Global Change in Mountain Regions – Strategies for Biosphere Reserves

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Executive Summary
Mountains are particularly fragile environments, which make them ideal for studying the impact of global (including climate) change. Their zonal vegetation belts, which vary with exposition but mainly with altitude, are likely to be influenced by global warming; increasing global temperatures will result in an upward shift of mountain vegetation zones and marked ecotones such as the timberline and the vegetation line. In addition to this phenomenon, changing precipitation patterns, in line with global warming, will seriously affect water run-off as well as glaciers and their water storage capacities for lowlands. Other effects include the socio-economic situation of mountain populations who have to cope with a shifting climatic context affecting their socio-economic well-being. Funded under the 6th Framework Programme of the European Commission (2003-2005), the Mountain Research Initiative (MRI) and the University of Vienna (Austria), in collaboration with UNESCO and its Man and the Biosphere (MAB) Programme, have embarked on a global study to assess the impact of global change on the biophysical environment and the socio-economic conditions and livelihoods of mountain people. UNESCO's World Network of Biosphere Reserves was utilized as monitoring and testing sites for the study, which resulted in the preparation of the "Global Change in Mountain Regions (GLOCHAMORE)" Research Strategy. Over 25 biosphere reserves participated in the study, with about 3-4 sites selected among the world's major mountain regions.

Fragile ecosystems and global change

With very good reason, mountains are labelled as *fragile ecosystems* in UNCED's Agenda 21. The introductory part of Chapter 12 of Agenda 21 stipulates:

> Fragile ecosystems are important ecosystems with unique features and resources. Fragile ecosystems include deserts, semi-arid lands, mountains, wetlands, small islands and certain coastal areas (UN Department of Public Information: *Agenda 21: Programme of Action for Sustainable Development*, UN 1994, page 98).

Moreover, in Chapter 13 of UNCED Agenda 21, which specifically refers to "Managing Fragile Ecosystems: Sustainable Mountain Development" (ditto, page 109), mountains are seen in the complex and interactive context of water, energy, biodiversity and land degradation:

> Mountains are an important source of water, energy and biological diversity. … As a major ecosystem representing the complex and interrelated ecology of our planet, mountain environments are essential to the survival of the global ecosystem. Mountain ecosystems

are, however, rapidly changing. They are susceptible to accelerated soil erosion, landslides and rapid loss of habitat and genetic diversity. On the human side, there is widespread poverty among mountain inhabitants and loss of indigenous knowledge. As a result, most global mountain areas are experiencing environmental degradation. Hence, the proper management of mountain resources and socio-economic development of the people deserves immediate action.

Already in 1992, Agenda 21 recognized that mountains are highly vulnerable to natural and anthropogenic ecological imbalance as they are particularly sensitive areas that respond to the full range of atmospheric climatic changes. Because of their vertical dimensions, mountains create gradients of temperature, precipitation and solar radiation. Thus a given mountain slope may include several climatic systems, such as tropical, subtropical, temperate and alpine, each of which represents a microcosm of a larger habitat diversity. There is, however, a lack of knowledge on mountain ecosystems and specific information on ecology, natural resource potential and socio-economic activities in mountains is often widely scattered, scant or inaccessible.

Worthwhile initiatives to generate and strengthen knowledge on the impact of climate change on mountain environments have started, such as the Global Observation Research Initiative in Alpine Environments (GLORIA), which set up monitoring sites on alpine vegetation in various sites around the world. However, assessing the impacts of global change on mountain environments and on mountain livelihoods in an interdisciplinary manner – comprising both natural and social sciences – using a world-wide harmonized approach did not exist in the early years of the current millennium.

The GLOCHAMORE Project

To redress this situation, a coherent and coordinated approach to study and monitor the impact of global change in major mountain ranges of the world was needed. Spearheaded by the Mountain Research Initiative (MRI) and coordinated by the University of Vienna, the "Global Change in Mountain Regions (GLOCHAMORE)" Project aimed at developing a better understanding of the causes and drivers that constitute current global, including climate, change.

Thanks to funding provided by the European Commission under its 6th Framework Programme, as well as by UNESCO's Man and the Biosphere (MAB) Programme and UNESCO's International Hydrological Programme (IHP) from 2003 to 2005, over 200 scientists and mountain biosphere reserve managers from the world over met at various international workshops and at an international Open Science Conference (Perth, United Kingdom) to understand the causes and impacts of global changes – whether generated from climate, land use change, biological invasion, global economic forces or other sources:

- International launching workshop on "Global Change in Mountain Biosphere Reserves" held at Entlebuch Biosphere Reserve (Switzerland) in November 2003;
- First thematic workshop on "Global Environmental and Social Monitoring" held at University of Vienna in May 2004;
- Second thematic workshop on "Projecting Global Change Impacts in Mountain Biosphere Reserves" held in Gran Sasso National Park (Italy) in November/December 2004;
- Third thematic workshop on "Sustainable Land Use and Natural Resources Management in Mountain Biosphere Reserves" held in Granada (Spain) in March 2005; and
- Fourth thematic workshop on "Process Studies Along Altitudinal Gradients" held in Samedan (Switzerland) in July 2005.

(Most of the workshop proceedings were published by UNESCO-MAB; for pdf files, see:

- http://unesdoc.unesco.org/images/0013/001358/135893e.pdf
- http://unesdoc.unesco.org/images/0013/001373/137359eo.pdf
- http://unesdoc.unesco.org/images/0014/001424/142482e.pdf).

The international Open Science Conference on “Global Change in Mountain Regions” (organized by the Centre for Mountain Studies in Perth, United Kingdom, in October 2005) also lead to the *Perth Declaration* which inter alia expresses the wish of mountain biosphere reserve managers and scientists to collaborate on global change issues in mountains (see http://www.unesco.org/mab/ecosyst/mountains/PerthDecl.pdf).

Mountain Biosphere Reserves

The main contribution of the UNESCO Man and the Biosphere (MAB) Programme to the GLOCHAMORE Project was to mobilize site managers of mountain biosphere reserves within the World Network of Biosphere Reserves. Biosphere reserves combine several important features that make them ideal for monitoring activities on global climate change; they have been internationally designated for their value in conservation (in particular biological diversity); for promoting sustainable development, based on local people participation in environmental management; and for their research infrastructure, with on-going scientific programmes on ecosystem structure, functioning and dynamics.

What are biosphere reserves? According to a short definition, biosphere reserves are areas of terrestrial ecosystems which are internationally recognized within the framework of UNESCO's Man and the Biosphere (MAB) Programme (UNESCO-MAB 2000: Biosphere Reserve Map, Paris, France). Collectively, they form a World Network. Nominated by national governments, they are required to meet a set of criteria and adhere to a set of conditions before being admitted into the World Network. Each biosphere reserve is intended to fulfill three basic functions, which are complementary and mutually reinforcing:

- a conservation function - to contribute to the conservation of landscapes, ecosystems, species and genetic variation;
- a development function - to foster economic and human development which is socio-culturally and ecologically sustainable;
- a logistic function - to provide support for research, monitoring, education and information exchange related to local, national and global issues of conservation and development.

In order to carry out the complementary activities of nature conservation and natural resources use, biosphere reserves are organized into three distinct yet interrelated zones, known as the core area(s), the buffer zone(s) and the transition area(s):

- The **core area** needs to be legally established and give long-term protection to the landscape, ecosystem and species it contains. It should be sufficiently large to meet conservation objectives. As nature is rarely uniform and as historical land-use constraints exist in many parts of the world, there may be several core areas in a single biosphere reserve to ensure a representative coverage of the mosaic of ecological systems. Normally, the core area is not subject to human activity, except research and monitoring and, as the case may be, to traditional extractive uses by local communities.
- A **buffer zone (or zones)** which is clearly delineated and which surrounds or is contiguous to the core area. Their role is to minimize negative and external effects of human-induced activities on the core areas. In addition to the buffering function related to the core areas, buffer zones can have their own intrinsic, ‘stand alone’ functions for maintaining anthropogenic, biological and cultural diversity. Buffer zones can also have an important connectivity function in a larger spatial context as they connect biodiversity components within core areas with those in transition areas. Buffer zones can be areas for experimental research, for example to discover ways to manage natural vegetation, croplands, forests, fisheries, to enhance high quality production while conserving natural processes and biodiversity, or to rehabilitate degraded areas.

- An **outer transition area**, which may contain a variety of agricultural activities, human settlements and other uses. It is here that the local communities, conservation agencies, scientists, civil associations, cultural groups, private enterprises and other stakeholders must agree to work together to manage and sustainably develop the area's resources for the benefit of the people who live there. Given the role that biosphere reserves should play in promoting the sustainable management of the natural resources of the region in which they lie, the transition area is of great economic and social significance for regional development.

Although schematically presented as a series of concentric rings, the three zones are usually defined in many different ways so as to accommodate local geographic conditions and constraints. They may have multiple core areas and buffer zones, which in turn are surrounded by the transition area marking the boundary of the entire management site This flexibility allows for creativity and adaptability, and is often considered as one of the greatest strengths of the concept.

UNESCO's 193 Member States formally recognize the World Network of Biosphere Reserves. To date (October 2008), 531 biosphere reserves can be found in 105 countries (see http://www.unesco.org/mab/BRs.shtml).

About forty per cent of all biosphere reserves are located in mountain areas (for individual site descriptions, see http://www.unesco.org/mab/wnbrs.shtml). The central question common to all biosphere reserves is: How can we conserve the environment (e.g. mountain ecosystems) while at the same time ensuring sustainable development for the local population? Or alternatively: How can we reconcile the conservation of biological resources with their sustainable use? Essentially, the answer lies with environmental management. Biosphere reserves aim at resolving land use conflicts by developing holistic economic and environmental management plans that afford protection to the natural resources yet allow for sustainable economic activities for the local population. Unlike most other protected areas, biosphere reserves assume a people-centred approach where solutions on sustainable land management are worked out among local stake-holders, scientists and government officials and are based upon scientific spatial analysis. The integration of nature conservation, sustainable development and environmental research and monitoring make biosphere reserves particularly appropriate for the study of global change impact on the biophysical environment and the livelihoods of mountain peoples.

For the GLOCHAMORE Project, the following mountain biosphere reserves participated in the study in an attempt to have representative sites covering the major mountain ranges of the world.

1. Australia: Kosciuszko
2. Austria: Gossenköllesee
3. Austria: Gurgler Kamm
4. Canada: Mount Arrowsmith
5. Chile: Araucarias
6. Chile: Torres del Paine
7. China: Changbaishan
8. Colombia: Cinturón Andino
9. Germany: Berchtesgaden Alps
10. India: Nanda Devi
11. Kenya: Mount Kenya
12. Kyrgyzstan: Issyk-Kul
13. Mongolia: Uvs Nuur Basin
14. Morocco: Oasis du Sud marocain
15. Peru: Huascarán
16. Russian Federation: Kavkazskiy
17. Russian Federation: Katunskiy
18. Russian Federation: Sikhote-Alin

19. South Africa: Kruger to Canyons
20. Spain: Sierra Nevada
21. Sweden: Lake Torne Area
22. Switzerland: Entlebuch
23. Switzerland: Swiss National Park
24. USA: Glacier
25. USA: Niwot Ridge
26. USA: Denali

With their gradients from virtually “zero” direct human interference in the legally protected zones (core areas) to medium (buffer zones) to strongly anthropogenically impacted areas (transition areas), biosphere reserves were considered as interesting study and monitoring sites to assess global change impacts in mountain ranges. Being part of a world network, the managers of the biosphere reserves could also be mobilized through the UNESCO-MAB institutional infrastructure of the World Network of Biosphere Reserves administered by UNESCO. Many biosphere reserves dispose of long term series of climate data (temperature, precipitation) and species lists which can be monitored over time and correlated with global warming. Moreover, biosphere reserves also include areas where people live and make a living in their transition zones, hence the repercussions of global warming can be assessed on local mountain economies and people's livelihoods.

The GLOCHAMORE Research Strategy

The main outcome of the GLOCHAMORE Project was the *GLOCHAMORE Research Strategy* as a blue print to guide managers of mountain biosphere reserves and scientists in implementing global change research in mountains (see pdf file at http://unesdoc.unesco.org/images/0014/001471/147170E.pdf).

The research strategy is built on the assumption that sustainable management can only be achieved with stakeholder involvement. Stakeholder involvement will not only increase the clarity of the research, but also enhance its relevance and acceptability, and thus the efficiency and impact of the research project. Consulting local people and the managers of mountain biosphere reserves is therefore central to the implementation of future GLOCHAMORE projects.

This research strategy is organized according to our current understanding of the main axes of causality. It focuses first on drivers of global change, then on the impacts of global change on ecosystems, then on the subsequent impacts on ecosystem goods and services, regional economies, and health, and finally on institutional arrangements. Placing the human dimension in the second half of the list emphasizes mountain and lowland people’s dependence on mountain goods and services that are affected by both indirect and direct impacts of global environmental change.

The Research Strategy addresses the following 10 themes, and 41 sub-themes:
1. Climate

2. Land Use Change
2.a Quantifying and Monitoring Land Use
2.b Understanding the Origins and Impacts of Land Use

3. The Cryosphere
3.a Glacier Extent
3.b Glacier Mass Balance and Melt Water Yield
3.c Snow Cover
3.d Snow Melt
3.e Permafrost

4. Water Systems
4.a Water Quantity
4.b Water Quality and Sediment Production
4.c Aquatic Community Structure

5. Ecosystem Function and Services
5.a Role of Alpine Areas in N and Water Cycles
5.b Role of Forest C Cycle and Resource Production
5.c the Role of Grazing Lands in C, N and Water Cycles, Slope Stability and Household Economy
5.d Soils Systems
5.e Pollution
5.f Plant Pests and Diseases

6. Biodiversity
6.a Biodiversity Assessment and Monitoring
6.b Biodiversity Functioning
6.c Biodiversity Management
6.d Alpine Community Change
6.e Key Fauna and Flora
6.f Forest Structure
6.g Culturally Dependent Species
6.h Impacts of Invasive Species

7. Hazards
7.a Floods
7.b Wildland Fire
7.c Mass Movements
7.d Avalanches

8. Health Determinants and Outcomes Afflicting Humans and Livestock

9. Mountain Economies
9.a Employment and Income
9.b Forest Products
9.c Mountain Pastures
9.d Valuation of Ecosystem Services
9.e Tourism and Recreation Economies

10. Society and Global Change
10.a Governance Institutions
10.b Rights and Access to Water Resources
10.c Conflict and Peace
10.d Traditional Knowledge and Belief Systems
10.e Development Trajectory and Vulnerability
10.f Urbanization in Mountain Regions

A critical and constructive assessment of the implementation of the GLOCHAMORE Research Strategy is provided by Greenwood at this conference, who also informs on various GLOCHAMORE follow-up meetings at regional level.

This paper outlines UNESCO's views on how global change in mountain regions could be operationalized, based on the GLOCHAMORE Research Strategy and using mountain biosphere reserves (and similarly managed areas) as study and monitoring sites.

While it would, indeed, be desirable to implement the GLOCHAMORE Research Strategy in its entirety for holistic reasons, both biosphere reserve managers and scientific institutions may not be able to afford the necessary human resources and technical/scientific infrastructure needed for such an undertaking. Biosphere reserves and scientists are therefore encouraged to tackle as many aspects and themes of the Research Strategy as possible and in line with their own local, national and regional priorities.

In order to keep the "global" approach of the GLOCHAMORE Research Strategy, in particular as regards the sharing of information in using a harmonized methodology in mountain ranges in both developing and industrialized countries, it is suggested to address only a few themes of the GLOCHAMORE Research Strategy. Common denominators that are relevant to biosphere reserves and scientists in the North and in the South alike are the following: (1) Biodiversity subject to global change impacts; (2) Availability of freshwater resources in the context of global warming; and (3) Mountain economies and livelihoods of mountain dwellers. UNESCO-MAB has prepared a project proposal entitled "Global Climate Change in Mountain Sites (GLOCHAMOST) - Elaborating Adaptation Strategies in Biosphere Reserves" for funding by potential funding sources, which would put the GLOCHAMORE Research Strategy to practice.

The main objective of the GLOCHAMOST Project is to implement the GLOCHAMORE Research Strategy in representative mountain biosphere reserves worldwide, with a view to develop adaptation strategies addressing the specific impacts of global change on these mountain environments, their inhabitants, and others who depend on goods and services deriving from these environments.

The specific objectives of the project are:

- To implement the research strategy in mountain biosphere reserves in order to address global climate and environmental change in mountains. This objective focuses on monitoring changes in the biophysical environment, and on understanding the interacting ecological and hydrological processes in mountain regions, both with and without local human interference, along altitudinal and other gradients (e.g. land use). Such work recognises the unique value of the many mountain ecosystems that have been, and remain, relatively uninfluenced by direct human activities, especially in protected areas such as the core areas of biosphere reserves. An important aspect of this objective is to further develop and consolidate a network of observation sites in mountains to serve as an 'early warning' system for assessing global change impacts.

- To evaluate the consequences of global changes for mountain regions as well as for lowland systems which depend on mountain resources. The emphasis of this objective is to increase our understanding of the consequences of global change for people and ecosystems in mountain regions and adjacent lowland areas. Credible impact assessments form the baseline for informing policy makers on issues of global changes at local to global levels. In addition, information from impact assessments has direct application to policies and strategies for resource management that are implemented at local and regional scales.

- To facilitate the development of adaptive sustainable land, water, and resource management strategies for mountain regions tailored to the specific needs and potentials of participating mountain biosphere reserves. The emphasis of this objective is to define a set of potential human responses to global climate change that can be implemented at local and regional scales. Adaptation strategies developed under this objective will assist policymakers by indicating the extent of degradation of key mountain resources, and by evaluating interactions between alternative resource management strategies and trajectories of change generated by global factors.

Regarding its approach, the project will foster collaboration and communication within the mountain research and global change scientific community in both industrialized and developing countries around the world. More importantly, the project will facilitate collaboration among researchers, managers of mountain biosphere reserves, and mountain communities affected by global change (including climate, environmental and socio-economic changes). As expressed in the *Perth Declaration*, mountain scholars and managers of mountain biosphere reserves declared their mutual commitment to continue work that has already begun under the GLOCHAMORE Project: global change scientists will link available knowledge systems and conduct research in MBRs, thus providing scientific advice to their managers in order to help to enhance the overall management of these sites in the context of global change. Inversely, MBR managers will continue collaboration with the scientific community and other relevant stakeholders on global change-related issues at site level.

The focus of the project will be on inter-regional and interdisciplinary studies that address the causes and, in particular, the impacts of environmental and socio-economic changes in mountain regions. To this end, the project will use a harmonized approach to assess the consequences of these changes for the biophysical environment and human societies, and to propose adaptation strategies to cope with these changes. It is anticipated that this integrative research framework will lead to the development of site-specific strategies, which can be used at a larger scale to shape policies to ensure sustainable development in mountain regions.

The implementation of the project will be continually reviewed during a series of annual meetings, which proved to be a very successful approach during the GLOCHAMORE project. The objectives outlined for the GLOCHAMOST project will be achieved by ensuring that appropriate on-site research activities are carried out in each participating mountain biosphere reserve, depending on local needs and resources, to be defined independently. The GLOCHAMORE Research Strategy has laid the foundation for ensuring that project activities are integrated, coordinated, consistent and effectively applied.

The project will be developed with a focus on selected mountain biosphere reserves that participated in the GLOCHAMORE project, and where a strong commitment for collaboration among scientists, site managers and local communities has been demonstrated in the past. The goal is to cover the Earth's major mountain ranges with sites that have varying socio-economic contexts. A strong focus on capacity building is embedded within the project; this will be achieved through information sharing between participants from industrialized and developing countries during the annual review workshops, as well as through training in data collection and data analysis. In addition, the project will bring together global change scientists from both the natural and the social sciences in an indispensable effort to formulate adaptation strategies in the context of global climate change, thereby facilitating the creation of synergies between the different groups of specialists and hence interdisciplinary cooperation, enhancing the spatial and temporal coordination of individual research projects.

To a large extent, the GLOCHAMOST Project relies on existing activities within both institutional networks, such as the World Network of Biosphere Reserves of UNESCO-MAB and the regional Global Change Research Networks of the MRI, and global change research institutions. It aims *inter alia* to create a coordinated network of study sites linked by a common understanding of purpose that provides benefits to each participating site in a way that exploits synergies. An inter-disciplinary approach will be ensured through the participation of a variety of scientific disciplines, including ecology, hydrology, forestry and agriculture, economy, sociology and protected area management.

While all ten themes stipulated in the GLOCHAMORE Research Strategy are relevant for global change studies, differing priorities, financial constraints, and the differences in available research and management capacity structures among the mountain biosphere reserves in industrialized and developing countries will require fine-tuning at each site.

For this reason, the GLOCHAMOST Project includes a *minimum set of topics* in order to ensure a common and harmonized approach among all participating sites, and to share similar management and research results among all project partners. First, biodiversity, particularly rare fauna and flora species, determines the conservation value of every biosphere reserve, and rare/endangered species may be threatened due to global and climate change. Second, the availability of freshwater resources for both ecosystem functioning and human well-being is a key issue in the context of climate change. Third, people, whose livelihood systems will need to adapt to global and climate change, live within and around all mountain biosphere reserves.

Accordingly, the new project should focus on the following themes:

- Biodiversity: Key fauna and flora (Item 6e of research strategy)
- Water: Water Quantity (item 4a of research strategy)
- Mountain Economies: Employment and Income (item 9a of research strategy)

Biodiversity: Key fauna and flora

Rationale: Certain species are politically very important and constitute a key reason for the creation of each biosphere reserve. The fate of the site is thus tied to the fate of the species – and this is frequently influenced by land use change and could be threatened by climate change.

Research goal: To predict the probability of local persistence of key species under different global climate change scenarios.

Actions:

- Collect presence, and if possible, abundance data on key species along with abiotic environmental data.
- Develop models that predict the likelihood of species occurrence (and if possible abundance) on the basis of abiotic environmental characteristics.
- Assess the extent to which biotic interactions (e.g., competition and facilitation) must be addressed in order to predict distribution and abundance.
- Undertake experimental studies on the response of common and rare species to climate change.
- Validate models and scenarios using empirical studies of basic population and organismic processes.
- Simulate future distribution and, if possible, abundance under different climate and land use scenarios (local and regional), and under different assumptions of species mobility.
- Identify key species at risk.

Water: Water Quantity

Rationale: Mountains are key sources of water for human consumption and economic use (agriculture, hydropower) both within mountain regions and in downstream lowlands. The main impact of climate change with respect to mountain areas may well relate to the amount and timing of water released.

Research goal: To determine and predict water balance and its components, particularly runoff and water yield of mountain catchments (including wetlands and glaciers), under different global change scenarios.

Actions:

- Establish and maintain gauging stations on representative drainages within MBRs.
- Determine the relationship between precipitation, temperature, soil moisture, evapotranspiration, runoff and land use characteristics within representative drainages.
- Develop models to predict discharge from representative drainages at several different timescales from monthly to hourly.
- Develop required input datasets for other basins and test model predictions against observed discharges at a range of time scales.

Mountain Economies: Employment and Income

Rationale: Global change will change the capacity of landscapes to generate wealth and to provide livelihoods for resident populations and for distant but nonetheless dependent populations. An understanding of these changes and local peoples' ability to respond is a prerequisite for successful adaptation to such impacts.

Research goal: To predict the impacts of global change scenarios on the economies of mountain regions and economies dependent on mountain goods and services and, hence, to assess the resilience of mountain societies to global change.

Actions:

- Compile data on incomes deriving from all economic sectors.
- Develop regional economic models (for both monetized and subsistence economies, as appropriate), taking into account environmental, demographic, economic, and political driving forces.
- Simulate possible future economies under different regional scenarios of climate, land use, human demography, and external forces.
- Identify attributes of mountain communities that make them resilient to global change.

The GLOCHAMOST Project proposal will be further discussed at the post-conference international workshop entitled "Research Strategy on Global Change in Mountain Biosphere Reserves" on 19 November 2008 here at ICIMOD. All interested persons are invited to attend this workshop.

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