warning systems, and adoption of mitigating measures. Ms. Shrestha stated that ICIMOD was working with its member countries as well as international experts to forge regional cooperation, with the aim of reducing these kinds of physical vulnerabilities in the Greater Himalaya region.

Conclusion

Like many issues that generate much debate, climate change in the Himalaya and its impact on glaciers is rife with competing arguments. While the efforts of activists making petitions can only be lauded in their intention, such efforts must be tempered with more extensive research and seek a broader opinion base.

When so many voices call attention to a plethora of issues, ill-researched and biased arguments tend to do a disservice to the larger issue, while trying to achieve the exact opposite. The use of the celebrity firepower of big-name climbers such as Chris Bonnington and Reinhold Messner to lead a petition drive in a 'top-down' fashion, without input from relevant local and national stakeholders, as well as from the researchers who have painstakingly documented the Everest region for decades, is counterproductive in the long run. Mountain Forum members remain acutely aware of the pitfalls of such an approach and continue to encourage all those involved with mountains and mountain development to debate such issues before hastening to any conclusions.

The messages to the mf-global discussion list on which this synthesis is based are archived at: http://www.bellanet.org/scripts/lyris.pl?visit=mf-global. Other members who contributed to this discussion (November 2004 to January 2005) on Mountain Forum's global discussion list were Peter Roderick, Director of the Climate Justice Programme, Dr Jane Pratt, Shan J. Ashton, Mr. Neel Kamal Chhetri, and Mr. Yubaraj Dinesh Babu of TERI.

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