GLOBAL CHANGE RESEARCH IN MOUNTAIN BIOSPHERE RESERVES

Proceedings of the International Launching Workshop
Entlebuch Biosphere Reserve
Switzerland
10–13 November 2003

Participants at the Entlebuch workshop

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The International Geosphere-Biosphere Programme (IGBP)

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W. Erdelen
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Following a decision of the General Assembly of the United Nations, the year 2002 was proclaimed as the 'International Year of Mountains'. Its main objective was to increase worldwide awareness of the importance of sustainable mountain development. Governments, mountain communities, international organizations, private enterprises and also the international scientific community were called upon to combine their actions so as to forge partnerships that would enhance sustainable development in mountains.

Global change triggered by rising temperatures and differing precipitation regimes on a global scale is intrinsically linked to sustainable development. We still do not know for sure which climate change scenarios will become prominent over the next ten to one hundred years. This is why the Director-General of UNESCO, Mr Koïchiro Matsuura, announced at the Bishkek Global Mountain Summit in October 2002 – the culminating event during the International Year of Mountains – that UNESCO with other partners would embark on a global study to assess the impact of global change on the bio-physical environment as well as on the socio-economic conditions of mountain inhabitants, using mountain biosphere reserves as monitoring sites. He highlighted the significance of embarking on an initiative that would be holistic and inter-disciplinary in its approach and which would involve both the scientific community and biosphere reserve managers. With 440 biosphere reserves in ninety-seven countries, the involvement of the World Network of Biosphere Reserves of UNESCO is both an astute and a strategic choice.

The statistics speak for themselves: 75 per cent of the world's countries have mountain ranges or high plateaus; one-eighth of the world's people live in the mountains; two billion people depend on mountains for food, hydroelectricity, timber or mineral resources; a staggering 50 per cent of the world's population rely on mountain watersheds for fresh water. These biologically and culturally heterogeneous regions are thus essential for the continued well-being of countries in which they are situated, but equally they play an increasingly dominant role on a global scale.

The 'Global Change Research in Mountain Biosphere Reserves' initiative thus emphasizes the global importance of mountains. The principal aim of this initiative is to identify bio-physical and socio-economic indicators of global change that will help to formulate strategies for mountain communities to better respond to global changes in the longer term.

The Entlebuch workshop saw the launch of the European Commission funded Initiative that involves a consortium of fourteen organizations and institutes specializing in global change issues. The next two years will see the organization of four thematic workshops and will culminate in an Open Science Conference in 2005. UNESCO is proud of the importance it plays in this initiative through the keen involvement of biosphere reserves managers and global change scientists and we very much welcome the synergistic participation of the other members of the consortium. I particularly wish to express gratitude to the Mountain Research Initiative (MRI) with the International Geosphere-Biosphere Programme (IGBP), the International Human Dimensions Programme on Global Environmenal Change (IHDP) and the Global Terrestrial Observing System (GTOS) for their commitment towards and support for the Initiative. UNESCO, with its Programme on Man and the Biosphere (MAB) and its International Hydrological Programme (IHP) stands ready to collaborate with these partner programmes to apply science for the benefit of sustainable development in mountains.

W. Erdelen
Assistant Director-General for Natural Sciences
UNESCO

Introduction

Background and Concepts for Collaborative Work: Global Change Research in Mountain Biosphere Reserves

Mel Reasoner (MRI), Harald Bugmann (ETH Zürich) and Thomas Schaaf (UNESCO-MAB)

GLOBAL CHANGE IN MOUNTAIN REGIONS

Mountain regions represent about one-fourth of the Earth's terrestrial surface, provide goods and services to more than half of humanity, and are in the nearby environs of approximately a quarter of the global population. Accordingly, mountains were a focus of attention at the 1992 United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro, with the inclusion of Chapter 13: 'Managing Fragile Ecosystems: Mountain Sustainable Development' in *Agenda 21*. More recently, the importance of mountains in the global ecosystem has been underscored with the UN declaration for the year 2002 as the 'International Year of Mountains'. Together, these measures have highlighted the critical role mountain systems play for delivering a wide array of goods and services to humanity, such as freshwater, biodiversity, carbon storage, forest products, minerals, refuges for threatened species, recreation opportunities and many others.

The functioning of fragile mountain systems is threatened today by an array of anthropogenic changes, ranging from land-use and land-cover changes (including touristic and agricultural over-exploitation or abandonment), acidic deposition, and increasing atmospheric CO_2 concentration leading to climatic changes. Thus, many of the world's mountain ecosystems are moving along trajectories that couple high rates of environmental change with major economic changes, whose collective effect may significantly change the ability of mountain regions to provide critical goods and services, both to mountain inhabitants and lowland communities. Ten years ago, Chapter 13 of *Agenda 21* acknowledged that mountains were undergoing rapid degradation. Although significant advances in knowledge and awareness of global change impacts in mountain regions have been achieved during the last decade, in many cases detrimental trajectories in mountain environments are continuing unabated.

An additional source of change in mountain environments is related to the process of globalization, that is, the growing global integration of social, political and economic relationships. Globalization, as it affects mountain environments, is reflected in demographic changes, the incorporation of mountain economies into extra-regional economies, the increasing influence of urban processes and perspectives, increases in consumption, and changes in the location of decision-making and institutional arrangements. For the next few decades, globalization processes are likely to be at least as important as environmental changes with respect to promoting change in mountain regions. At the same time, however, the severity of both systemic human impacts, which affect environments at the global scale, and cumulative ones, which operate at local scales but are becoming globally pervasive, may significantly threaten the ability of mountain regions to provide the critical goods and services described above to mountain inhabitants and to supply the extra-regional demands of other communities.

A complex network of biophysical and socio-economic factors currently affects fragile mountain environments and these impacts are in turn likely to have substantial direct and indirect consequences for large segments of humanity. It is therefore clear that the implementation of a concerted and multidisciplinary approach to addressing these issues is urgently required. The strategy should comprise a series of coordinated experimental, observational and modeling studies that are aimed at detecting and assessing the consequences of global environmental change on mountain regions and, in addition, this strategy should inform policy processes at local to global scales.

The Mountain Research Initiative

To address the many important and complex issues of global change in mountain regions briefly reviewed above, a multidisciplinary initiative 'Global Change and Mountain Regions: The Mountain Research Initiative' (MRI) was launched in July 2001 as a joint endeavour of the International Geosphere-Biosphere Programme (IGBP), the International Human Dimensions Programme on Global Environmental Change (IHDP) and the Global Terrestrial Observing System (GTOS). The ultimate objectives of the MRI are to develop strategies for detecting signals of global environmental change in mountain environments, to define the consequences of these changes for mountain regions as well as lowland areas dependent on mountain resources, and to facilitate the development of sustainable resource management policies for mountain regions. MRI publishes a newsletter bi-annually in the journal *Mountain Research and Development* and, in addition, has initiated activities with UN FAO and with UNESCO (this project). Most recently, MRI has joined IUCN's Mountain Initiative Taskforce and the International Partnership for Sustainable Development in Mountain Regions (IPSDMR), which was launched during the World Summit on Sustainable Development in Johannesburg, South Africa.

To achieve the above long-term objectives, the MRI research strategy has been structured around the following four primary 'Activities' (themes), each of which is divided into a number of specific tasks.

- *Activity 1: Long-term monitoring and analysis of indicators of environmental change in mountain regions.* This element of the Initiative focuses on mountain-specific indicators of environmental change, which are sensitive to climate, atmospheric chemistry, radiation and land use/land cover. A set of four mountain-specific indicator groups is considered:
  - cryospheric indicators related to snow conditions, glaciers, permafrost and solifluction processes

  - terrestrial ecosystems, particularly mountain plant communities and soils
  - freshwater ecosystems, in particular high mountain streams and lakes
  - watershed hydrology, that is, water balance components of high mountain watersheds/headwater basins.
- *Activity 2: Integrated model-based studies of environmental change in different mountain regions.* To achieve the overall goals of the MRI, it is necessary to develop a framework that permits the analysis and prediction of hydrological and ecological characteristics and their linkages with land use and climate at various spatial and temporal scales. Accordingly, this activity is organized around the following:
  - development of coupled ecological, hydrological and land use models for the simulation of land cover and land surface processes in complex mountain landscapes
  - development of regional scale atmospheric models for mountain regions
  - integrated analysis of environmental change in mountain regions by means of fully coupled land–atmosphere models or by qualitative assessments
  - regional-scale mountain land experiment to support the development, application and validation of the above models.
- *Activity 3: Process studies along altitudinal gradients and in associated headwater basins.* Ecological and hydrological field studies and experiments along altitudinal gradients and at sensitive sites can provide invaluable data on potential responses of mountain ecosystems to anthropogenically induced environmental change. Research themes to be addressed within this activity include:
  - development of indicators of mountain ecosystem response to environmental forcing factors to facilitate process-related interpretation of historical and paleorecords
  - assessment of runoff generation and flowpath dynamics on steep hillslopes and in head-water catchments
  - the relationship between diversity and ecosystem function, taking advantage of the strong changes of diversity along altitudinal gradients.
- *Activity 4: Sustainable land use and natural resource management.* The ultimate objective of the MRI is to evaluate and enhance sustainable land, water and resource management strategies for mountain regions worldwide. Three priority areas are suggested for assessment:
  - changes in forest resources, with potential implications for agriculture, rates of erosion and magnitude of floods, and biodiversity
  - intensification and/or extensification of agriculture (including grazing), with potential implications for food security, rates of erosion and magnitude of floods, and biodiversity
  - changes in water resources due to factors such as changing agricultural practices, increasing temporary or permanent population, and/or increasing energy generation, with implications for downstream water supply, energy availability, flooding, and sediment transfer.

On the scientific level, the Initiative expects to achieve:

- improved knowledge of the dominant processes underlying global changes and their future development in different mountain regions of the world

- comparative analyses of the sensitivity and vulnerability of mountain regions to anthropogenic and natural driving forces
- identification of suitable indicators of global changes, and development of protocols for the detection and attribution of such changes
- tools for the integrated assessment of global changes in specific mountain regions
- an improved knowledge base for defining strategies towards the sustainable development of mountain regions.

On a 'meta' level, the expected results of the MRI include:

- the formation of a global network of scientists who are dealing with global change processes in mountain regions
- minimization of redundancies and overlap in ongoing research efforts
- exploitation of synergies between research groups from various disciplines and various geographical regions
- 'adding value' to current, often fragmented, research efforts by providing a common theoretical framework and focus for the research.

It is especially the 'meta' level of the MRI that provides an important link between regional mountain-related research and global research efforts.

UNESCO-MAB MOUNTAIN BIOSPHERE RESERVES

Mountain regions play a prominent role within the framework of UNESCO's Programme on Man and the Biosphere (MAB), and particularly within the World Network of Biosphere Reserves. Biosphere reserves are internationally recognized, nominated by national governments, remain under sovereign jurisdiction of the states where they are located, and are established to promote and demonstrate a balanced relationship between humans and the biosphere. In many ways biosphere reserves are 'living laboratories' for testing out and demonstrating integrated management of land, water and biodiversity. Each biosphere reserve is intended to fulfil three basic functions, which are complementary and mutually reinforcing:

- A conservation function: to contribute to the conservation of landscapes, ecosystems, species and genetic variation in the biosphere reserves' core area(s), which are legally protected.
- A development function: to foster economic and human development which is socio-culturally and ecologically sustainable in the sites' buffer and transition zones.
- A logistic function: to provide support for research, monitoring, education and information exchange related to local, national and global issues of conservation and development. This function applies to the entire biosphere reserve, its core, buffer and transition zones.

The significance of mountain regions within the World Network of Biosphere Reserves is clear: of the 440 biosphere reserves, over 40 per cent are situated in mountainous regions, and these are widely distributed in over forty countries around the world.

Providing a better understanding of global environmental change through research activities in biosphere reserves is an explicit priority for the UNESCO-MAB Programme. Biosphere reserves encourage research, for example on ecological processes or on biological diversity. They are areas offering a growing database on which to build new hypotheses and experiments. In addition, biosphere reserves provide long-term security for permanent plots and monitoring activities as they contain protected areas (such as national parks or nature reserves) which serve to identify longer-term trends over short-term fluctuations, as may be caused by changes in climate and so on. Biosphere reserves also allow for interdisciplinary research and monitoring, and information exchange.

Unlike 'classical' types of protected areas (for instance, national parks), biosphere reserves also comprise people in their buffer zone and, more importantly, in their transition zones. These are the areas where people live and make a living, but where economic activities are carried out in line with conservation objectives so as not to impact negatively on the core zone(s) of a biosphere reserve. Each biosphere reserve, therefore, is an ideal site to study human–environment interactions as the overall management of a biosphere reserve includes both the protected and the non-protected areas.

The understanding gained from scientific research in mountain biosphere reserves provide government decision makers and agencies with better information on natural resources, and enhanced technical and institutional capabilities to manage natural resources in a sustainable manner. This research also helps to procure greater public support of nature conservation through demonstrating the practical benefits involved. Further, these activities may serve as working examples to explore how natural resources can be managed within sustainable limits at the local and regional levels, and what institutional and legal mechanisms are needed in order to achieve this. In doing so, biosphere reserves may serve as tools that enable countries to meet their obligations under international Conventions, such as those on Biological Diversity, Combating Desertification, and *Agenda 21.*

OPPORTUNITIES FOR GLOBAL CHANGE RESEARCH IN MOUNTAIN BIOSPHERE RESERVES

The strong altitudinal gradients in mountain biosphere reserves provide excellent opportunities to detect and analyse global change processes and phenomena. Meteorological, hydrological, cryospheric and ecological conditions change strongly over relatively short distances. Thus biodiversity tends to be high, and characteristic sequences of ecosystems and cryospheric systems are found along mountain slopes. The boundaries between these systems, in particular at the ecotones of the forest zone, the alpine zone and the nival zone, experience shifts due to environmental change and may be used as sensitive indicators of forcing mechanisms. In addition, the core areas (often the higher parts) of mountain biosphere reserves are not heavily affected by direct human activities, and consequently provide locations where the environmental impacts of climate change alone can be studied directly. Lastly, mountain biosphere reserves are widely distributed across the globe, from the Tropics nearly to the Poles and from oceanic to highly continental climates. This wide and varied distribution provides opportunities for comparative regional studies and for analyses of regional differentiation of environmental change processes. Related to the changing environmental conditions along mountain slopes, changes also occur in socio-economic conditions, land-use and land-management practices, resource exploitation and the appeal of mountain regions for tourism. Hence, the high environmental sensitivity of many mountain biosphere reserves provides ideal circumstances for studying global change phenomena.

A corollary of this environmental sensitivity, often coupled with marginal economic circumstances, is that mountain regions will likely be particularly vulnerable to the anticipated global changes of the twenty-first century. Addressing the potential impacts and consequences of global change in mountain biosphere reserves, and identifying the best approach for effectively mitigating these issues will require innovative strategies. Such strategies not only need to integrate research within the physical sciences, but they must also incorporate research efforts from the social sciences in order to forge an overarching research framework.

By establishing a cooperative research programme, both MRI and UNESCO-MAB intend to realize significant added value to their research efforts. On the one hand, the MRI represents a network of global change researchers, from a wide variety of disciplines, who are keenly interested in global change research in mountain regions and who would benefit from working with the UNESCO-MAB infrastructure that links mountain biosphere reserves worldwide. The global change scientific community would also benefit from the valuable experience gained by UNESCO-MAB concerning global change issues in the many mountain biosphere reserves (including traditional knowledge). In many cases, the structure of UNESCO mountain biosphere reserves provides ideal natural global change laboratories with core, protected, mountainous areas surrounded by lower-elevation buffer zones and transition areas that are more strongly influenced by human activities. For its part, the UNESCO-MAB Programme would benefit from the accelerated level of global change science in the mountain biosphere reserves and both the experience of the scientific community and the linkages to global change organizations such as IGBP, IHDP, GTOS, GMBA and GLORIA, to name a few. The establishment of MRI research programmes within biosphere reserves will therefore strengthen the significance of the reserves and will contribute to longer term monitoring of natural and human induced environmental change.

Consequently, the MRI Scientific Advisory Board and the international UNESCO-MAB Secretariat at UNESCO's Division of Ecological Sciences have agreed in principle to cooperate on developing a strategy for implementing global change research in mountain biosphere reserves around the world. The ultimate objective of this collaboration is to provide an integrative research framework for inter-regional interdisciplinary studies that addresses the causes and impacts of environmental and socio-economic changes in mountain biosphere reserves. Such an overarching research framework is necessary for the development of effective strategies, and ultimately policies, that will ensure sustainable development within the mountain biosphere reserves. Moreover, we believe that the project, which has been launched with this 'kick-off' workshop, should provide a valuable template for research projects geared towards elucidating, assessing and predicting global change processes in mountain regions in general and their consequences for nature and humanity. Through such an integrated research framework, it should be possible to attain the critical mass of researchers from separate disciplines that will be necessary to establish crosscutting linkages between research activities, including long-term assessments, integrated model-based studies, process studies along altitudinal gradients, and sustainability strategies in mountain regions. In addition, the framework will provide means to explore and develop strategies that will ensure these activities are integrated, coordinated, consistent and effectively applied.

Moreover, the involvement of UNESCO's International Hydrological Programme (IHP) is an asset to this project. IHP is an intergovernmental scientific cooperative programme in water resources, which aims at the improvement of the scientific and technological basis for the development of methods for the rational management of water resources, including the protection of the environment. It strives to minimize the risks to water resources systems, taking fully into account social challenges and interactions and developing appropriate approaches for sound water management.

Given the large number of mountain biosphere reserves, their diverse settings and the various degrees to which global change research programmes have been established within these sites, it will be necessary to focus the initial efforts of the joint UNESCO/MRI project on a few carefully selected 'case study' biosphere reserves. However, the concept and work programme is designed to be of relevance for implementation in all mountain biosphere reserves across the globe and mountain regions in general. Prior to the first workshop, a review and selection process has been initiated with the aim of identifying a set of between fifteen and twenty mountain biosphere reserves that are currently host to ongoing research programmes that represent one or more of the MRI's activities. This will provide a firm understanding of the volume of information that is currently available concerning global change research activities in mountain biosphere reserves. In addition, this initial step will select mountain biosphere reserves that, first, represent most of the world's major mountain ranges, second, span a large altitudinal gradient, and third, represent diverse physical and socio-economic settings.

In a first attempt of selecting case studies of mountain biosphere reserves, we have identified the ones listed below, although this list may still be subject to change. We are glad that several biosphere reserve managers were among the workshop participants and thus were able to provide information on their specific site.

Africa

- Algeria: Tassili N'Ajjer BR (2,158 m)
- Kenya: Mount Kenya BR (5,199 m)
- Morocco: Oasis du Sud BR (4,071 m)
- South Africa : Kruger to Canyons BR (2,050 m)

Asia-Pacific

- Australia: Kosciuszko BR (2,228 m)
- China: Changbaishan BR (2,691 m)
- India: Nanda Devi BR (7,800 m). Note: has been recently proposed for BR designation
- Kyrgyzstan: Issyk-Kul BR (7,439 m)
- Mongolia: Uvs Nuur Basin BR (3,966 m)

Europe

- Austria: Gossenköllersee (2,828 m) and Gurgler Kamm BRs (3,400 m)
- Germany: Berchtesgaden Alps BR (2,713 m)
- Spain: Sierra Nevada BR (3,482 m)
- Sweden: Lake Torne BR (1,610 m)
- Switzerland: Entlebuch BR (2,350 m)
- Switzerland: Swiss National Park (3,174 m)

North America

- Canada: Mount Arrowsmith BR (1,817 m)
- USA: Glacier National Park BR (3,185 m)
- USA: Niwot Ridge BR (3,780 m)
- USA: Denali BR (6,194 m)

Latin America

- Chile: Araucarias BR (3,124 m)
- Chile: Torres del Paine BR (3,050 m)
- Colombia: Cinturón Andino BR (5,750 m)
- Peru: Huascarán BR (6,768 m)

We are happy that all the components of the MRI's implementation plan were addressed during the initial workshop at the Entlebuch Biosphere Reserve (Switzerland). The primary objectives for the workshop were:

- To review the state of global change research (natural, social, cultural, economic and political sciences) in a range of mountain biosphere reserves that could be used as pilot study areas for implementing the activities defined (and prioritized) by the MRI.
- To refine and prioritize the MRI activities to an operational level.
- To identify gaps in coverage and methodological problems with respect to global change research in mountain biosphere reserves.
- To provide guidelines for implementing, fostering and coordinating integrated global change research in mountain biosphere reserves around the world, with a view towards general applicability in mountain regions.

1. Australia: Kosciuszko National Park, Biosphere Reserve and GLORIA Site

Ken Green, National Parks and Wildlife Service, Snowy Mountains Region, Jindabyne, Australia

INTRODUCTION

The National Park and Wildlife Service has over 600 designated protected areas, including parks and reserves, which together cover more than 6 per cent of the state of New South Wales. Kosciuszko National Park is one of the world's great national parks, and the largest in New South Wales. It was established as the Kosciusko State Park in 1944 and covered 5,000 km^2. The Kosciusko State Park Trust managed the park until 1967 when it became the Kosciusko National Park under the control of the National Parks and Wildlife Service (the spelling has since changed to Kosciuszko). The former Trust became the local Advisory Committee. Formal recognition of the park's international, as well as national, significance came in 1977, when it became a Biosphere Reserve under UNESCO's Man and the Biosphere (MAB) programme. With various additions in recent years, Kosciuszko National Park now covers almost 6,750 km^2. The Biosphere Reserve contains the highest mountains in Australia, a great variety of outstanding scenery and natural features, plant and animal communities, historic features and opportunities for recreation purposes. The snow-fed rivers of the mountains provide some of Australia's most important water catchments, the protection of which was a major factor in the granting of the State Park status in 1944. These catchments are now at the centre of major artificial features in the Biosphere Reserve: the Snowy Mountains Hydroelectric Scheme.

Kosciuszko Biosphere Reserve is a part of the Australian Alps that stretch from Canberra through to the Brindabella Range in the Australian Capital Territory, and the Snowy Mountains of New South Wales and along the Great Dividing Range through Victoria. This mountain environment, a mountainous biogeographical region in a predominantly dry and flat continent, is a unique part of Australia and contains all the alpine and subalpine habitats found on the mainland. The national parks and reserves in the Australian Alps comprise over 16,000 km^2 of protected areas across both State and Territory borders. Nine conservation reserves are collectively referred to as the Australian Alps national parks. The reserves are managed as part of the Alps programme under a Memorandum of Understanding (MoU) between the political divisions, and include, Kosciuszko, Namadgi, Alpine, Mount Buffalo, Snowy River and Brindabella National Parks, Bimberi Nature Reserve, Scabby Range Nature Reserve and the Avon Wilderness. Through cooperation and joint management the national parks and reserves in the Australian Alps are managed as one biogeographical entity.

To assist conservation agencies to manage these parks in a consistent and compatible manner, the ministers responsible for the management of these protected areas signed a Memorandum of Understanding in July 1986 with respect to the cooperative management of the Australian Alps. Responsibility for the day-to-day management of the Australian Alps national parks remains vested with each agency, party to the MoU. The majority of works undertaken within the Australian Alps national parks are undertaken by the managing agencies in line with agreed strategies and statutory management plans.

LOCATION AND DESCRIPTION

Kosciuszko Biosphere Reserve is located 500 km southwest of Sydney at approximately 36°30'S, 148°15'E. It contains the highest mountains in Australia, including 250 km^2 of alpine and 1,065 km^2 of subalpine vegetation, and all New South Wales ski fields. It is located in the state of New South Wales, extending from the border with Victoria in the south to the border with the Australian Capital Territory (containing the nation's capital, Canberra) in the north. Kosciuszko Biosphere Reserve straddles the Great Dividing Range (locally known as the Snowy Mountains) and is the main water catchment for the headwaters of the Murrumbidgee and Murray Rivers (both flowing towards the west) and the Snowy River flowing to the south.

During the Ordovician period the area now occupied by the Kosciuszko Biosphere Reserve was part of a deep marine basin in which coastal sediments, ash and lava flows accumulated. Today, these uplifted and altered Ordovician sediments have only a limited extension, outcropping as a series of narrow belts in the Kosciuszko Biosphere Reserve. The rocks associated with these areas consist of folded and deformed sandstone, siltstone, shale, chert, agglomerate, and various volcanic rocks such as basalt and gabbro. In many places the softer sedimentary rocks have been deeply eroded and now contribute to the steeper and more dissected mountain landscapes such as those that occur on the western side of the Main Range near Mt. Kosciuszko. Deposition of sediments, together with folding and uplift, continued until the late Silurian when granitic intrusion occurred in the deformed sediments. The granites formed at this time make up the Kosciuszko batholith. The main rocks in these areas are biotite granodiorite, adamellite, granite and quartz porphory. These granitic rocks are now the most common and widespread rock types in the Kosciuszko Biosphere Reserve.

Crustal stability accompanied by erosion during the ensuing 300 million years again led to the gradual levelling of these mountains and the formation of a relatively flat land surface. Volcanic activity and the uplifting of fault blocks throughout much of the Tertiary led to the formation of much of the present topography. The basalt lavas in the northern Snowy Mountains represent rock types formed during the Tertiary. The Tertiary lava flows frequently followed the line of former river valleys and now occur as distinctive flat-topped mountains and ridges.

During the Pleistocene the alpine areas were subjected to a series of intense and relatively dry, cold periods with the most recent (35,000 to 12,000 years ago) being sufficiently cold to allow for the formation of small valley glaciers in the Snowy Mountains. This glaciation resulted in the present day glacial features including lakes, tarns, moraines and boulder erratics. At lower altitudes, in what is now the subalpine zone, the cold climate was responsible for the development of a number of periglacial features such as blockstreams, nivation hollows, non-sorted steps, earth hummocks and solifluction deposits. The last glacial period ended 12,000 years ago, and 10,000 years ago the climate and natural vegetation resembled that existing today.

Much of the Kosciuszko Biosphere Reserve consists of deeply dissected uplifted mountain ranges and high plains that lie between about 1,400 and 1,800 m above sea level. The highest summits occur in the Snowy Mountains region where they make up an extensive, rolling alpine ridge usually referred to as the Main Range. To the northwest of the Snowy Mountains the land drops very steeply to the Geehi River at 400 m above sea level. In contrast, the land surface to the east and south descends gradually in a series of steps to the lower Monaro Tableland which lies at about 900 m above sea level. Some 40 kilometres north of the Snowy Mountains the Bimberi Range represents a significant outlier of rugged subalpine country. To the south and east of the Main Range are further tracts of subalpine country which include the Pilot, and across the border in Victoria, extensive mountain areas in the Cobberas and the Davies Plain to the west of the upper Murray River.

Most of the subalpine and alpine areas of the Snowy Mountains have a covering of soil. In granite areas the soil can be very deep, but the soils derived from the weathering of fine-grained igneous rocks such as porphries and lavas are usually shallow. The soils are uniformly acidic to strongly acidic and low in available nutrients. The most common soil type in the snow-country is the alpine humus soil, which occurs in a wide range of environments above the winter snow-line, except in extremely windswept areas or areas with impeded drainage. It is characterized by a dark, friable appearance and is rich in organic material, including earthworms. At lower altitudes, alpine humus soil is replaced by transitional humus soil and brown podzolic soil. Lithosol soils occur on steep, exposed and snowpatch sites, usually at high elevations. In more sheltered environments where drainage is impeded, the soils include bog peats, humified peats, fen peats and meadow soils.

VEGETATION ZONES IN THE BIOSPHERE RESERVE

The vegetation communities reflect the variation in both altitude and rainfall. The western forests are tall and carry thick understoreys of ferns, blanket leaf, blackwood and other species; cool temperate rainforest gullies are also present. The western escarpment of the Main Range has the greatest range (and quickest changes) in vegetation. Often in distinct bands, the montane forests are dominated by stringy barks and gums, and change in sequence through swamp gums, peppermint forests, blue gums, mountain gum, candlebark and ribbon gum, snow gum and alpine ash, before reaching pure snow gum stands immediately below the treeline.

The area above the treeline also displays remarkable diversity, and some of the rarest plant communities of the Kosciuszko Biosphere Reserve are found there. The true alpine area forms a minute fraction of the continent of Australia but contains a wide range of plant communities such as tall alpine herbfields, heathlands, sphagnum bog and fen communities, and very rare communities including short alpine herbfield, windswept feldmark and snowpatch feldmark. In the undulating terrain of the eastern fall, large basins are collecting areas for cold air on still nights. These 'frost hollows' are naturally treeless. East of the higher peaks it is drier and at lower altitudes there are extensive stands of native cypress pines.

DEMOGRAPHIC AND ECONOMIC CHARACTERIZATION OF THE BIOSPHERE RESERVE (INCLUDING LAND USES)

The present status of the Kosciuszko Biosphere Reserve is only the latest in a succession of land uses in the area following Aboriginal occupation (dated back to at least 21000 B.P. just north of the Kosciuszko Biosphere Reserve at Birrigai): European exploration, grazing, mining, skiing, tourism and, after the establishment of the park, construction of the Snowy Mountains Hydroelectric Scheme.

The main economic value of the Kosciuszko Biosphere Reserve is derived from the major water catchments and tourism: the Reserve includes the headwaters of the Murray, Murrumbidgee and Snowy Rivers systems, which together constitute one of the most important protected water catchment areas in Australia. Water supplies for many towns and cities, for irrigation in the Murray Valley (in three states) and in the Murrumbidgee Irrigation Area, and for peak-load power for the cities and industries of New South Wales, Victoria and the ACT depend to a considerable extent on the protection of the water catchments and snowfields within Kosciuszko Biosphere Reserve. Snowy Hydro Limited operates and maintains the Snowy Mountains Scheme, an integrated water and hydroelectric power project that generates around 4,500 gigawatt hours of electricity each year. Snowy Hydro also manages water flows from the Snowy Mountains Region into several rivers, including the Murrumbidgee and Murray. It is a self-supporting corporation jointly owned by Governments of the Commonwealth (13 per cent), New South Wales (58 per cent) and Victoria (29 per cent). It brings in total annual revenues of approximately AUS$160 million.

Summer tourism is concentrated in areas of aesthetic appreciation: for example, snow-covered ranges, the area above the treeline, the glacial lakes, rugged gorges and forested mountain ranges, the broad expanses of wooded hills and open valleys, limestone caves (such as Yarrangobilly and Cooleman Plain), waterfalls and cliffs. Over 2,000 people per day visit the alpine area during the peak summer holiday period. The main appeals of the alpine area are: the highest point in Australia, Mt. Kosciuszko at 2,228m; the presence of snow in drifts, sometimes right throughout the summer; and the wildflower display. The main activities include car and bus touring, sightseeing, picnicking, camping, bushwalking, rock-climbing, caving, horse-riding, cycling, canoeing, hang-gliding, fishing, swimming, photography and painting. Summer tourism brings an estimated AUS$70–100 million per year into the area.

Winter tourism activities include alpine skiing, nordic skiing, ski touring, tobogganing and general snow recreation. There are four major ski resorts within the KBR and winter tourism brings an estimated AUS$190 million into the area annually.

ONGOING GLOBAL CHANGE PROGRAMMES AND RESEARCH PROJECTS

Availability of Climate, Vegetation, Hydrological, Economic and Demographic Data

Systematic climate data collection was first recorded from the goldrush town of Kiandra (now abandoned) in 1887; the final recordings were taken in 1995. Recordings from the nearby Snowy Mountains Hydroelectric Scheme town at Cabramurra have also covered the area since 1955.

Table 1.1 *Long-term monitoring in Kosciuszko Biosphere Reserve*

Contact	Discipline	Location	Description	Year
Australian Bureau of Meteorology (BOM)	Weather	Snowy Mountains	Weather stations at various locations (see text)	1887–present
Snowy Hydro	Weather	Snowy Mountains	Weather stations at various locations	1953–present
Ken Green	Climate	South Ramshead	Ambient, subnivean and soil temperatures above treeline	1981–present
Snowy Hydro	Snow	Snowy Mountains	Snow course measurements at three sites weekly and ten additional snowcourses monthly	1954–present
Ken Green	Snow and ice	Blue Lake	Ice breakup date and ice thickness	historical–present
Ken Green	Snow	Whites River	Weekly snow course measurement	1998–present
Will Osborne/ Ken Green	UV-B	Snowy Mountains	UV-B Pyranometers	1998–present
Catherine Pickering/ Ken Green	Vegetation	Mt. Clarke	GLORIA	2002 onwards
Jennie Whinam	Botany	Snowy Mountains, New England, ACT highlands	Changes in extent and health of Sphagnum moss beds	2001–present (some 1954 data)
Keith McDougall/ Neville Walsh	Plant ecology	Treeless plant communities (frost hollows)	Permanent quadrats (c. 210)	2002 onwards
Pascal Scherrer/ Dane Wimbush/ Alec Costin	Vegetation/ Ecology	Kosciuszko and Gungartan	Vegetation succession, restoration and climatic influences	Monitoring began in 1959 (last surveyed 2002)
Ken Green	Zoology	9 locations	Population monitoring of Broad-toothed Rat	1978–present
Linda Broome	Zoology	4 locations	Population monitoring of Mountain pygmy-possum	1982–present
Ken Green	Zoology	Disappointment Spur	Bird migration in relation to snow cover and flowering phenology	2000–2 (continuing new location 2003)
Ken Green	Zoology	Snowy Mountains	Soil and soil-surface invertebrates above treeline	2003 onwards

Tourism, as the next major economic activity, began recordings at Charlottes Pass (1,759 m) in 1930 and later with skiing from Thredbo Crackenback (1,957 m) in 1966; Thredbo Valley (1,366 m) in 1969; and Perisher Valley (1,720 m) in 1976. This data is available from the Australian Bureau of Meteorology. A major boost to monitoring within the Kosciuszko Biosphere Reserve came about with the establishment of the Snowy Mountains Hydroelectric Scheme, and consequently data is available from Tooma Dam (1,220 m) since 1959; Guthega Power Station (1,340 m) since 1953; and Jagungal Pluviograph (1,670 m) since 1958. This data is available upon request from Snowy Hydro Limited.

The Snowy Mountains Hydroelectric Authority (now Snowy Hydro Ltd.) has taken measurements of snow depth and water content at a number of sites since 1954. Three sites are measured weekly and ten additional snow courses are measured monthly. Historical data from the three snow courses measured weekly are available on the Internet (www.snowyhydro.com.au). Snow course measurements throughout the winter season from the three sites measured weekly can be monitored on www.bom.gov.au. Monthly data measurements for Whites River snow course since 1957 and weekly measurements since 1999 are available from Ken Green. Other snow course data may be available on request from Snowy Hydro Limited for research purposes

Data on UV-B from Pyranometers at Perisher Valley (1,720 m) and at Berridale (800 m) from 1998 to the present are available from Ken Green.

A map of vegetation classes for the Kosciuszko Biosphere Reserve produced by McCrae is available on GIS. There is also a vegetation database based on vegetation survey, and a herbarium is located within the park. This data is available upon request from NPWS. A publication on the flora of the alpine zone (Costin et al.) has recently been reprinted.

Hydrological data from gauging stations on major rivers, originating mainly from the Mountains Hydroelectric Scheme, is available for research purposes upon request from Snowy Hydro Limited.

There is little economic and demographic data pertaining to the Kosciuszko Biosphere Reserve. It has virtually no permanent residents but there are several small communities situated just outside its border, particularly at Jindabyne in the southeast and Tumut in the northwest, where the main administrative offices for Kosciuszko Biosphere Reserve are located.

CONCLUSION

The Kosciuszko Biosphere Reserve is an excellent place to assess the impacts of global changes on mountain ecosystems because the Snowy Mountains have marginal snow conditions that are very important to a dry, flat continent. The Reserve has a history of intensive long-term study dating back to the work of Alec Costin, which began in 1946 and in which he is still involved. Because of this we have a good record (both documented and oral) of changes that have occurred in the past fifty years and as a consequence we are now able to distinguish which changes can be attributed to climatic change rather than local disturbances. The Kosciuszko Biosphere Reserve has a relatively small scientific research infrastructure but has a tradition of long-term monitoring with a number of databases, a well-stocked herbarium, and some accommodation for visiting researchers, and is very receptive to invitations to participate in collaborative studies.

2. Austria: Gossenköllesee Biosphere Reserve

Roland Psenner and Birgit Sattler, University of Innsbruck, Institute of Zoology and Limnology, Innsbruck, Austria

INTRODUCTION

The County of Tyrol has two biosphere reserves in its alpine region: Gurgler Kamm Biosphere Reserve in the inner Ötztal Valley, and Gossenköllesee Biosphere Reserve in Kühtai. The latter is the smallest biosphere reserve in the World Network of Biosphere Reserves.

The UNESCO Gossenköllesee Biosphere Reserve was established in 1977 in order to guarantee long-term ecological research. It is characteristic for high alpine regions and has a largely intact natural environment. The centre of scientific interest in the Reserve is the long-term change of alpine lakes, streams and entire catchments. The two lakes, Vorderer and Hinterer Finstertaler See, were converted into a reservoir for hydroelectric power generation in 1974, and dam construction flooded the existing limnological research station, established in 1959 on the shore of the Vorderer Finstertaler See. A new station was built in 1975 on the opposite slope of the Kühtai Valley, the so-called Limnological Station Gossenköllesee, and was completely reshaped and enlarged in 1995. After twenty-five years, this is still an attractive and highly relevant subject for both ecological research and environmental protection.

LOCATION AND DESCRIPTION

Gossenköllesee Biosphere Reserve is located in the Stubaier Alps at an elevation ranging from 2,417 m (lake level) to 2,828 m above sea level (Pirchkogel) at 47°14'N and 11°01'E, and has an area of 85 ha. During the Ice Age the whole area was glaciated. After the ice retreated at the beginning of the Holocene several lakes were formed, four of which still exist today; the largest of these is Gossenköllesee. The bedrock of the drainage area is granitic and consists of crystalline schist and gneiss. The moraine forming the natural dam of Gossenköllesee is composed of amphibolites, granite gneiss and mica slate.

The lake – the core area of the biosphere – is subpolar, oligotrophic and dimictic in character with a maximum depth of 9.9 m and an area of 16,700 m^2. It is covered for up to eight months of the year with an alternating sheet of ice, snow and slush, which has a critical influence on light transmission, stratification and nutrient exchange of the pelagic zone. The lake has no surface inflows and outflows, except a small outlet during snowmelt. It harbours one of the last populations of the Danubian brown trout (*Salmo trutta*), probably descended from fish stocked by the Emperor Maximilian in A.D.1500. It is accessible all year round, lying within an hour's walking distance from the small village of Kühtai, a well-known ski resort situated about 30 km west of Innsbruck that can be reached daily by car and public transport.

The Gossenköllesee Biosphere Reserve is a centre of alpine research for the European Union with a fully equipped research station at the shore of the lake that undertakes the collection (and to some extent analysis) of sensitive samples and maintains automated observation of climate and hydrology on site. The station has accommodation for up to six people, and was modernized and equipped with telephone, modem and electrical energy in 1994, allowing for emission-free heating and operation of the equipment. Since 1992, Gossenköllesee has been a key site in various EU projects (ALPE, MOLAR, EMERGE) and is included in the Integrated Project EUROLIMPACS and the Network of Excellence ALTER-NET (6th Framework Programme). Over the last three decades the atmospheric deposition, lakes, streams, soils and vegetation of the Biosphere Reserve have been subjects of MSc dissertations, PhD theses and international projects. Beginning in 2004, Gossenköllesee BR, which is unique as a centre of scientific education, will be the principal site for research focus of the Innsbruck University (ALPINER RAUM–ALPINE SPACE). The importance of the station for research and teaching can be illustrated by a few examples:

- Since the renovation of the research station in 1994 close to 3.5 million euros has been invested in research; this amounts to a total investment of about 5.7 million euros since the creation of the station in 1975.
- Since 1975, twenty-four students have conducted research related to Gossenköllesee Biosphere Reserve for their MSc or PhD theses.
- To date, 154 reports, theses and scientific papers have been published.
- Since 1997, 108 talks or displays have been presented at scientific events.
- Results from the Biosphere Reserve have drawn great attention in public media (newspapers, journals, magazines, radio and television): over 100 reports, more than thirty interviews and about ten TV documentaries have been broadcast.

VEGETATION ZONES IN THE BIOSPHERE

The Biosphere Reserve lies entirely in the alpine zone, that is, above the present and possibly also the historical treeline. It harbours several alpine plant species such as rhododendron, dwarf shrubs and typical representatives of alpine grass heath.

CHARACTERIZATION OF THE SITE ABOVE THE VEGETATION LINE

Approximately 10 per cent of the catchment area is covered by thin soils, mostly raw and podsolic soils with low pH. The surroundings are characterized by large rocks and moraines, which offer shelter to marmots, chamois, ermines, foxes and adders.

DEMOGRAPHIC AND ECONOMIC CHARACTERIZATION OF THE BIOSPHERE RESERVE (INCLUDING LAND USES)

The Biosphere Reserve, which is part of the local agrarian community, is bordered by a ski resort and can be reached during winter after a short journey using skies or snowshoes.

During the summer Gossenköllesee BR is accessible on foot via a narrow trail (one-hour walk), and in good weather conditions (in late summer) is even accessible by jeep. As a result of the moraine, the lake and the station are hidden from view and therefore rarely visited by hikers or skiers. During the summer sheep graze in Kühtai, and some go as far as the Gossenköllesee catchment, thus providing additional nutrient input.

A serious problem may arise from a new ski lift that is being proposed to connect Kühtai with its neighbour valleys, Ötztal and Inntal; this would traverse the Biosphere Reserve. The county minister responsible for environmental affairs of the Tyrolean Government has rejected the project because of environmental concerns but there are rumours of a new plan. This may be backed by the new Governor of Tyrol, the son-in-law of Governor Wallnöfer who, ironically, established the Biosphere Reserve in 1977. If the lift were put in operation, several long-term research projects and many of the monitoring activities would be in jeopardy.

ONGOING PROJECTS AND RESEARCH ACTIVITIES

- EURO-LIMPACS, 6th FP, Integrated Project to Evaluate the Impacts of Global Change on European Freshwater Ecosystems, 2004–9.
- ALTER-Net: A long-term Biodiversity, Ecosystem and Awareness Research Network of Excellence, 2003–8.

HYDROLOGY AND CHEMISTRY OF ALPINE LAKES INCLUDING TRIBUTARIES AND GROUNDWATER

Mass fluxes of Gossenköllesee BR are assessed by long-term monitoring and the study of biogeochemical processes in the catchment, the tributaries and the lake. Gauges installed at the outlet and the springs measure input and output of the water flow of the lake, and hence the length of time of residual water. Additionally, lithium chloride (LiCl) was applied as a tracer substance to estimate residual time. To minimize visits to the station, data loggers were installed to provide enhanced data at the tributaries and the lake itself, which is crucial for long-term monitoring and for future plans to include the Biosphere Reserve in the LTER-initiative (long-term ecological research).

MICROBIOLOGY IN ICE AND SNOW

The winter cover of the high mountain lakes (lasting for six to eight months of the year) is a highly active microbial ecosystem. The winter cover, with a thickness of up to 2 m, is composed of alternating layers of slush and ice inhabited by an assemblage of bacteria, algae and protozoa (and metazoans), which are defined as Lake Ice Microbial Communities (LIMCOs) originating from lake water, adjacent soils, the littoral zone and the atmosphere. The winter cover is therefore not solely a physical barrier but exerts an influence on food webs in the pelagic zone as well. It can thus be described as a transient ecotone of high ecological relevance.

AQUATIC PHOTOBIOLOGY AND PLANKTON ECOLOGY

This research topic strives toward a comprehensive understanding of the role of solar UV radiation in the ecology of lakes, and in particular, the influence of UV radiation on carbon and nutrient cycling and species competition. Because of the very low concentration of humus matter, alpine lakes are transparent to UV radiation – in contrast to lakes in forested catchments. Mycosporine-like amino acids, produced by algae, can absorb radiation at 300–340 nm. If taken up by small crustaceans, they provide effective protection against harmful UV radiation. Gossenköllesee was the first freshwater lake where these substances were described. The strategies involved in the protection of aquatic organisms (phytoplankton, protists and zooplankton) against UV damage are assessed in the context of global change.

PALAEOLIMNOLOGY

Palaeolimnology can be seen as a tool to identify past environmental changes that are reconstructed from biological, physical and geochemical records in lake sediment profiles. Climate-driven changes in alpine lakes and their catchments can also be investigated, as well as the impact of atmospheric deposition and pollution. Sediment records evaluated from Gossenköllesee show distinct pollution of lake sediments with metals and with PCBs (polychlorinated biphenyls – chlorinated pesticides).

AQUATIC MICROBIAL ECOLOGY

Gossenköllesee is an oligotrophic lake where microorganisms (viruses, bacteria, heterotrophic nanoflagellates, ciliates and algae) play a major role in the cycling of carbon, nitrogen and phosphorus. Phyolegenetic and physiological studies are performed with the use of modern techniques such as flow cytometry and fluorescent *in situ* hybridization.

FISH ECOLOGY

A durable population of brown trout, originating from the Danube phylotype, can be found in Gossenköllesee Biosphere Reserve. Emperor Maximilian I introduced these fish in A.D.1500, which gives the lake a historical as well as biodiversity value.

Table 2.1 *Chronology of limnological research in Kühtai*

Date	Activities
1933	First investigation of Gossenköllesee by Leutelt-Kipke.
1934–8	Investigation of high alpine lakes in Kühtai by Steinböck.
1959	Construction of the first Limnological Research Station (2,240 m) on the southern shore of Vorderer Finstertaler See.
1962–8	Investigation of hydrological, physical and biological parameters of Gossenköllesee by Nauwerck, Rhode, Eppacher and Pechlaner.
1975	Erection of the new research station on the opposite slope of the valley.
1977	Gossenköllesee and its catchment area is designated as a UNESCO Biosphere Reserve. The Governor of Tyrol, Eduard Wallnöfer, signs the treaty.
1975–93	Limnological research, education of students, meetings, excursions etc.
1994	Complete renovation of the station (telephone, electricity etc.)
1994 onwards	Intensive research, education of students, international courses, large investments in research and expansion of equipment. Start of EU and FWF-projects, funding of the National Bank, bilateral and international projects and co-operation.
1998	The ski lift company presents plans to build a ski lift across the biosphere reserve.
2000	The biosphere reserve is the site of an international meeting ('High Mountain Lakes and Streams') where the scientific and cultural values of alpine regions are discussed.
2002	The Tyrolean government rejects the ski lift project.

3. *China: Global Change Monitoring Activities in Changbaishan Biosphere Reserve*

Li Yang, Changbaishan Biosphere Reserve, Jilin Province, People's Republic of China

Changbaishan Natural Reserve, founded in 1960, is located to the southeast of Jilin province, and bordered by North Korea to the southeast. It is situated at longitude 127°42'55"–128°16'48"E and latitude 41°41'49"–42°25'18"N. The longest stretch of the reserve extends 80 km from south to north and 42 km from east to west. It occupies 196,465 ha with 80 per cent of the area covered by forest. It represents a typical mountain forest reserve.

Changbaishan Biosphere Reserve is rich in natural resources and diversified ecosystems, and is thus of considerable value for research and conservation. In 1980, Changbaishan Natural Reserve joined the World Network of Biosphere Reserves and became an international nature conservation base. The major objectives of the Reserve are:

- To protect natural resources, the environment and its historical heritage.
- To save rare and endangered species.
- To manage and utilize the natural resources appropriately; to establish a preservation base for the conservation of the various species; promote scientific research, education, environment monitoring and natural landscape conservation; and ensure and maintain its ecological balance.

Changbaishan Biosphere Reserve is surrounded by a vast natural forest and is centred on the peak of Changbaishan, rising to 2,691 m, which was formed by a series of volcanic eruptions. The most recent of these occurred in 1702 and the resulting fires destroyed more than 50 km^2 of forest; we can still find carbonized wood buried in the volcanic ash. The mountain summit, which is covered by volcanic ash, is generally capped by snow from October to June.

The climate in the region is typically continental and mountainous, with a long winter and a short, warm, rainy summer. The mean annual temperature ranges from 3 °C to –7 °C, with about 2,300 hours of sunshine annually. The frost-free period lasts about 100 days, with only sixty frost-free days at the mountain peak. Precipitation is abundant with an annual average of 700 mm to 1,400 mm, 60–70 per cent of which occurs from June through to September. At the mountain summit, the precipitation is mainly in the form of snow. The thickness of snow in winter is generally about 50 cm and can be more than 70 cm in some areas.

There are no inhabitants within the reserve, though there are people working on monitoring sites for environmental and ecological studies as well as earthquake/volcanic activity. Approximately 250,000 people live in the nearby twenty-two villages or towns, the biggest of which is Erdaobaihe with about 50,000 inhabitants. A significant proportion of the inhabitants who live on the periphery or intermittent patches of the forest cultivate crops for Chinese herbal medicine, particularly ginseng and edible fungus, from which they earn an income. Other inhabitants run the restaurants, hotels and other services that cater for tourists. Other professions include local government officers, teachers, bankers, doctors and tax officers.

The integrated impacts of climate, soil and hydrology are responsible for the formation of the unique vegetation and biological communities of diversified species from temperate to polar zones. Within a horizontal distance of 45 km, the elevation rises almost 2,000 m from the lowlands to the mountain summit, providing a wide variation of climate, soil and species that form several distinct vegetation zones. The lowest zone comprises the broad-leaved Korean pine mixed forests, then come coniferous forest, subalpine Erman's birch dwarf forests and alpine tundra, which represent all the ecological landscapes from temperate to polar zones.

Flora in the reserve can be classified into the following groups: Changbai flora, south Okhotsk flora and polar flora. Mixed forests of broad-leaved Korean pine *spp.* belong mainly to the Changbai flora group, species found in the dark coniferous forest belong principally to the south Okhotsk flora, and species of the alpine tundra are typically polar flora. According to the preliminary survey, there are more than 2,210 plant species in the Biosphere Reserve, including:

- 1,329 species of angiosperms belonging to 92 families and 441 genera
- 17 species of gymnosperms belonging to 3 families
- 125 species of ferns belonging to 21 families and 38 genera
- 170 species of moss belonging to 32 families and 80 genera
- 213 species of lichen belonging 20 families and 43 genera
- 365 species of fungus belonging to 27 families and 95 genera.

Thirty-seven of these are considered rare and endangered species and are thus nationally protected, including *Panax ginseng*, *Chosenia arbutifolia*, *Pinus ednsiflora var. sylvestriformis* and *Rhodiola angusta*.

Figures 3.1 and 3.2 show the monthly average temperature and precipitation variations throughout the year among the four zones, which range from 750 m to 2,600 m in elevation. The meteorological data monitored over the last twenty years indicate that the average annual temperature from 1982–2002 shows an increasing trend (Figure 3.3) while annual precipitation remains almost unchanged (Figure 3.4).

There is evidence from observation and monitoring studies to suggest that certain natural phenomena have gradually changed over the last thirty years. During the early 1970s, we observed that the snow period usually began in mid-September, ending in July of the following year. However, we now observe the snow period beginning in October and ending earlier; the period when snow is seen on the mountain summit has also diminished. Twenty years ago there were perennial scattered snow patches in the valleys throughout the year above 2,300 m elevation. Today no snow patches are found during the hot summer months.

Figure 3.1
Monthly average temperature of each zone

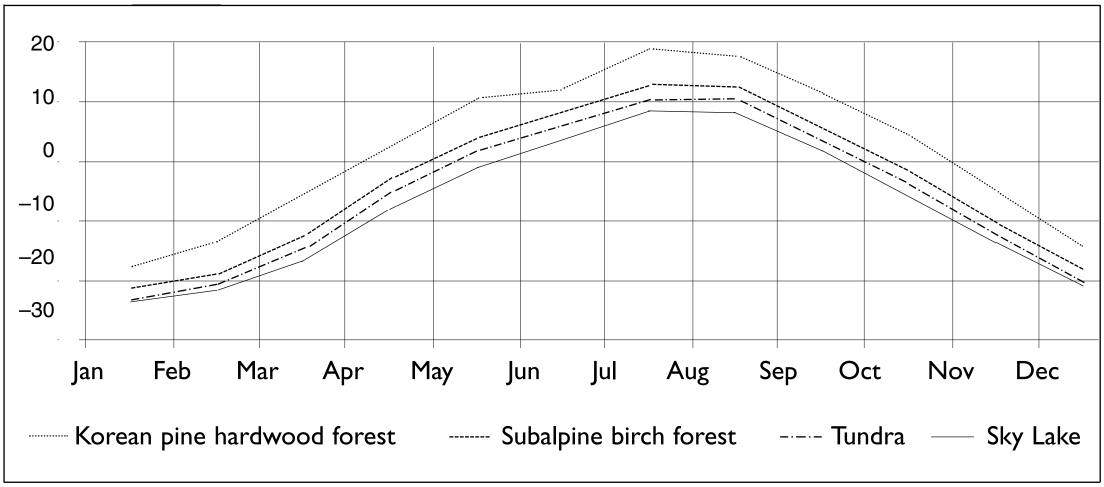


Figure 3.2
Monthly average precipitation at each zone

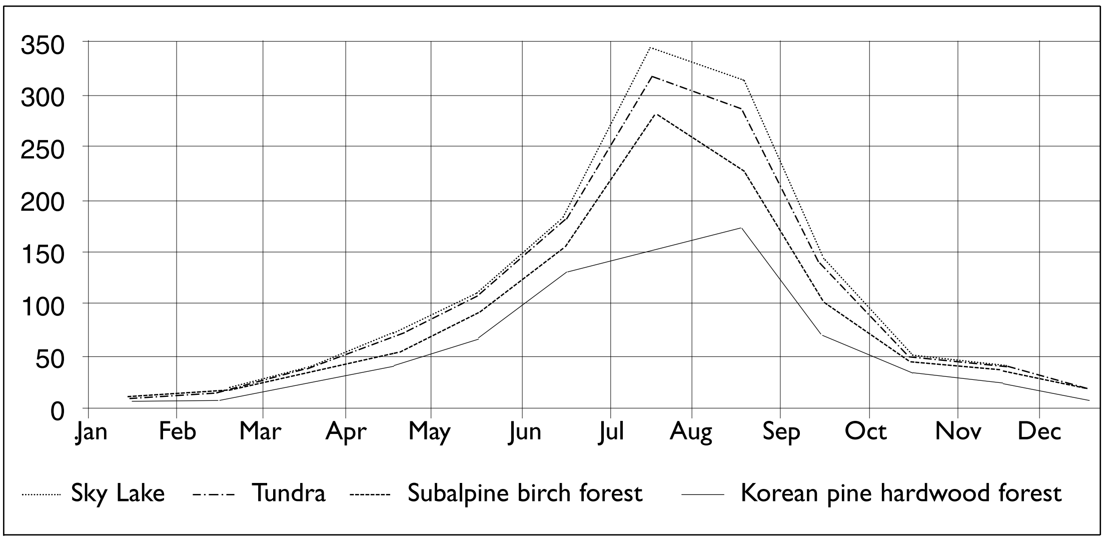
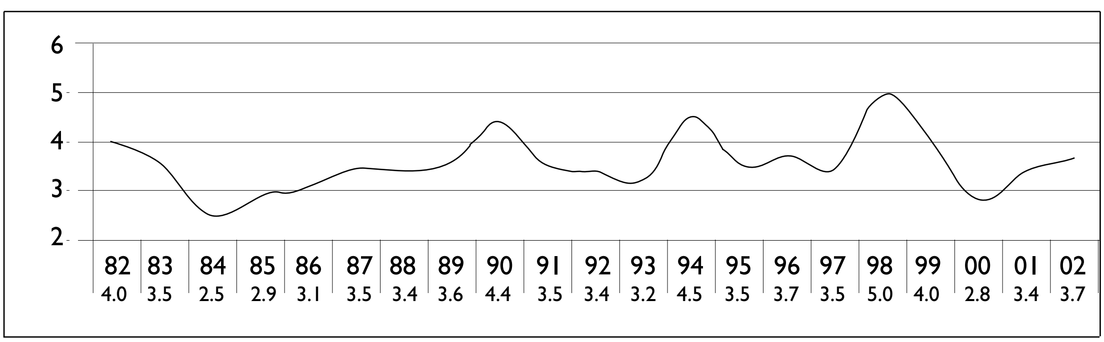


Figure 3.3
Annual average temperature, 1982–2002



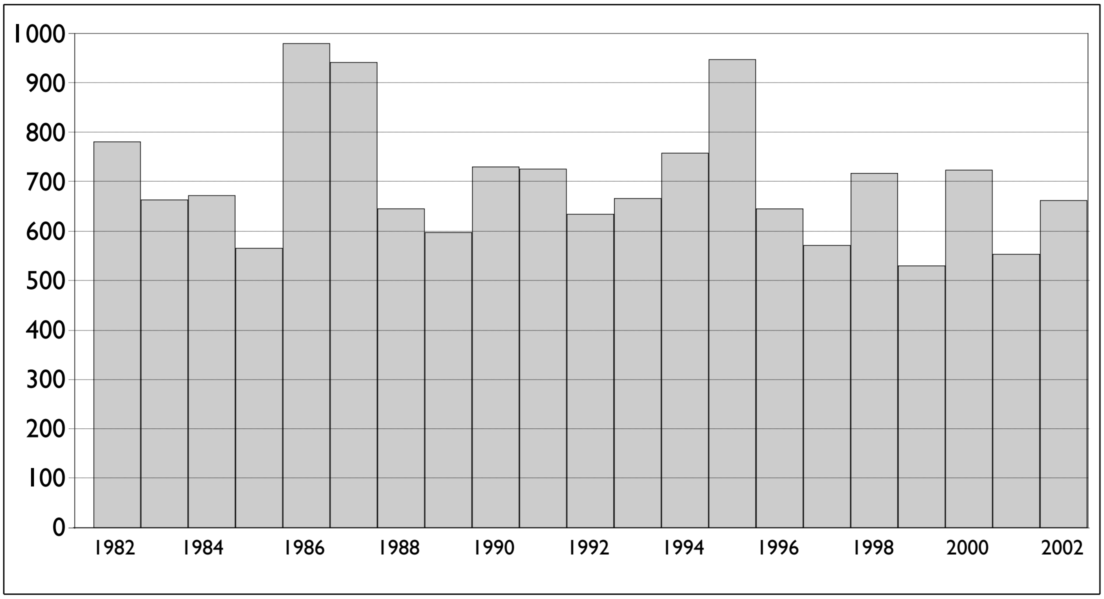


Figure 3.4
Annual average precipitation, 1982–2002

Landslides often occur on the mountain slopes, particularly along the riverbanks, and the shifting river channels at high elevations have destroyed some alpine plants situated in proximity to the landslide area. Due to the decreasing length of time that snow remains on the mountain, the flow of water into the rivers during the dry season has declined. The water rate observed at the Changbai waterfall has decreased, indicating a drop in the net water level of Sky Lake. This will inevitably affect the amount of water flowing into the river in the long term and will thus influence irrigation of farmland in the middle and lower reaches of the rivers.

The greatest impact of climate warming observed in nature can be seen in the response of vegetation. Many annual observations and interviews with local people show that alpine *ermannii* birch has moved toward the tundra ecosystem over the last twenty years. Researchers from the Chinese Academy of Sciences (Zhanqing Hao, Limin Dai and Hong S.) have employed the LINKAGES model to simulate the potential responses of major tree species to climate warming in each ecotype found in Changbaishan Biosphere Reserve. The range of temperatures employed in the model simulation included the current climate (based on current climate data) and a warmer climate, with an increase of 5 °C, with all other parameters remaining constant. Results show that for alpine *ermanii* birch forests, *Betula ermanii* remains the dominant tree species. Other companion species, such as *Larix olgensis* and *Abies nephrolepis*, indicate an apparent increase in their biomass with climate warming; that is, the distribution of these species will move up with an increase in temperature. For spruce fir forests, the biomass of the dominant species, *Picea jezoensis* and *Abies nephrolepis*, will increase with climate warming; that is, these species will maintain their composition and structure in a future warmer climate. In the case of the broad-leaved Korean pine mixed forest, the biomass of the most dominant species will increase slightly; this effect will be greater than that observed at lower altitudes after climate warming.

Since the establishment of Changbaishan Biosphere Reserve, environmental and ecological monitoring has become an integral part of our work. We are, however, aware that more could be done if there were fewer financial constraints and more professional staff. Fortunately, we cooperate with scientific institutes and environmental organizations at the national, provincial and local government levels in order to carry out our work, and a wealth of useful data has been collected in recent years.

The Sky Lake Meteorological Station, at an elevation of 2,624 m, was set up in the 1950s by a local environmental organization and focuses on the monitoring of temperature and precipitation changes on the Changbaishan summit. The Changbaishan Hydrological Station was established in the 1970s and is responsible for monitoring water quality and fluctuations in rivers originating in the Changbaishan area. The Changbaishan Earthquake and Volcano Monitoring Station is a disaster prevention station set up by the provincial government in the 1980s and is responsible for monitoring earthquake, volcanic and landslide activity, as well as other geological movements. The Changbaishan Ecological Research Station, at an elevation of 740 m, was built by the Chinese Academy of Sciences in 1982, and is involved in research into the forest ecosystem in the Changbaishan region, partially working on the responses of vegetation zonation and species to global change, particularly climate warming.

In recent years a basic atmospheric monitoring program has been launched, focusing on twenty-five parameters in eight categories, including the monitoring of greenhouse gases such as carbon dioxide, methane, freon, ozone, active gases, solar radiation and ultraviolet rays, radioactive substances and volatile organic substances. There are four ongoing research projects: Carbon Circulation Process Research in Forest Ecosystems; Research on the Service Function of the Forest Ecosystem; Adaptability Simulation Study of Trees in Conditions of Increasing Carbon Dioxide Density; and the Impact of Climate Warming among Dominant Tree Species in Changbaishan Biosphere Reserve.

In the near future, and in light of the Entlebuch workshop on 'Global Change Research in Mountain Biosphere Reserves', we are looking to strengthen our work on global change monitoring and research with the added possibility of cooperation and support at the national and international level.

4. A Colombian Case: Cinturón Andino Biosphere Reserve

Marcela Cañón, National Natural Parks Unit, Colombia

LOCATION AND GENERAL CONTEXT

Colombia is located at the northwestern tip of South America and is the only South American country with coastlines on both the Atlantic (Caribbean) and Pacific Oceans. The country's population is estimated at 44 million. Crude oil, coal, coffee and cut flowers are the principal legal exports. Economic growth for the year 2002 was estimated at 1.6 per cent, while inflation was measured at over 7 per cent. Income distribution is heavily skewed, with 67 per cent of the population living in poverty.

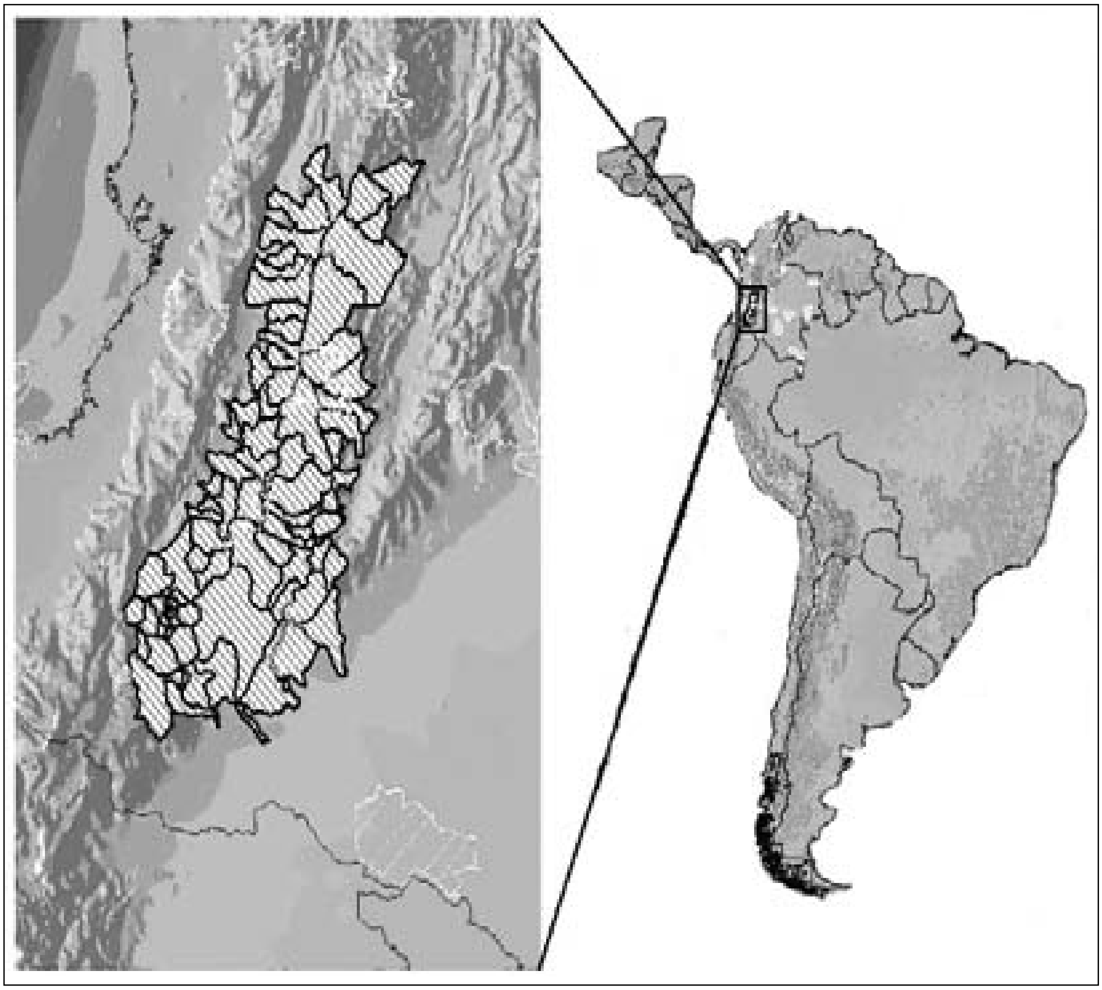
Colombia's topography is dominated by the Andean highlands, which effectively separate the country's eastern lowland regions from the Pacific coastal lowlands in the west and the Caribbean coast in the northwest. The Colombian Andes consist of three major ranges (cordilleras) extending like fingers from the Ecuadorian border to the Caribbean Sea. The western range (Cordillera Occidental) and the central range (Cordillera Central) are separated by a rift valley enclosing the Cauca River. The Cordillera Occidental parallels the sparsely populated Pacific coast and recedes, as does the Cordillera Central, into the Caribbean lowlands in the northwest.

At the Great Colombian Massif (about latitude 3°N) the Cordillera Oriental branches off to the northeast from the Cordillera Central, creating the Magdalena River valley, the major longitudinal basin of the Colombian Andes. The Cordillera Oriental is the longest of the three ranges and extends some 1,200 km.

To the southwest of the Cordillera Oriental lie the vast, barely populated lowlands, of the Llanos (Orinoquia) and the Amazonia regions. Together they account for 60 per cent of the country's landmass. The area is drained by the Orinoco river (the northern half) and by the Amazon river. The entire Magdalena river basin lies within Colombia, and accounts for most of the flow from the Caribbean watershed, from which almost all of the country's irrigation is supplied.

The Cinturón Andino Biosphere Reserve, at the core of the Colombian Massif, is located in the southwest of Colombia at the origin of the Eastern Cordillera of the Andes and slightly to the north of the origin of the Western and Central Cordilleras (see Map 4.1). Although dominated by the Central Cordillera, it includes areas of the Eastern Cordillera, forming the only continuous high altitude link between these ranges, and linking the Central Cordillera with the Amazon Basin through the eastern foothills of the Andean range. The massif is known as the Colombian river star because it is the water source for four of Colombia's main rivers: the Magdalena, Cauca, Patia and Caqueta, which provide 70 per cent of the national population with water, making it the one of the most important areas in the country in terms of environmental goods and services. Due to its

Map 4.1
Location of Colombia and the massif



position, the Colombian Massif is vital in species dispersion and gene flow (Instituto Alexander von Humboldt – IAvH, 1998); it houses the Huila Pleistocene refuge, which played a critical role in the origin and distribution of the South American biota (Hernandez et al., 1992). In addition, the Colombian Massif has exceptionally high biological diversity arising from its wide range of topography and climate, and from the influence of the three biogeographic regions that converge in it (the Pacific, the Andes and the Amazon). It displays a variety of thermic levels as a result of the wide variation in air temperature at higher altitudes. The snowline, with temperatures below zero (0 °C), is found at levels higher than 4,600 m above sea level.

The Colombian Massif has been far less degraded then other parts of the Andes, with lower levels of deforestation and habitat degradation than the national average. This is due both to the remoteness of the region and the action taken by the government of Colombia, who established some of the country's first protected areas in the region. This brings 3,750 km^2 of the Colombian Massif under protection in three National Parks in the massif nucleus where five different montane forest ecoregions converge and the largest areas of paramo in the country are found.

International recognition of these parks came in 1980 when UNESCO declared Cinturón Andino a Biosphere Reserve, incorporating the parks and 1,500 km² of the area connecting them. While the park's core areas were designated within the Biosphere Reserve, no zoning of buffer areas or transition zones have been allocated, and local communities are not entirely aware of its existence, with the result that it has yet to achieve its intended role in conserving the region's outstanding natural assets.

Since its creation, a number of areas have been brought under some form of protection within the Reserve in the form of private, indigenous, peasant and municipal reserves. These have the potential to form additional core zones for the purposes of strict conservation within the Reserve, providing valuable corridors between parks or, depending on their management categories, acting as transition zones between core areas. Despite this, biodiversity in the region is under increasing pressure for two principal reasons. First, the core zones of the Biosphere Reserve and other protected areas are not able to realize their full potential in terms of biodiversity conservation. They are currently not operating at the optimum level required to ensure long-term survival of endemic species, particularly large mammals, nor to prevent habitat fragmentation and the gradual erosion of genetic diversity. Second, land-use practices outside these core zones – agricultural practices, livestock rearing, natural resource exploitation and illicit crop cultivation – are leading to further habitat fragmentation, transformation and loss.

In addition to its biological wealth, the massif is well known for its cultural heritage. The high mountain zones of the National Parks and corridors between them are inhabited by Indian communities from the following ethnic groups: Paez, Guambiano, Koconuco, Yanacona, Kamtzá, Totoró and Ingano. These groups, because of their traditional cosmology, have maintained wide areas of conservation in those sites they consider to be 'sacred areas', from where they take numerous plants and animals to use as the basis for their traditional and magic medicines. The zone is also used for sacred rituals.

This biological, ecological and cultural wealth has been disturbed by the continuing internal armed conflict that has raged in the area, with varying levels of intensity, for almost forty years. However, peace initiatives are very strong, with social organizations and territorial government institutions such as Municipalities and Departments (*Surcolombianidad*) taking the lead. International cooperation and support for the peace process is growing, as is demonstrated by proposals such as the peace laboratory, which is supported by the European Union.

The government's response to conservation needs, the pressure on biodiversity and the water supply of the massif and its regulatory function has largely taken the form of the establishment of National Natural Parks. However, in the face of increasingly aggressive land-use changes, poverty and internal armed conflict, the government is broadening the region's conservation strategy by seeking to include a wider range of actors in establishing social agreements and different management approaches in conservation areas, and to address the root causes of biodiversity loss outside the parks through the policy 'Social participation in Conservation – Parks with the People'.

Under this initiative, steps are being taken, spearheaded by the South Andean region of the National Natural Park System Special Administrative Unit (NNPSSAU) to complement the processes of conservation and control already under way. This is demonstrated by the creation of regulatory intercultural systems with those indigenous groups living in the parks in their area of influence, as well as by developing productive processes compatible with the ecosystems' characteristics and the demand for environmental goods and services through the 'Parks with the People' policy. The regional system of protected areas of the Colombian Massif is thus being implemented to form part of the regional development of the National System of Protected Areas in an attempt to connect five national natural parks (three of which are from the Biosphere Reserve) through the Paramo and High Mountain Forest, and two new protected areas adjacent to the Parks (Serranía de Minas and Serranía de los Churumbelos).

The Unit is currently developing a project financed by GEF, the Global Environment Facility, that addresses some of the issues mentioned earlier.

BIODIVERSITY CONTEXT

The Colombian Massif is characterized by paramo and montane forest ecoregions. At altitudes above 3,200 m it is characterized by large intact blocks of paramo vegetation with high levels of endemism as well as key functions in water supply and regulation, and as carbon sinks. These paramos form one of the most important examples of the globally significant Northern Andean Paramo ecoregion. At lower altitudes, between 3,000 m and 1,500 m, the massif is characterized by extensive stands of montane forest. Andean montane forests are particularly rich in species diversity and have high levels of endemism due to the varying conditions between and within each Cordillera and leading to evolutionary divergence among many taxa.[1] This endemism is particularly marked in the northern Andes, and has led experts to delineate seven separate montane forest ecoregions in Colombia and Venezuela (Dinerstein et al, 1995). Five of these converge in the Colombian Massif; all of them are globally outstanding in terms of their associated biodiversity and have been assigned the highest priority for conservation.[2]

Vegetation

Paramo is found at altitudes between 3,200/3,500 m and 4,500 m above sea level, although seasonal paramo can be found as low as 2,500 m. This is a fragile and highly specialized shrub-like savannah with up to 1,800 species, many of which are endemic, dominated by large clumped tussock grass, terrestrial bromeliads and ferns and shrubs up to 4 metres tall. Four main plant associations occur in the paramo. The most characteristic is dominated by *Espeletia hartwegiana* (fraylejones), a slow-growing plant with yellow flowers that attract many hummingbirds and bees, and short, thick, woolly trunks topped by rosettes of thick leaves with soft hairs that help minimize water evaporation and heat loss. Other associations are those dominated by *Calamagrostis spp.* and other grasses with sparse shrubs, areas of 'chusque' *Swallenochola* aff. *tessellata* and areas of waterlogged peat bog known as 'achupallales' that are characterized by abundant terrestrial bromeliads, principally of the genus *Puya*, and mosses of the *Sphagnum* genus.

Paramo soils are deep, low density and highly porous, favouring extremely high levels of water retention. This, coupled with low levels of evapo-transpiration and high levels of precipitation, explains the vital role paramos play in water regulation and storage. The soils also have high levels of organic material at different stages of decomposition, containing up to 50 per cent carbon compared with the average 3 per cent of most other soil types. In paramo soils at a depth of 2 metres, it has been estimated that 17,000 ton/ha of carbon could be stored compared with a value of 50 ton/ha in tropical forest soils (Grupo de Paramos de Ecuador). The role of paramos in carbon sequestration and storage is thus increasingly recognized. If paramo vegetation is lost, when exposed to high levels of insolation, the dark rich soils will increase microbiological activity and thus organic material decomposition, oxidation and consequent liberation of carbon into the atmosphere (Revista Innovacion y Ciencia).

From 1,500 to 2,300 m above sea level, the cool and humid montane forest is characterized by high biomass; trees of up to 25 metres and an abundance of epiphyte orchids, bromeliads, tree ferns (*Cyathea spp.*), mosses, lycopodes and bamboo (*Chusquera spp.*). At higher altitudes and up to 3,200 m, it is characterized predominantly by smaller trees, including species such as *Podocarpus, Clusia* and *Gnoxeys.* In common with all montane forests, those in the Colombian Massif have high levels of endemism as a consequence of the diverse topography and climate. Northern Andean montane forests, however, have such a high degree of endemism that experts have differentiated seven separate montane forest ecoregions in Colombia and Venezuela (Dinerstein et al., 1995). The WWF have used this regional assessment and applied more detailed data to fine-tune ecoregion borders to a scale that can better serve to determine conservation priorities at the national level. Using this more detailed analysis, it is clear that five of the seven montane forest ecoregions in the Northern Andes converge in the Colombian Massif: the Northwestern Andean, the Cauca Valley, the Magdalena Valley, the Eastern Cordillera Real and the Cordillera Oriental Montane Forest Ecoregions; all of these are globally outstanding in terms of their associated biodiversity.

The fine-tuned ecoregion classification has also been cross-referenced with the IAvH ecosystem classification for Colombia to further assist the evaluation of conservation priorities in the country and detect gaps in protected area coverage. Within the massif, the main ecosystem types, using the IAvH classification are:

- Medium dense forest (1,000–2,000 m), characterized by *Ocotea, Clinchona, Ceroxylon.*
- Low-density forest (2,000–3,500 m), characterized by *Weinmannia, Hedysomum, Ocotea*, and in areas of more dense forest at these altitudes characterized by *Quercus.*
- Humid paramo 3,500–4,000 m, characterized by *Espeletia, Swallenochloa* and *Calamagrostis.*
- Supra-paramo higher than 4,000 m, characterized by *Draba, Senecio*, mosses and lichens.

In addition to the unique mix represented by the convergence of the five montane ecoregions, the massif also has significant percentages of the remnants of each ecoregion (around 20 per cent for Cauca, Magdalena and Eastern Cordillera Real, 2 per cent for Northwestern Andean and Oriental Cordillera, and 26 per cent of North Andean Paramo). When ecosystem types within each ecoregion are considered these percentages rise considerably, with the massif occupying 70 per cent of the country's remaining humid low dense forest in the Cauca and Magdalena Valley montane forests and 30 per cent of the same ecotype in the eastern Cordillera Real montane forest – a particularly important fact considering that currently none of this latter category is covered by national parks and that it makes up large areas of the proposed Serrania de Churumbelos protected area.

For the evaluation of possible impact of climate change on vegetation, and for identification of its vulnerability, an analysis for the displacement of Holdridge's life zones with a view to the scenario of climate change was made by the Colombian government, identifying vegetation affected by displacement. The country was zoned by degrees of vulnerability of vegetation in the event of climate change. According to this, the glacier areas would be affected by 92 per cent, with 62 per cent moving to paramo (subalpine rainy paramo) and 27 per cent to super-paramo (alpine rainy tundra). Montane, subalpine and alpine life zones above 2,500 m, corresponding to sub-paramos, paramos, superparamos, and snow, could be affected by as much as 90 to 100 per cent.

The great fragility of the Andean mountain forest and the very strong human pressure they face within their area (fragmentation, biotic losses and degradation) makes them one of the most vulnerable ecosystems to climate change. Adaptation could only be proposed as an immediate measure. The particular location of the paramo ecosystem in the high mountains makes them spatially vulnerable. If warming occurs their area will reduce in size, with a subsequent decrease in their biodiversity. Furthermore, their location in an altitudinal zone where there are highly dynamic social and economic processes makes the paramo areas considerably more vulnerable (Colombia, Climate Change First National Communication, 2000).

Fauna

The convergence of these globally outstanding ecoregions in the core of the massif (Biosphere Reserve) forms a unique mosaic of species composition and habitat diversity unparalleled in a country well known for its megadiversity. Over 10 per cent of Colombian flora and 60 per cent of all Andean fauna are found in the Colombian Massif. It is particularly rich in bird life, with 586 registered species, including 15 per cent of all humming birds (Trochillidae) registered in the Americas, numerous tanagers such as the blue and black, golden-crowned, masked mountain, hooded mountain, and buff-breasted tanagers; endangered species such as the condor and Andean cock of the rock; and the endemic bi-coloured antpitta, black tinamou, golden-plumed parakeet and red-breasted parrot.

Mammalian life is also highly diverse, with a total of seventy-three registered species including the endemic small Andean deer as well as many species with very restricted distribution, such as the Andean dwarf squirrel and Andean rabbit. The list includes 28 per cent of all endangered mammals in Colombia (twenty-five species, including the spectacled bear and paramo tapir). Despite incomplete inventories, other taxa are also known to be well represented and in many cases include endemic species. For example, the massif is home to 43 per cent of the country's amphibian species, including 28 per cent of endemic amphibian species of the Central Cordillera, the endemic tree lizard *Anolis huilae*, the endemic fish *Astroblephus grixalvi* and the endemic spider *Heterophrynus nicefori*.

Glacier Zones

Since the end of the Small Ice Age (1850), the glacier regions of Colombia have lost 80 per cent of their area. Considering current climate change trends, an analysis of this process suggests that the glaciers will disappear completely within the next century, as has already happened to other glaciers in the country. During the last century in the Biosphere Reserve the NNP Puracé has lost two glaciers: Puracé volcano in 1940 and Sotará volcano in 1948.

As Table 4.1 demonstrates, photogrammetric calculations showed that the rate of annual loss in the Nevado del Huila glacier was 0.64 for the period between the 1950s and 1990s. Studies show that glaciers located in non-active volcanos have the same rate of loss as those located on rock, indicating that the loss is caused by external agents such as climate change.

SOCIOECONOMIC, CULTURAL AND INSTITUTIONAL CONTEXT

The Colombia Massif covers 36,780 km^2, including over sixty-five municipalities in the departments of Cauca (twenty-four), Huila (sixteen), Nariño (fifteen), Putumayo (five), Tolima (two) and Caquetá (two). The core of the massif, is generally considered to be a smaller area covering thirty-three municipalities and approximately 20,000 km^2 of land at an altitude greater than 2,000 m. Living conditions in the region are harsh, with indices of living standards and basic needs fulfilment, falling below the national average at levels between regular, bad and very bad (CI and NBI).[3] Access to the core of the massif is particularly difficult, and poverty in rural communities there is even more accentuated. Rural electricity provides on average 50 per cent of energy needs but many of the municipalities near the national parks in the area have much lower provision; for example, Santa Rosa has 0.8 per cent, Almaguer 9.5 per cent, Timbío 14.3 per cent, Belén de los Andaquíes 20.5 per cent, and Puracé 20.8 per cent.

The regional economy is largely based on livestock rearing and agriculture. Natural and improved pastures cover 1.1 million hectares throughout the whole massif and support 239,126 head of cattle (1 per cent of national total). Within the area, producers are mainly of small and medium size and are most concentrated in the land between the Natural National Park (NNP) of Nevado del Huila and NPP Puracé. In paramo and sub-paramo areas cattle-rearing densities are 1 head for every 12 hectares rising to 1 to 2 heads per hectare in montane forest areas. Agricultural land makes up 3 per cent of the massif with approximately 80 per cent reserved for permanent crops, principally below 1,800 m, including coffee (42 per cent), sugar cane (24 per cent), bananas (2.5 per cent) and sisal (35 per cent). The remaining 20 per cent is dedicated to annual and transitory crops including maize

Table 4.1
Glacier loss analysis for the Nevado del Huila volcano

Glacier	Year	Total area (km^2)	Total loss over period (km^2)		Yearly retrocess Area (km^2)	Yearly retrocess Area (%)
Nevado	1850	33.7	(1850–1959)	16.2	0.148	0.4
del Huila	1959	17.5	(1959–65)	1.2	0.200	1.1
volcano	1965	16.3	(1965–81)	0.9	0.056	0.3
	1981	15.4	(1981–90)	1.5	0.167	1.1
	1990	13.9	(1990–96)	0.6	0.100	0.7
	1996	13.3				

(12 per cent), potatoes (2 per cent), beans (4.5 per cent), peas (0.8 per cent) and cassava (2.2 per cent). Agricultural activities within the area mainly consist of subsistence farming with smallholdings of less than 2 hectares growing almost exclusively potatoes, with small areas of maize, traditional beans and peas in association with onions, garlic and cold climate fruits such as curuba and lulo. Any surplus is sold in local markets and peasant farmers rely on day work in coffee plantations at lower altitudinal levels to augment their income.

In addition to its biological wealth, the massif is well known for its cultural heritage, with seven indigenous groups with a population of 191,000 living in the region (the Paeces, Yanaconas, Guambianos, Koconucos, Totoroes, Inganos and Kamtza); this is equivalent to 27 per cent of the nation's indigenous population in only 1.7 per cent of the country's territory. These indigenous groups are located in autonomous reserves covering approximately 3,750 km^2, or 18 per cent of the area. They all have perceptions of the universe that centre on the sacredness of the environment and natural phenomena, and hence represent important partners in the quest for strengthening biodiversity conservation in the massif. The Kokonucos and Guambianos are closely linked to paramos areas, which provide their medicinal plants and serve as sites for spiritual ceremonies. The Paeces, also closely linked with the paramos, have recently taken a stand against illicit crop cultivation and are not permitting this in their reserves. Despite much assimilation of Western culture, the Totoroes also maintain some traditional beliefs that are similar to the Paezes', particularly their understanding and keen observation of natural phenomena, which they use to guide the timing of sowing and harvesting.

As the source of four of Colombia's main rivers, housing rich cultural and biological diversity, the massif was flagged as a strategic ecoregion. More recently, the MMA identified the priority areas within each strategic ecoregion.[4] In the massif these are the National Parks – Hermosas, Nevado del Huila, Puracé and Cueva de Guacharos – as well as three currently unprotected areas: Serrania de Churumbelos, Doña Juana and Serrania de Minas, some of which are part of the Biosphere Reserve.

The 1991 Constitution established that reserves, such as peasant and indigenous reserves (*resguardos*), could be allocated for communal use and could not be confiscated. Subsequently, Law 160 of 1994 and Decree 2164 granted communal ownership status to these reserves. Large areas of Colombia are now recognized as indigenous reserves under autonomous management processes and structures, and the Ministry of Environment, Housing and Territorial Development (MAVDT) acknowledges the value of these in the conservation of the nation's biological heritage in addition to their clear cultural value. In effect, Decree 622 of 1997, which established norms for identifying administrative categories and management systems for the National Natural Parks System (SNNP), recognizes that legally constituted indigenous reserves and national parks have common goals in conservation and are compatible, thus effectively abandoning previous stances and acknowledging the territorial rights of indigenous groups within park areas. As territorial units, indigenous councils of the reserves have similar responsibilities to municipalities for environmental management and planning. Law 388 of 1997 establishes that all municipalities should develop nine-year land-zoning plans (MOTs) in which current and potential protected areas are identified. Indigenous groups have autonomously adopted planning processes under the format of Life Plans in which they also

	Population (1993 census)	Area of reserves (hectares)	Reserves	Overlaps with parks	Main settlements related to protected areas in project area	Ecotype
Kokonukos	6 141	24 462	6	6	Puracé Park, Corridor Huila/ Purace	Paramo–High Andean montane
Guambianos	20 782	247 194	4	0	Puracé Park, Corridor Nevado/ Huila	Paramo–High Andean montane
Inganos	17 855	10 000	3	0	Cueva de Guacharos/ Serrania de Churumbelos corridor	Andean montane and pre-montane forest
Paeces	100 000	270 000	25	14	Nevado del Huila and Puracé Parks, Corridor Hermosos/ Nevado, and Nevado del Huila/ Puracé	Paramo–High Andean montane and montane forest
Totoroes	3 654	4 160	3	0	Corridor Purace/Nevado del Huila	Paramo– High Andean
Kamtza	250	500	1	0	Corridor Guacharos/ Churumbelos	Andean-Amazonian
Yanaconas	19 623	42 376	8	0	Puracé Park and corridor Puracé/ Guacharos	Paramo–High Andean montane and montane forest
Total	168 305	598 692	50	20		

Table 4.2
Indigenous groups, relation to protected areas and ecotypes

include environmental plans and specific sacred areas for strict protection of environmental, spiritual, mystic and religious attributes.

The organizational processes in the massif are extensive, and include the traditional Indian councils and the various peasant organizations. The Indian communities have built various regional organizations such as the Asociacion de Cabildos Indígenas del Norte (ACIN), la Corporación Nasa Chacha in Tierradentro, and the Indian regional councils of Cauca, Tolima, Nariño, Valle and Huila.

In about fifteen municipalities of the massif and south of Cauca, north of Nariño and south-east of Huila, the inhabitants have created a movement, led by the 'voceros del Macizo' (Massif spokespeople), which has begun negotiations with the central government to obtain important resources in the fields of the environment, health, education, infrastructure, agriculture and forestry.

INSTITUTIONAL CONTEXT

The Ministry of Environment, Housing and Territorial Development (MAVDT) is the highest authority for environmental affairs in Colombia. Created in 1993 as the Ministry of Environment and remodeled as the MAVDT in 2003, it is charged with the definition of the nation's natural renewable resources and environmental policies and norms. It has two vice ministers and a National Parks Administrative Unit (UAESPNN). This Unit is charged with defining the framework for conserving the nation's natural and cultural heritage through planning, and managing the SPNN to protect biodiversity and environmental services and provide opportunities for recreation, research, culture and spiritual development. More recently this mandate has been expanded to include leadership and coordination to structure the National System of Protected Areas in such a way as to promote diverse figures and categories of conservation

Under Colombia's 1991 Constitution, the responsibility for environmental management was passed to the thirty-three Autonomous Regional Environmental Authorities (CAR) and these were mandated under Law 99/93 to protect natural resources and control exploitation in areas under their jurisdiction. Four Regional Environment Authorities have jurisdiction in the area.[5] In addition to these institutions, there are two research institutes affiliated to MAVDT: the Instituto Alexander Von Humboldt (IAvH), mandated to promote, coordinate and undertake research that contributes to biodiversity conservation, and the Institute for Environmental Studies, which collects and analyses relevant climate change data. A range of Indigenous *cabildos* and community councils also have important roles in environmental management in the massif, as well as numerous environmental non-governmental organizations, including larger nationally based ones, such as Ecofondo, and locally based specific ones such as Fundacion Serrania de Churumbelos.

The National Biodiversity Strategy and Action Plan (1998) illustrates the national importance of the project objectives, identifying the Andes as the top regional priority in terms of its biodiversity conservation and sustainable use. This is reflected in the *National Strategy for the Conservation of the Andes*, developed in July 1999 by the MMA, which includes four complementary projects, two of which are being prepared for GEF financing consideration and two in development. The NBSAP proposes consolidating the National System of Protected areas (SIRAP) as part of a conservation strategy that would include the National Park Systems as well as a range of regional, local, private and public reserves under different management categories, thus broadening stakeholder responsibility in protected area management. In 1999, the National Parks Administrative Unit (UAESPPN) was charged through Decree 1124 with leading the creation of the SIRAP and its coordination once established. Recent policy papers reflect this commitment to the social dimension of conservation.

LAND-USE PRACTICES OUTSIDE CORE ZONES

Agricultural Practices and Livestock Rearing

Despite the rich indigenous heritage of the region, traditional knowledge of the use of biodiversity and benign cultivation techniques is poorly disseminated. The region's farmers adopt standardized agricultural models and introduce land-clearing techniques and production systems with little training in biodiversity conservation and management. Currently 70 per cent of the farm economy comes from monoculture of introduced species with heavy reliance on chemicals, using methods unsuitable for the fragile mountain soils and causing land degradation, soil erosion, biodiversity loss and, eventually, productivity decline. Livestock rearing, with high densities of cattle on steep slopes, is causing overgrazing, leading to soil compaction and drying and loss of organic layers. The seasonal use of paramo and sub-paramo for grazing, and the burning of this to stimulate shoot production, is causing increased habitat loss in this fragile ecosystem. A heavy reliance on intermediaries because of a lack of familiarity with processing technologies and commercial systems, along with a lack of storage facilities, transport and distribution systems, reduces profit margins still further and so increases the need for aggressive practices to increase production.

NATURAL RESOURCE EXPLOITATION

Natural resource exploitation in the massif is also causing habitat fragmentation, transformation and loss. Wood-collection for domestic purposes such as cooking and fencing occurs throughout the region. The supply of electricity in the region is very low and alternative forms of energy, such as gas, are too expensive for poor inhabitants and culturally unacceptable to indigenous groups that use open fires as the centre of cultural and religious beliefs. There are few community reforestation schemes, and communities lack the knowledge and skills to access the limited funds available for these. Commercial logging takes place alongside a lack of experience in sustainable forestry techniques and poorly developed forestry permit processes, causing over-exploitation in some areas. This is exacerbated by the increasing scarcity of forest in other regions of the country, leading to increased logging in the massif, and encroachment on buffer zones and park lands that are operational at sub-optimum levels. The lack of awareness of park boundaries and the role of different species in ecosystem dynamics and conservation of natural resources, together with increasing food security problems and animals straying from small or badly shaped parks, is leading to illegal hunting and plant and egg collection. Although very limited, this is causing pressure on some species, including mosses, orchids and bromeliads. Isolated cases of arson to settle land disputes and personal vendettas has led to some habitat loss, and sulphur mining in very isolated locations is having minor impacts in corresponding river beds.

Illicit crop cultivation, particularly poppy growing, is starting to occur in limited areas within the massif, causing habitat loss in high montane forest and sub-paramo areas. Unsustainable agricultural practices leading to crop failure and soil degradation, coupled with the lack of alternative ways to earn a living, high levels of poverty and illicit crop production in areas adjacent to the massif, is causing some farmers to turn to poppy cultivation as a means of survival. Fortunately however, the isolation of the region and the strong presence in the zone of indigenous groups who have taken a stand against illicit crop production, in addition to good public order exercised in the region, has limited this to isolated pockets.

Projects in the area that address global change issues or provide valuable information related to this topic include:

1. GEF Project. Conservation of montane forest and paramo in the Colombian Massif. The project is a two-phase initiative structured to conserve biodiversity in six globally outstanding ecoregions converging in the heart of the Colombian Massif by designing and rendering operational a broad-based Massif Protected Area System (MPAS). Four National Parks, three of them comprising the Cinturón Andino Biosphere Reserve, will be operating with increased efficiency and in close coordination with local communities under the framework of jointly developed management plans for park and buffer zones. To this end, the project will establish the necessary mechanisms and processes to effectively decentralize and broaden stakeholder involvement and responsibility in protected area management. In an area encompassing seven distinct indigenous groups (27 per cent of the country's indigenous population), conservation-compatible land-use practices, enriched by traditional knowledge of biodiversity use, will be employed in buffer zones and in the areas forming corridors between the targeted parks. These corridors will comprise an additional 1,500 km^2 under a mosaic of land uses, including private reserves, conservation areas within peasant farms, and indigenous reserves, all providing critical habitat requirements within the overall greater ecosystem. In addition, a further 5,750 km^2 will be placed under conservation by way of three new large protected areas of different management categories and regimes, including combinations of indigenous, private, municipal, and national authorities. These efforts will raise the area of natural forest and paramos under protection in the massif to at least 11,000 km^2, or over 50 per cent of the project area, ensuring considerable benefits to global biodiversity and carbon storage values, as well as significant contributions to the protection of important watersheds. The result will be an archipelago of wildland areas of appropriate size and shape that provide sufficient connectivity in the landscape to ensure adaptive potential for change, migration and dispersal, all nested within bio-regional, social and community development programmes. The project provides a framework for regional conservation firmly embedded in a significant sustainable development baseline, thereby ensuring global biodiversity benefits over the long-term.
2. Project Ariadna. Natural resources characterization and management using remote sensing tools. Implemented by the University of Cauca in conjunction with the Parks Unit and the Colombian Institute of Geology and Mining (INGEOMINAS). The purpose of the project is to design and implement a prototype for an integrated environmental information system that allows environmental monitoring in one of the core zones (NNP Puracé), formulation of management plans, disaster prevention and land planning for natural resources protection, and the development of models for hydric balance and geology. The main results are geographical information on the study area,[6] a prototype module for remote capture of environmental information,[7] information management modules[8] and an integration platform.[9]
3. Participative monitoring of the arlequín frog (Amphibia: *Bufonidae-Atelopus*) in the Colombian Massif, as complement to wider research in the Colombian Andes. The objective of the project is to evaluate, with local community participation, the conservation status of the arlequín frog in the South Colombian Andes. The specific objectives are:
   a) to provide local information for the national project in order to identify the presence or absence of populations and species of the *Atelopus* frog in the Colombian Andes

b) to analyse and fine-tune the protocol for the monitoring of the *Atelopus* population in the country, considering local conditions and fieldwork
c) to organize a local work team
d) to define and articulate an education strategy to include local schools and community leaders
e) to arrange monitoring and training workshops for local community leaders.

The national project objectives are: to identify populations and species of *Atelopus* that require immediate conservation action: to measure the impact of decline and identify the magnitude and geographic scale of the effects (local or regional); to standardize field protocol for biological monitoring for Andean frogs; to determine whether the root causes for the decline of the high Andean frogs are still operating in Colombia.

4. Monitoring of the Nevado del Huila glacier loss (developed by Ingeominas with participation from the Parks Unit and Dusseldörf University, Germany). The glacier was monitored by means of photogrammetric calculations between 1961 and 1996. Lack of financial resources has halted the project, but since 1996 the Parks Unit (with support from the World Wide Fund for Nature) has developed a small-scale multi-temporal analysis of soil cover in the Nevado del Huila Park.
5. Biophysical characterization of the zone that comprises the paramos Santo Domingo, Moras and las Delicias. The Fundación Universitaria de Popayán (FUP) is carrying out a study in the zone between NNP Nevado del Huila and Puracé, which is subject to entropic pressure, in particular from illicit crops and livestock, with support from the Corporación Autónoma Regional del Cauca (CRC) and the South-Andean region of the NNPSSAU, which is expected to generate some conservation and sustainable development programmes.
6. Biodiversity Conservation Plan. The CAM[10] has been formulating a Biodiversity Conservation Plan in the municipalities of San Agustin, Pitalito, Palestina and Acevedo, located in the East Range that emerges from the massif. Its objective is to create a biological corridor to join the NNPs Puracé and Cueva de los Guácharos and to identify the different categories of conservation in the high Andean forest ecosystems. For the conservation management of the corridor and sustainable development of local communities, the CAM is developing a project focused on Clean Development Mechanisms (CDM), financed by the French government's technical cooperation. Its main objectives relate to forest regeneration and forestation as a strategy for CO_2 assimilation and fixation, land use change to conserve and recover vegetation and soil, and agrosystems development. Eight hundred hectares of forest have been geo-referenced, covering 670 land dwellers in forestry agrosystems and the landscape ecology with thematic maps on a scale of 1:100,000 (vegetation cover, landscape units, physiographic map), fragmentation analysis, and annual monitoring for multi-temporal analysis. Data has been collected for habitat availability for spectacled bear and Andean tapir, and water quality.
7. Integrated Development Programme. The European Union and the Nasa Chacha Programme are carrying out an Integrated Development Programme for Tierradentro, in the Indian, Black and mixed communities affected by the Nevado del Huila earthquake and the avalanche of the Paez river caused by glacier melt.

8. Geographic Information System. WWF have been developing a Geographic Information System (GIS) which covers the so-called eco-region of the Northern Andes including the mountains of Peru, Ecuador, Colombia and Venezuela, incorporating satellite information and digital and aerial photographs of a large area of the zone; some of the data was collected in collaboration with other institutions.
9. The environmental rehabilitation of the Colombian Massif Programme (Promacizo). This project, financed by the Netherlands government, has developed a GIS that includes cartographic, agricultural, hydrological and vegetation cover information. The nodes of the system are located in the CARs at four Massif public information locations and two traditional Indian councils, with the central node managed by the Parks Unit.

INFORMATION AVAILABILITY

The Environmental Studies Institute (IDEAM) of the MAVDT has meteorological, pluviometric, pluviographic, limnimetric and limnigraphic stations in the area of the Biosphere Reserve. Data are available for the main river streams and every park has meteorological stations. With the GEF project, new electronically operated stations (using Swiss technology) will be located in the core zones. Data have been collected since 1904, but most of the area has information dating back twenty years. Climatologic stations gather information on precipitation, temperature, humidity, wind velocity, cloud cover and other phenomena. Hydrological stations measure water flow, sediments and so on. The main rivers in the area, such as Magdalena, Cauca and Caqueta, have data collected over a period of twenty years. Data on glaciers and land cover change are available for the period since 1950. In general, data are available from the last fifty years, but reliable data on meteorological conditions, vegetation cover and demography have been compiled over approximately the last thirty years. Information on land use is very recent and does not cover the entire area.

Funds are available over the next three years from different international cooperation projects, as previously described. However, specific global change research needs require financial assistance because the information colleted by the projects mentioned do not necessarily come from the study area. The GEF projects for the conservation of the Andean montane forest and paramo in the Colombian Massif, as well as for the conservation corridor between Guacharos and Puracé, will gather information on vegetation, hydrology, demography and human activities in the area.

NOTES

1. The Andean range and the Amazon Basin for instance, have similar numbers of bird species (788 and 791 respectively) but the Andes have twice as many endemic bird species (Stolz et al., 1996).
2. The Northwestern Andean, the Cauca Valley, the Magdalena Valley, the Eastern Cordillera Real and the Cordillera Oriental Montane Forest Ecoregions.
3. The NBI index includes parameters such as education, health, income and access to public services. The CI life index includes the NBI and population densities, number of family members and access to social services such as retirement benefits.
4. Strategic Regional Ecosystem Programme: headed by the MAVDT Directorate for Information, Planning and Coordination of the National Environment System. Sub region 6: Region Southwest Andean Region Map 2000.

5. CAM department of Huila, CRC department of Cauca, CORTOLIMA department of Tolima, and to a smaller extent CORPOAMAZONIA departments of Caqueta and Amazonas.
6. Digital topographic cartography scale 1:25,000, selected window, photogrammetry of the project area scale 1:100,000, selected window. Elevation digital models (selected window). Geological map (selected window) scale 1:50,000. Volcanic threat map of the Puracé Volcano. Acidification sensibility map (selected window). Hydrological map scale 1:25,000 (selected window). Map of vegetation cover and fragmentation in the study area.
7. Conceptual configuration of the environmental monitoring system. Development of the system with radio equipment. To install an environmental monitoring system in one station of NNP Puracé.
8. Information systems for geological information management. Information system for hydrological information management.
9. Development of a platform: to access the data from the GIS prototype of the Environmental Information Integrated System.
10. CAM: Autonomous regional corporation from the Alto Magdalena, with jurisdiction in the Department of Huila.

5. Kenya: Mount Kenya Biosphere Reserve

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INTRODUCTION

Many significant changes are taking place on the Earth's surface and in the atmosphere that affect our planet. The accelerated pace of erosion, deforestation, pollution (on land and in the air, ocean and so on) and desertification is largely due to human activities. The causes of such environmental destruction have been studied intensively over the last thirty years. Leaders in this effort include the work undertaken by GCTE (later IGBP), mainly with the financial support of ICSU and the IGFA.

On closer examination of the many programmes coordinated by these organizations, it is clear that biosphere reserves can provide an ideal laboratory for study of global change. I would like to begin by taking this opportunity to thank the organizers of this timely workshop on behalf of the National MAB Committee of Kenya. In UNESCO's MAB and IHP programmes, stream-flow fluctuations and changes of land-use/land-cover in different ecosystems have been central to our studies. I strongly hope that the Mount Kenya case study can contribute to the deliberations of this workshop in order to develop a joint international effort to better understand research, monitoring and conservation processes and to provide a working model for the sustainable use of our mountain resources using the biosphere reserve approach.

MOUNT KENYA

Relief and Geological Background

Mount Kenya, with its highest peak at 5,199 metres above sea level, is located in the centre of the country and enjoys a commanding position from which virtually the entire country can be observed.

This mountain massif is a dormant composite volcano of the Vesuvian type. Its main eruptive phases occurred during the early Pleistocene period. The rocks from the eruptions are mainly basalts, rhomb porphyries, trachytes and kenytes. The plug, forming a ring structure, is composed of syenites and phonolites (Baker, 1967).

Climate

Mount Kenya receives orographic rainfall from the southeast trade winds coming from the Indian Ocean. Its eastern and southern slopes are therefore wetter than the leeward western and northwest sides. Records for Nyeri, Embu and Meru are shown in the tables at the end of the article.

They suggest declining levels of rainfall compared with previous records. The Meteorological Station on the Naro Moru route has a mean annual precipitation of 1,378 mm, Sirimon has 672 mm and Teleki Camp 687 mm.

Most of the rain falls between 2,700–3,100 m above sea level; above 4,500 m precipitation occurs mainly as hail or snow. Frost is also common above 2,500 m, and above 3,000 m ice and frost melt is common by mid-day. The tables at the end also give other useful climatic parameters.

GLACIERS ON MOUNT KENYA

Studies conducted during the last International Geophysical Year (IGY) (1957–8) and by Baker (1967) provide the following information: during the period of maximum glaciation, the snowline was situated at approximately 3,962 m on the eastern and southern sectors and around 3,658 m on the northern and western sectors. Between 1899 and 1958, a steady warming of the Lewis Glacier has been observed, with a mean annual rate of retreat of around 7.47 m.

Following measurements of studies undertaken during the IGY, the remaining surface areas of the main glaciers on Mt. Kenya are shown in Table 5.1 (in km^2). These figures indicate a total snow cover of 0.742 km^2 on Mt. Kenya during that period. Using estimates of the present and former snowline, the following can be deduced:

Table 5.1 *Glaciers in the Mount Kenya BR*

Main glaciers	Km^2
Lewis	0.360
Tyndall	0.105
Gregory	0.073
Cesar and Joseph	0.067
Krapf	0.040
Northey	0.033
Darwin	0.031
Forel	0.016
Heim	0.011
Melheish	0.006

- The lowest limit of glaciers at last glaciation was from 2,622 to 3,749 m above sea level.
- The snowline at maximum glaciation was 3,810 m.
- The present snowline is 4,754.88 m.

Because of its conical shape, the mountain is drained by radial streams, which on their upper parts exhibit deeply incised youthful valleys that are clearly due to earlier extensive glacial erosion. Older glaciers (as these are known locally) were much more extensive than the present remnants suggest. They are thought to have extended downwards to about 3,360 m on the eastern slopes. The younger glaciers only descended to about 3,048 m above sea level.

MOUNT KENYA GLOBAL ATMOSPHERE WATCH (GAW) STATION

The station is part of the World Meteorological Organization's (WMO) Global Atmosphere Watch Programme and was inaugurated in the year 2000. It is located at about 4,000 m along the western Sirimon route. The programme's objective is to monitor atmospheric composition change by measuring the chemical and physical properties of the atmosphere. The main greenhouse gases include CO_2, methane, Nitrous Oxide, HCFCs, CFCs and HFCs. These are the principal gases affecting global change, especially land cover and climate.

The establishment of the station was funded by the World Bank's Global Environment Facility (GEF) and built by the Institute for Atmospheric Environmental Research in Germany; it was added to the WMO's list in 1993. It is designed to relay its data by satellite communication directly to the Kenya Meteorological Department in Nairobi. The Kenya Meteorological Station then relays the data to the rest of the globe via a Global Telecommunications System (GTS). A number of other facilities are still lacking due to the absence of codes such as BUFFR; these include pollution monitoring. At present, the station only has codes for transmitting normal meteorological parameters. When it becomes fully operational it will also have a small on-site research station where scientists will be able to camp and carry out their tasks.

FLORA AND FAUNA

In 2001, the Kenya Wildlife Service (KWS) commissioned Martina Höft, with funding from UNESCO's World Heritage Centre, to prepare the 2002–7 Management Plan for the Mount Kenya Ecosystem. The section on flora and fauna is excellent. I sought permission from KWS to share it with you (without forgetting to note that her section is based on the success of earlier scholars). She wrote:

> The mountain falls into distinct belts distinguished by altitude and vegetation. The central rocky peak area (nival belt) lies above 4,419 m. Between 4,418 m and 3,400 m, a belt of Afroalpine vegetation is characterized by tussock grass, lobelia and giant groundsel (Beck et al., 1998). The lower part of the alpine belt, also referred to as the ericaceous belt, between 3,400 and 3,600 m, is covered with giant heather and *Hypericum relutum* trees.
> (Höft/KWS, 2001)

Moist Afromontane forest occurs in areas of over 2,200 mm rainfall per annum at 1,600–2,800 m on the northeast, east and south sides of the mountain. Vascular epiphytes are few, while epiphytic bryophytes and lichens are common. The montane forest belt is characterized by broad leaved and coniferous trees, and there are three distinct zones:

- the Hagenia-hypericum zone (3,200–3,400 m)
- the bamboo zone (2,440–3,200 m, mainly on the south-eastern slopes)
- the montane rainforest (2,000–2,400 m on the western and 2,400–2,700 m on the north-eastern slopes).

Some rare forest types occur at lower altitudes. They include the dry upland evergreen forest of C*roton megalocarpus, Brachylaena huillensis* and *Calodendrum capense*, which are limited in extent, and forest with *Celtis durandii, Croton sylvaticus* and *Premna maxima* on the northeastern slopes, and the only known occurrence of this forest type.

In 1994, Bussmann published a list of 882 plant species belonging to 479 genera in 146 families, which he identified in the forest zone of Mount Kenya (Bussmann, 1994). Bryophytes have been intensively studied by Chuah-Petiot (1995). The estimated number of moss species on Mount Kenya is about 350. Endemism among bryoflora is low, although there are a number of species with distinct distributions. The number of liverwort species is estimated to be well over 100.

There are at least eleven strict endemic species of higher plants and more than 150 near-endemics, that is, species that also occur on one or more of the following ranges: Aberdare Mountains, Mt. Kilimanjaro, Mt. Elgon, Mt. Meru and the Ruwenzori Mountains.

Of the 284 woody species occurring in the forests, 26 per cent are used for timber, 16 per cent are used medicinally, 9 per cent have edible fruits and 16 per cent are used for other purposes, for instance, tool handles, glue, arrow poison and soap (IUCN, 1994).

Mount Kenya is an important bird area and home to the threatened and little known Abott's Starling. Fifty-three of Kenya's sixty-seven African Highland biome species, at least thirty-five forest species and six of the eight species from Kenyan Mountains Endemic Bird Area reportedly occur on Mount Kenya (Bennun and Njoroge, 1999).

The Red Data Book for large forest mammals includes leopard, Eastern bongoi, giant forest hog, black rhino, African elephant (Appendix II of CITES listing) and black-fronted duiker. Other wildlife encountered includes Cape buffalo, Defassa waterbuck, black and white colobus, Sykes's monkey, Olive baboon, eland, zebra and reedbuck, spotted hyena, serval, genet and mongoose. Notable smaller and rare mammals reportedly include the Mount Kenya mole-shrew, mole-rat and thicket rat, highland musk shrew and East African rock hyrax (Coe and Foster, 1972; Young and Evans, 1993; Davies and Vanden Berghe, 1994).

MOUNT KENYA AND THE BIOSPHERE RESERVE

Mt. Kenya Biosphere Reserve straddles the equator between latitudes 37° and 38°E, and has a total area of 71,759 hectares. It was designated by UNESCO-MAB as a biosphere reserve (BR) in 1978 and in 1997 the park and the forest reserve was also designated a World Heritage Site. Its biome is a typically mixed mountain and highland ecosystem with a rich altitudinal plant zonation making it an excellent site for ethnobotanical studies and an importantly rich area for biodiversity.

Mount Kenya Biosphere Reserve is typical of the model biosphere reserve zonation, with the National Park making up the core zone, the National Forest Reserve in the buffer zone, and a very active region with a cultivated and settled lower part making up the transition zone. The mountain is truly the 'water tower' for almost 25 per cent of Kenya's population. Its plant resources meet the national needs for biodiversity and timber. The Mount Kenya forest block, which covers 213,000 hectares of gazetted forest, is highly important because it includes ecological, economic, conservation, water provision biodiversity and aesthetic values, along with trees such as the camphor, Meru oak and cypress that are now threatened. Mount Kenya is the source of Kenya's largest river, the Tana, whose course supplies water to hydropower stations and the major irrigation schemes (for instance, the Mwea Rice Scheme, Bura Settlement Scheme and Tana Delta Irrigation Scheme).

To the west and north of the mountain an important river, Ewaso Nyiro, also flows (with its tributaries) through the semi-arid plateaux of Laikipia and Samburu, providing water to livestock, wild animals and people. Its importance can be seen by the extent to which tourist lodges depend on this river. Diminishing flows of these two rivers bring power crises, hunger and even famine to the population, and death to both domesticated animals and wildlife. Within a period of a generation, rivers that once flowed constantly are becoming conspicuously seasonal even on the wetter western and southern slopes!

WHAT MIGHT WE STUDY IN THE THREE ZONES OF THE BR?

The Core Zone

The core zone covers the area of Mount Kenya National Park (gazetted in 1949). It consists of the Upper Montane and the Afroalpine wilderness, which is commonly referred to as the Moorland zone. The WMO's new Global Atmosphere Watch (GAW) centre is located here but currently there is little ongoing research. The zone offers a good laboratory for monitoring changes taking place in the field, especially glacial processes, the past and present extent of glaciations, as can be recorded from ground features. Studies of mountain palaeoclimatology can be compared with studies in other East African mountains and the East African Rift Valley pluvials and interpluvials during the Quaternary. The ten or so remaining glaciers provide good indicators of earlier events or current phenomena. Comparison with extra-tropical glaciations can also be done when more facts become available. To date, we have extremely scanty data to interpret in order to arrive at rather major comparisons or conclusions. With better equipment now available, we should be able to obtain more accurate data.

Baker (1967) states that erosion on the peak of Mount Kenya has reduced the height of the original peak from over 6,096 m to 5,199 m at present. If so, the change is significant because the present topography is just at its early youthful dissection stage.

The Buffer Zone

The buffer zone is the area covered by Mount Kenya National Reserve, which was wisely established in 1932. It covers some 2,124 km². The forest has a rich biological diversity (both in terms of ecosystems and species). Bussman (1994) identified 882 plant species, of which eighty-one are said to be endemic. The most popularly sought large tree species are listed in Table 5.2.

It is said today that the forest is under threat from illegal harvesting and charcoal burning. Over 4,200 kilns have been counted from the most damaged eastern slopes. Tea plantations are gaining ground although their conservation role in the forest has yet to be quantified. Marijuana is also illegally grown, especially along the Ruguti and Thuchi river valleys. Logging, especially for the tree species listed in Table 5.2, is also taking place without the proper permits. In addition to the indigenous plantations, exotic plantations are expanding.

The Forest Department encouraged a programme known as 'Non Residential Cultivation' or 'Shamba Cultivation' in the forest, whereby the landless are allowed to cultivate crops in the forest, and new tree seedlings are planted four or five years later on the destroyed forest patches. This had proved economical for the Forest Department but wildlife was destroying the crops and the technique was abandoned.

Table 5.2
Most sought-after large tree species

Botanical name	Common name
Ocotea usambarensis	Camphor
Juniperus procera	Cedar
Olea europaea	Wild olive
Vitex keniensis	Meru oak
Podocarpus latifolius	Podo
Hagenia abyssinica	East African rosewood
Croton marcostachyus	Croton
Ficus thonningii	Mugumo

There are an estimated 2,000 elephants in the forest. Their migration to the adjoining Aberdare Forest has declined as their corridors have been blocked by human settlements. The KWS would like to increase the numbers of eastern bongo (*Tragelaphus eurycerus isaaci*) and the black rhino (*Diceros bicornis*) in Mt. Kenya but the logistics for this have yet to be agreed upon, and are being discussed in consultation with IUCN's East Africa office.

What then are the issues that deserve research as part of global change studies in this buffer zone? I would say they centre on conservation: to help in rehabilitating the degraded vital water catchments, protect biodiversity and the endangered wildlife species, and make this important water tower a dependable source for lowland inhabitants.

The Transition Zone

The transition zone corresponds to the area occupied by local communities who live in proximity to the buffer zone and naturally interact intimately with this zone on an almost daily basis. From here the destructive effects of humans on their environment can clearly be seen. The foothills of Mt. Kenya are densely populated and pose the greatest threat to the sustainable use of mountain resources. The situation is untenable and the only way the KWS can keep people off the forest is by armed deterrence, and a longer-term solution must be found because this fragile situation cannot be maintained. The sustainable management and future of this biosphere reserve will depend on being able to involve the local communities in a successful participatory process based on dialogue, training and education, and equitable sharing of the resources in the biosphere reserve.

As far as global change issues are concerned, this zone is under intense cultivation of both subsistence and cash crops – maize, beans, coffee, tea and so on – especially in Nyeri. This is now a truly anthropogenic landscape with little remaining of the original indigenous forest vegetation; 80 per cent of the land surface has been changed (Jaetzold and Schmidt, 1983).

PEOPLE AND CULTURE

The population places great importance on land ownership. The resulting land fragmentation is such that many households own no more than 0.4 hectares. Many attempt zero-grazing and practice agroforestry for their fuelwood needs. Urban settlements are poorly planned with roads responsible for gully erosion, which is exacerbated by the steep slopes.

MANAGEMENT OF THE BIOSPHERE RESERVE

The government has assigned the management of Mt. Kenya Biosphere Reserve to KWS, while the Forest Department is responsible for forest plantation. These two Departments fall under the Ministry of Environment and Natural Resources.

Concern for the sustainability of the Mt. Kenya ecosystem and resources has attracted support from UNDP, FAO and the Swiss Development Cooperation (SDC). They are independently teaming up with local communities through Community Management and

Table 5.3
Population growth over the years

District	Area (Km^2)	1969	1979	1999	No. of Households	
					1979	1999
Nyeri	3 284	360 845	486 477	661 156	98 222	168 786
Embu	2714	178 912	263 173	278 196	50 241	121 168
Meru	9 922	596 506	830 179	1 409 373	150 662	286 913
Isiolo	25 605	30 135	43 478	100 861	10 097	22 583
Kirinyaga	1 437	216 988	291 431	457 105	53 729	114 439
Laikipia	9 718	66 506	134 524	322 187	30 281	78 175

Protected Areas Conservation (CMPACT) to eradicate charcoal burning, illegal logging, forest fires, overgrazing and illegal cultivation in the forest. They provide water to some communities so as to prevent the illegal over-harvesting of water. They also encourage and support educational and public awareness programmes within the communities.

As previously mentioned, the main challenge lies in whether research can provide the solution towards sustainable land use in the Biosphere Reserve thus meeting the needs of present and future generations. The way forward is through appropriate and relevant research that generates training and demonstration models that can be used in conservation and development programmes that also alleviate poverty. Can we borrow a leaf from START (global change System for Analysis, Research and Training)? One of START's objectives is to enhance scientific capacity in developing countries: 'global change science to those regions of the world where there is shortfall of scientists … and where the need for research and action is pressing'.

The population living within the transition zone need to be provided with better living standards through better agriculture, land ownership and planned settlements. This requires greater and more effective involvement of the Kenyan authorities. The two development authorities, the Tana-Athi River (established 1974) and Ewaso Nyiro (North) authorities have vital roles to play in the water management of the two rivers. Clearly each needs to strengthen its research component so that water resources from the biosphere reserve can be better quantified and apportioned, and the sustainability of the supply properly addressed.

Our deep gratitude is owed to the Swiss Government for their support through the Laikipia Research Programme, which provides an existing base for expansion.

CONCLUDING REMARKS

For Mt. Kenya Biosphere Reserve, the fact that it is located in an essentially semi-arid setting makes global change research timely. Its equatorial position is an advantage and can play an important role in GAW. Furthermore, the high population in the transition zone provides the study with greater challenges to encourage the integration of scientific research with social research and the work of managers and administrators for development. Wiesmann (1991) suggests 'research with the aim of assisting development'.

This chapter has highlighted the wisdom of empowering the developing countries through training, education and research, thus involving the local communities so that they can be the advocates for the biosphere reserve concept. This last point can only be realized if the communities are sufficiently convinced that conservation will meet their immediate and future needs.

ACKNOWLEDGEMENTS

The preparation of this chapter has been greatly enhanced by useful discussions held with officers at KWS (Kenya Meteorological Department) and with R. S. Odingo, Kenya's representative on the IPCC. However, I wish to stress that the views expressed herein are those of the author alone.

Nyeri Met. Station (station number 90.36/288; latitude 00°26'S; longitude 36°58'E; altitude 5,771 feet (1,815 metres)																	
Month	Atmospheric pressure (1978–80)		Temperature									Relative humidity		Rainfall			
			Means			Extremes		Dry bulb		Dew point							
	0600 GMT	1200 GMT	Max.	Min.	Range	Highest	Lowest	0600 GMT	1200 GMT	0600 GMT	1200 GMT	300 GMT	600 GMT	Mean	Highest	Lowest	Max . 24-hour fall
	Mb	Mb	°C	°C	°C	°C	°C	°C	°C	°C	°C	%	%	mm	mm	mm	mm
January	825.6	822.1	24.7	10.3	14.4	28.8	5.7	16.7	23.0	12.4	12.9	76	54	103	170	63	38.5
February	825.3	821.7	25.7	11.0	14.7	30.3	4.7	17.0	24.0	12.9	12.7	77	50	68	133	20	29.5
March	825.0	821.5	25.8	11.8	14.0	31.4	5.5	17.7	24.0	13.3	13.1	77	51	91	119	38	61.0
April	825.1	821.9	24.0	14.0	10.0	28.0	11.5	17.6	22.1	14.9	14.8	85	64	93	157	57	29.9
May	826.2	823.5	22.6	14.1	8.5	26.2	9.5	16.8	21.6	14.8	14.7	88	65	213	360	69	56.0
June	826.9	824.4	21.2	12.5	8.7	24.0	8.7	15.1	20.2	13.0	13.7	85	65	41	82	3	28.7
July	827.3	824.9	20.0	11.9	8.1	24.5	8.3	13.8	18.8	12.2	12.6	90	66	20	35	6	10.7
August	826.8	824.2	20.6	11.8	8.8	25.3	6.3	14.0	19.4	12.2	12.2	90	68	31	46	31	22.3
September	826.5	824.1	23.3	12.4	10.9	29.1	7.3	15.3	22.2	12.3	11.4	82	50	19	175	4	28.2
October	826.4	822.9	24.5	13.1	11.4	27.4	8.0	17.0	23.1	13.3	11.9	79	50	120	185	89	44.7
November	825.8	822.4	23.0	12.4	10.6	27.0	6.7	17.0	20.8	14.0	13.9	82	65	152	185	121	44.2
December	825.5	822.2	23.5	11.4	12.1	28.8	4.1	17.0	21.6	13.4	14.3	79	65	72	95	52	25.7
Year	826.0	822.8	23.2	12.2	11.0	31.4	4.1	16.3	20.1	13.2	13.2	83	59	1023	1249	505	61.0

Table 5.4a
Nyeri Met. Station (1)

Nyeri Met. Station												
Month	No. of days of		Daily sunshine (1977–80)			Daily radiation (1976–80) Instrument: 'gb'			Monthly evaporation (1977–80) Pan type: 'a'		
	Rain	Thunder	Mean	Max. mean	Min. mean	Mean	Max. mean	Min. mean	Mean	Highest	Lowest
	>1mm	days	hours	hours	hours	langleys	langleys	langleys	mm	mm	mm
January	8	4	7.3	8.8	5.7	379	453	286	127	148	105
February	7	4	8.0	9.6	7.2	419	525	376	137	158	112
March	11	8	7.2	8.6	5.5	406	485	334	143	167	116
April	14	9	5.5	7.3	4.7	341	463	279	117	139	101
May	16	2	6.7	7.2	6.1	363	418	338	123	134	108
June	6	1	5.6	5.9	5.2	323	372	292	94	99	90
July	6	2	3.9	5.3	2.6	244	325	185	79	101	67
August	7	2	4.3	5.9	2.2	278	344	211	94	117	73
September	4	4	5.1	6.8	5.1	376	449	339	136	144	123
October	10	2	7.1	7.7	5.4	397	480	326	161	177	125
November	14	6	5.7	5.9	5.3	327	370	297	109	113	97
December	10	6	6.7	7.8	5.8	362	482	297	118	118	108
Year	113	50	6.1	6.9	5.5	351	429	325	1440	1498	1204

Table 5.4b
Nyeri Met. Station (2)

Nyeri Met. Station													
Cloud amount (1976–80)				Daily wind run	Wind speed (1976–80)		Calms (1976–80)		Visibility (1976–80)				
Total		Low							Fog		Mist/Haze		
0600 GMT	1200 GMT	0600 GMT	1200 GMT	(1976–80)	0600 GMT	1200 GMT	0600 GMT	1200 GMT	0600 GMT	1200 GMT	0600 GMT	1200 GMT
Otkas	Otkas	Otkas	Otkas	Miles	Knots	Knots	Days	Days	Days	Days	Days	Days
4.6	5.6	3.2	4.6	88.5	5	9	6	2	0	0	0	0
4.2	5.6	3.0	5.0	94.6	4	10	6	2	0	0	0	0
5.2	6.2	3.8	5.2	105.0	4	10	6	2	0	0	0	0
6.4	6.8	4.8	5.2	81.5	5	10	6	5	1	0	0	0
6.2	5.8	5.0	4.4	81.8	5	9	7	1	1	0	0	0
6.4	6.2	5.4	4.8	72.5	5	8	7	1	1	0	0	0
7.2	6.6	6.6	5.4	72.3	5	9	10	2	2	0	0	0
7.0	6.2	6.6	5.4	77.5	5	9	9	1	0	0	0	0
6.0	5.4	6.0	4.0	92.0	5	10	5	0	0	0	0	0
6.0	5.8	5.2	4.4	89.6	6	10	6	0	0	0	0	0
5.8	6.4	4.8	5.4	55.9	4	8	13	0	0	0	0	0
5.2	5.8	3.8	5.0	68.4	5	8	8	0	0	0	0	0
5.8	6.0	4.8	4.9	81.6	5	9	89	25	6	0	0	0

Table 5.4c
Nyeri Met. Station (3)

Embu Met. Station (station number 90.37/202; latitude 00°30'S; longitude 37°27'E; altitude 4,900 feet (1,508 metres)																		
Month	Atmospheric pressure		Temperature (1977–80)									Relative humidity			Rainfall (1975–80)			
			Means			Extremes		Dry bulb		Dew points								
	0600 GMT	1200 GMT	Max.	Min.	Range	High-est	Low-est	0600 GMT	1200 GMT	0600 GMT	1200 GMT	0300 GMT	0600 GMT	0600 GMT	Mean	High-est	Low-est	Max. 24 hour fall
	Mb	Mb	°C	°C	°C	°C	°C	°C	°C	°C	°C	%	%	%	mm	mm	mm	mm
January	852.6	849.0	24.4	12.1	12.3	28.4	9.0	19.3	23.0	13.5	15.0	86	71	61	65	144	7	28.5
February	852.2	849.0	26.0	13.1	12.9	29.7	7.9	19.2	24.6	14.5	14.5	86	74	54	60	114	0	53.6
March	851.7	848.6	26.3	14.0	12.3	31.4	10.5	19.2	25.1	15.2	14.3	88	78	52	111	189	39	40.0
April	851.9	849.1	24.8	15.4	9.4	29.3	12.7	18.4	23.9	16.4	15.9	95	88	68	322	431	148	83.4
May	853.1	850.2	23.7	14.9	8.8	27.5	11.2	18.0	22.7	15.4	15.4	95	85	63	189	244	66	48.8
June	854.7	851.2	22.2	13.3	8.9	25.8	9.5	16.0	21.3	13.6	14.2	92	86	60	25	44	4	33.4
July	854.6	852.5	20.8	12.6	8.2	25.0	9.4	14.9	19.8	12.7	12.6	94	85	64	38	63	10	17.6
August	854.4	851.3	21.7	12.1	9.6	25.8	8.5	14.8	20.6	12.8	12.7	94	88	61	44	56	34	13.3
September	854.5	850.9	24.7	12.7	12.0	28.9	8.6	16.0	23.6	13.1	11.4	92	83	46	40	80	10	45.6
October	853.7	850.0	25.8	13.9	11.9	29.5	9.4	17.4	24.9	14.3	12.1	93	82	48	157	256	66	89.4
November	852.8	849.6	23.6	13.6	10.0	26.4	8.5	18.2	22.4	15.3	15.7	93	83	66	259	391	152	74.0
December	852.5	849.5	23.8	12.8	11.0	26.9	8.7	19.1	22.8	14.5	15.7	90	75	65	54	104	30	26.3
Year	853.2	850.0	24.0	13.4	10.6	31.4	7.9	17.5	22.9	14.3	14.1	91	82	59	1364	1580	97	89.4

Table 5.5a
Embu Met. Station (1)

Embu Met. Station											
Month	No. of days of		Daily sunshine (1977–80)			Daily radiation (1976–80) Instrument: 'gb'			Monthly evaporation (1977–80) Pan type: 'a'		
	Rain	Thunder	Mean	Max. mean	Min. mean	Mean	Max. mean	Min. mean	Mean	Highest	Lowest
	>1mm	days	hours	hours	hours	langleys	langleys	langleys	mm	mm	mm
January	7	3	8.5	9.4	7.2	475	516	418	158	181	135
February	4	4	9.0	10.2	8.3	489	538	457	159	199	123
March	11	4	8.1	8.9	6.5	480	510	423	163	221	127
April	20	5	6.6	7.4	5.5	443	462	423	143	171	125
May	15	4	6.2	6.6	5.8	428	534	381	131	136	123
June	4	1	4.3	4.6	3.9	356	427	314	96	100	91
July	9	0	2.4	3.5	1.3	435	479	381	77	93	66
August	10	1	3.8	5.1	3.2	362	456	308	93	107	75
September	4	4	5.4	5.8	4.9	423	490	386	128	144	114
October	12	2	7.1	8.1	5.3	440	463	381	146	167	116
November	17	4	6.9	7.6	5.4	419	439	386	134	140	128
December	10	2	8.4	9.2	7.4	452	503	431	145	166	132
Year	123	34	6.4	6.9	6.0	433	445	422	1573	1823	1185

Table 5.5b
Embu Met. Station (2)

Embu Met. Station													
Cloud amount (1977–80)				Daily wind run	Wind speed (1977–80)		Calms (1975–80)		Visibility (1977–80)				
Total		Low							Fog		Mist/Haze		
0600 GMT	1200 GMT	0600 GMT	1200 GMT	(1976–80)	0600 GMT	1200 GMT	0600 GMT	1200 GMT	0600 GMT	1200 GMT	0600 GMT	1200 GMT	
Otkas	Otkas	Otkas	Otkas	Miles	Knots	Knots	Days	Days	Days	Days	Days	Days	
5.0	4.7	3.3	3.3	76.0	4	6	11	2	1	0	0	0	
4.5	4.2	3.2	3.8	89.3	4	7	6	0	0	0	0	0	
5.5	5.0	4.5	4.2	87.4	4	7	6	2	1	0	0	0	
6.5	5.7	5.2	5.2	69.5	3	5	8	3	3	0	0	0	
5.7	6.0	4.8	5.0	57.1	2	4	8	2	4	2	0	0	
6.2	6.0	5.2	5.5	63.6	3	3	6	4	3	0	0	0	
7.0	7.0	6.0	6.0	77.1	2	3	7	6	1	0	0	0	
6.7	6.7	6.0	6.2	71.5	3	4	8	6	2	0	0	0	
6.5	5.0	6.0	4.8	64.5	3	4	6	5	1	1	0	3	
6.0	5.7	5.5	5.8	65.6	3	5	7	2	2	1	0	0	
6.2	5.7	5.2	5.2	85.7	4	7	5	2	3	0	0	0	
5.2	5.0	4.0	4.8	23.9	4	7	6	2	1	0	0	0	
5.9	5.6	4.9	5.0	73.4	3	5	84	36	22	4	0	3	

Table 5.5c
Embu Met. Station (3)

Meru Met. Station (station number 89.37/065; latitude 00°05'N; longitude 37°39'E; altitude 5,100 feet (1,555 metres)																		
Month	Atmospheric pressure		Temperature (1975–80)									Relative humidity			Rainfall (1975–80)			
			Means			Extremes		Dry bulb		Dew points								
	0600 GMT	1200 GMT	Max	Min	Range	High-est	Low-est	0600 GMT	1200 GMT	0600 GMT	1200 GMT	0300 GMT	0600 GMT	0600 GMT	Mean	High-est	Low-est	Max 24 hour fall
	Mb	Mb	°C	°C	°C	°C	°C	°C	°C	°C	°C	%	%	%	mm	mm	mm	mm
January			23.4	11.4	12.0	26.0	6.4	18.3	22.1	14.4	14.3	92	79	67	80	263	11	75.6
February			24.7	11.9	12.8	28.3	6.9	18.7	23.8	14.8	14.7	91	78	50	39	75	0	28.7
March			25.7	13.0	12.7	29.8	9.2	19.4	24.6	15.1	14.3	91	78	55	126	526	5	91.3
April			24.1	14.3	9.8	28.6	10.6	19.3	23.1	16.0	16.2	95	81	67	282	481	122	102.2
May			22.8	13.7	9.1	25.5	8.9	18.5	22.0	15.4	16.4	95	83	71	86	133	19	54.4
June			22.1	12.0	10.1	25.2	7.0	16.9	21.5	13.4	14.1	94	81	63	5	3	0	6.3
July			21.5	11.9	9.6	24.6	7.5	15.7	20.6	12.7	12.4	95	84	61	10	7	1	7..5
August			22.1	12.0	10.1	26.2	8.5	15.5	21.1	12.3	11.9	93	83	56	8	12	5	6.1
September			24.4	12.3	12.1	28.7	7.8	16.8	23.7	12.9	11.8	93	78	49	16	28	2	19.9
October			25.1	13.5	11.6	30.0	9.0	18.1	24.2	14.3	11.9	93	79	49	140	241	79	105.5
November			22.8	13.1	9.7	25.7	9.2	18.4	21.6	15.2	15.5	96	83	71	328	607	158	93.3
December			22.7	12.0	10.7	25.7	8.0	18.4	21.6	15.1	16.1	95	81	73	139	259	23	90.1
Year			23.4	12.6	10.8	30.0	6.4	17.8	22.5	14.3	14.1	94	81	61	1259	1905	870	105.5

Table 5.6a
Meru Met. Station (1)

Meru Met. Station											
Month	No. of days of		Daily sunshine (1975–80)			Daily radiation (1979–9) Instrument: 'gb'			Monthly evaporation (1976–7, 1979–80) Pan type: 'a'		
	Rain	Thunder	Mean	Max. mean	Min. mean	Mean	Max. mean	Min. mean	Mean	Highest	Lowest
	>1mm	days	hours	hours	hours	langleys	langleys	langleys	mm	mm	mm
January	7	6	8.1	9.7	5.8	379	400	357	120	137	97
February	6	7	8.6	10.1	7.1	432	452	410	129	149	104
March	8	8	8.3	9.2	5.5	429	481	375	157	178	144
April	17	11	7.5	9.1	6.4	384	415	360	134	150	119
May	10	5	8.1	9.2	7.1	382	397	369	117	127	111
June	3	1	7.5	9.4	6.5	365	380	342	115	131	103
July	3	2	6.1	7.6	5.6	315	348	294	115	137	931
August	3	1	6.5	8.3	5.1	366	405	328	133	157	101
September	4	3	7.7	8.7	6.8	431	443	417	148	173	341
October	9	2	7.9	8.8	5.9	426	451	382	170	187	468
November	17	8	6.4	8.0	4.7	361	385	314	110	131	495
December	12	7	7.0	8.9	4.7	335	342	327	111	122	
Year	99	61	7.5	8.3	6.4	384	404	366	1559	1719	1449

Table 5.6b
Meru Met. Station (2)

Meru Met. Station												
Cloud amount (1975–80)				Daily wind run (1975–80)	Wind speed (1975–80)		Calms (1975–80)		Visibility (1975–80)			
Total		Low							Fog		Mist/Haze	
0600 GMT	1200 GMT	0600 GMT	1200 GMT		0600 GMT	1200 GMT	0600 GMT	1200 GMT	0600 GMT	1200 GMT	0600 GMT	1200 GMT
Otkas	Otkas	Otkas	Otkas	Miles	Knots	Knots	Days	Days	Days	Days	Days	Days
5.7	5.8	3.8	4.7	66.8	5	8	1	0	3	1	0	0
5.5	5.8	4.2	4.7	67.7	5	8	2	0	2	1	0	0
6.0	6.3	4.5	5.2	63.5	5	8	1	1	3	1	0	0
6.5	6.7	4.0	5.5	53.6	6	8	2	0	3	0	0	0
5.8	6.2	4.3	5.5	62.9	7	9	1	0	7	2	0	0
5.8	5.8	4.8	4.7	58.1	7	10	1	0	5	1	0	0
6.5	6.5	5.2	5.2	62.1	7	11	1	0	8	1	0	2
6.5	6.2	5.5	4.5	75.2	7	10	0	0	7	2	0	1
5.7	4.8	5.3	3.7	82.7	7	11	0	0	4	1	0	1
6.0	5.6	4.6	4.4	75.3	7	9	1	0	4	0	0	0
6.3	6.6	4.6	5.4	50.9	5	7	1	1	3	0	0	0
5.3	6.3	4.1	5.4	50.8	5	7	3	1	3	1	0	0
6.0	6.1	4.6	4.9	64.1	6	9	14	3	52	11	0	4

Table 5.6c
Meru Met. Station (3)

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6. *Kyrgyzstan: Issyk-Kul Biosphere Reserve, Kyrgyz Republic*

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The mountain area of the central Tien Shan region, with Lake Issyk-Kul located at its centre, is an ecosystem of global importance containing a significant number of endemic species of flora and fauna. Lake Issyk-Kul, measuring 180 × 60 km, is the biggest and second-highest mountain lake in the world. It is located 1,600 meters above sea level and is surrounded by high mountain ranges rising to an attitude of more than 7,000 m.

Starting from the lakeshore, many diverse landscapes can be found, ranging from subtropic to tundra. There are deserts, semi-deserts, dry steppes, steppes, alpine meadows, shrubs and the Tien Shan spruce forests. On the northern slopes there are subalpine and alpine meadows and pastures, swamps on permafrost soils, and areas of tundra vegetation on subnival and nival levels; all of these can be seen during a four-hour trip.

This unique landscape has been appropriated by the Kyrgyz people, who have been living in close harmony with nature and enjoying its wealth of resources for centuries. These resources include the rich meadows on the upper reaches of the mountains at an altitude of 4,000 m above sea level. They can only be reached during the summer months. The nomadic Kyrgyz culture – symbolically represented by the felt yurts, the traditional dwellings of the nomadic people – has an economic structure that makes it possible to ensure stable and quite intensive use of available natural resources over many generations: in short, 'sustainable development'.

The people living in the Republic today are made up of various ethnic groups, but are mainly tribes and peoples of the Turkish-language family who came from Southern Siberia and Central Asia. The most ancient archaeological monuments found on this territory date back to the Palaeolithic period. Rare items have been discovered dating back to the Mesolithic and early Neolithic period; even more surprisingly, some items have been dated to the 'remarkable stratum' period or Bronze Age. Further development of this area is connected with the spreading of the Sacks culture (seventh–second centuries B.C.) and the subsequent alliance of Usuns (third century B.C. to early A.D.). The best-known monuments are the flooded medieval ruins of 'Timur's Palace'. In the Middle Ages, development was influenced by active trade relations between the east and west – some branches of the Great Silk Road actually ran through the Issyk-Kul valley. Chinese sources from the first and second centuries A.D. reveal that Lake Issy-Kul was called 'Je Hi' (warm sea). According to the world map of the eleventh century A.D. drawn by the central Asian scientist Mahmud Kashgarski, Isig Kel also means 'Sacred Lake'.

The diverse and rich nature of this territory and its geographical relation to the Great Silk Road brought economic benefits and an improved standard of living that drew many curious travellers and scientists. Indeed, historical studies of the Tian Shan covering many centuries have been produced by travellers and scholars from more than forty countries of the Old and New Worlds. Researchers of the ancient period were of Greek and Roman origin and from the Ancient East. From the Middle Ages, Arabs were represented. Between 1902 and 1903 the German scientists G. Mertsbaher and Keidel visited the Central Tian Shan and, among other things, established the exact topographical site of Khan Tengry Peak. In Soviet times the Tian Shan was studied by Soviet scientists, who explored modern aspects of the Tian Shan such as its population, development issues and future prospects.

GLOBAL EXPERIENCE

Taking into account the essentially damaging anthropomorphic impacts on the environment during the last century, and considering the importance of the ecological aspects for humankind's existence with the purpose of preserving global natural resources, UNESCO, within the framework of the MAB programme 'Man and Biosphere', is working to establish a universal network of biosphere territories. The territory of Issyk-Kul, in the northeastern part of the Tian Shan, has attracted the attention of the scientific community for many years. Scientists are attracted not only to the mountainous lake and its closed valleys, but also to its 'syrts' (subalpine and alpine meadows) and their permanent freezing, with the highest peaks, Victory and Khan Tengry and the extensive frozen zones of the Central Asian region and the river mouths of the Aral and Tarim water basins.

THE ISSYK-KUL BIOSPHERE RESERVE

Issyk-Kul Biosphere Reserve is a model landscape that is sustainable from an ecological viewpoint. Today, scientists, managers and the community of the Kyrgyz Republic are agreed about the need for practical activities to preserve and support the dynamic equilibrium of the environment. This is especially important in those areas most vulnerable to external influences in high mountainous terrain, particularly in areas with unique natural conditions. Unfortunately however, economic crises, lack of financial resources, a decline in living standards and a number of depressed socio-economic processes mean that ecological issues are not considered as priorities. At the same time, market transformation processes, unsystematic economic management with no normative legal basis, and the unrestrained attitude of the local authorities can be seen as some of the causes for increasing environmental pressure.

In the Kyrgyz Republic, the National Environmental Action Plan (October 1995) approved the concept of ecological safety; it also accepted a number of important normative legal acts concerning environmental protection. In 1998 the Environment Action Plan approved the concept of strengthening and developing environmental protection activities for 1998–2001. In August 1998, the state-initiated programme 'The Earth' was approved for the period up to 2005; this includes the important aspects of protection and rational use of natural resources. The German government offered technical assistance to the Kyrgyz Republic for activities to create the biosphere reserve in the Issyk-Kul province, and the intergovernmental agreement for financial and technical cooperation was made in June 1996 in Bonn.

Issyk-Kul Biosphere Reserve has a surface area of 43,000 km^2, which is equivalent to 22 per cent of the total area of the Kyrgyz Republic. The population of 429,000 (296,000 of whom are rural) is mainly concentrated around the lake basin, and represents 9.2 per cent of the total population of the country. Industry has developed in two large provincial cities and a number of urban settlements, and the area accounts for 18 per cent of the country's industrial production. There are also many mineral deposits. Agriculture accounts for only 14 per cent of the total national agricultural output. In the drier western parts of the basin, sheep rearing is more developed, with minor irrigated farming (mostly mechanical irrigation by underground water). In the more humidified eastern parts of the basin, intensive livestock farming methods have developed. The unique mountainous landscapes, the therapeutic warm waters of the lake itself, together with the favourable climate, provide an opportunity to promote recreational activities.

The ecologically oriented planning of land tenure takes on targeted socioeconomic parameters, which are developed according to priorities and criteria thresholds for the territory. This approach towards socioeconomic territorial development will be coordinated alongside indicative state plans and strategies for the development of the province until 2005. Conceptually, limited economic growth is compatible with environmental protection. Technical and technological restructuring of manufacturing industry, the introduction of international standards of production, quality control and the establishment of an appropriate infrastructure network all require additional financial support.

A National Environmental Action Plan has been approved; it consists of a code of relevant normative acts based on international experience and includes UNESCO's Man and Biosphere (MAB) Programme. The substantiation of ecological criteria is fundamental to this project and will be the basis for the institutional transformation in establishing new legal and economic mechanisms to regulate interactions between the state, at different levels, and the natural resource users. This would have the effect of incorporating ecological requirements into the administrative decision procedure with respect to the economic efficiency of decisions.

Relief

On a macro level, the territory area is divided according to its relief into two large parts: Central and Inner Tien Shan. The lake basin is framed by ranges of sub-latitude extension, the Teskey and Kungey Ala-Too ranges, which rise to 5,000 m. These ranges are visible as two imposing mountain arches surrounding the basin and incorporating the western and eastern parts. At the western extremity of the lake, the Kungey Ala-Too reaches a height of about 3,000 m above sea level; a little further to the East it reaches 4,771 m, but gradually lowers as it moves more easterly.

Climate

Issyk-Kul province is characterized by significant seasonal and high-altitude variability. The Eurasian continent is typically dry and humid, but a high mountainous relief and the associated orographic features bring about an increase of precipitation in different regions. The ruggedness of the relief and the inner mountain of the Issyk-Kul Biosphere Reserve strongly influence its climatic conditions. Southern and southwestern winds are quite weak there, while in other regions of Kyrgyzstan they are more powerful.

The rugged relief and the valley orientation have an effect on the amount of insolation. An increase in precipitation with altitude is characteristic for all the regions. Distinct regional features are portrayed in the wind type, and in the distribution and formation of constant snow cover.

The mitigation of lake temperatures is shown quite noticeably along the entire length of the shore except its eastern parts. Here, during the winter, the gulf winds press into the frozen lands and snow cover is rapidly established on the bordering sites. In the mid-mountainous and high mountainous zones of the Issyk-Kul basin the climate varies from moderate to moderately cold and the influence of the lake is hardly apparent.

In the syrtis zones the climate, especially at altitudes above 3,000 m, resembles Arctic tundra. At the upper Bolshoy Naryn, the average minimum temperature is always below freezing throughout the year. At altitudes of 2,800 m, temperatures reach above zero only during the summer months.

The minimum annual humidity is typical of the westerly and flat parts of the region. About 120 mm of rain falls here annually. Rainfall increases from 242 mm to 579 mm in an easterly direction towards the extreme eastern part of the lake – the village of Tyup – from both the southern and northern coasts. There is a patchy distribution of snow cover; in fact a significant part of the territory has little or no snow cover.

The annual pattern of rainfall and temperatures are asynchronous, which in turn leads to the evolution of freezing processes. The increased loss of dust leads to earlier tailing, which in turn increases the period of ice thaw and partly accounts for the imbalance of the ice substrate. The location of the nearby Kumtor Gold Mining Company has an effect on the glaciers and contributes to their chemical pollution; according to recent research data an increase in the chemical pollution of glaciers has been noted. Unfortunately, conditions will worsen if predictions of climate warming are realized. The deterioration of conditions for the glaciers is not only linked to an increase in temperature but also to changes in rainfall patterns. A decrease in rainfall will in turn increase the number of solar days and the early onset of thawing. The majority of glaciers on the Jetym and Jetybel ranges are under threat while glaciers on the southern slope of the Kungey Ala-Too and the Borkoldoy range may disappear altogether. Minor changes could also affect the largest glacier system, Enylchek.

Flora

The vegetation of the region is particularly noteworthy due to the variety of natural and climatic conditions. The mountainous surface structure, combined wtih the natural and climatic conditions at different altitudes, determines the vertical zoning of vegetation in the territory. The dominant species among the seed plants are perennials and annual herbs, bushes and trees.

There are few endemic plants – only around 4 per cent of the total flora – and they are mainly found at high altitudes. Relic plants can also be found within the territory; sixty-five species of medicinal herbs, forty-five species of melliferous plants, and a few plant species used for dyeing. There are eleven species found in Issyk-Kul Biosphere Reserve that are included in the *Red Book of Endangered Species* of the Kyrgyz Republic.

Over the last century, when the lake's water level dropped the subsoil waters would serve to strengthen the coastal sands and protect them from weathering. Moreover, subsoil water is significant in the formation of coastal vegetation. In this way a special microclimate is created with less evaporation and more humidity; while during winter, snow accumulates and melts at a slower rate than in open areas. These conditions provide a favourable environment for grass and other plants.

In Western Issyk-Kul the sandy coastline of the lake supports the growth of grass such as sparkling chi and in the rocky parts of the coastline silver chingil and Ephedra horsetail can be found. Many species of medicinal, melliferous and decorative plants grow in natural fodder areas.

Considering the importance of the study of changes in the world climate, it should be clear that there is a need to implement practices accumulated by the world community with the goal of creating conditions for sustainable socio-economic and ecological development in the region.

7. Mongolia: Protected Area Network in Mongolia: The Example of Uvs Nuur Basin Biosphere Reserve

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HISTORICAL AND PRESENT STATUS OF NATURE CONSERVATION IN MONGOLIA

Since ancient times, the Mongolian people have had a tradition of conserving nature that has been recorded in historical documents and religious texts. Examples include the Law of the Great State during the Chinggis Khan period ('Ikh Zasag'-Great Yassa), Khalkha Juram during the Middle Ages, and the Teachings of the King in Eastern Mongolia.

In more recent times, the Mongolian government has approved thirty-one laws on environmental protection and conservation, and has ratified ten international conventions. In order to implement these laws, the government and parliament have enacted more than fifty rules and regulations. The Law on Protected Areas of 1994, the Law on Buffer-Zone Areas in Protected Areas of 1997, and the National Programme on Protected Areas approved in 1998 are the main documents governing the management of protected areas today.

At present, there are fifty-four protected areas in Mongolia. They comprise 13.4 per cent of the national territory (1.5 million km^2) and cover a total of 20.95 million hectares. In addition, locally protected areas cover another 3 million hectares. The government of Mongolia intends to establish more protected areas in the future, with an ultimate goal of 30 per cent of the total land area of Mongolia under protected area status.

Mongolia also has a long tradition of putting into practice one of the best-known methods of conserving nature: setting aside certain areas or species for special protection. The first such area to be set aside, Bogd Khan Mountain, was officially given protected status in 1778, and is recognized as one of the oldest protected areas in the world. This park, situated next to the largest city in Mongolia (its capital, Ulaanbaatar), still exists today and continues to support the conservation efforts of the country.

In terms of decreasing levels of protection, the fifty-four protected areas comprise twelve Strictly Protected Areas, such as the Uvs Nuur (Lake) Basin complex (10.5 million hectares), eighteen National Parks (8.5 million hectares), eighteen Nature Reserves (1.9 million hectares), and six National Monuments (80,000 hectares).

Established in 1993, the Uvs Lake Basin complex includes four separate Strictly Protected Areas:

Uvs Lake proper, Golden Sands (Altan Els), Tsagaan Shuvuut Mountain and Turgen Mountain. Together, these protect over 700,000 hectares of land and water, and the wide range of ecological zones represented is matched by few places in the world. From the perpetual snowfields and permafrost of Turgen Mountain to the desert sands of Altan Els, the variety of habitats supports an impressive array of plant and animal species.

Uvs Lake is the largest lake in Mongolia in terms of surface area, and the fact that it is a completely enclosed basin results in waters that are up to five times saltier than the oceans. Because of its shallowness, even small increases or decreases in the lake level can have dramatic impacts on habitats, particularly along the east and south shorelines where lands are quite flat.

The Uvs Lake Basin was designated an International Biosphere Reserve under the UNESCO-MAB programme in 1998, and was selected as Mongolia's first World Heritage Site in July 2003. The basin is part of the larger Altai-Sayan Ecoregion, named by the WWF as one of the top 200 areas in the world needing global attention during the twenty-first century. The basin was also selected by the UNESCO-International Geosphere-Biosphere Programme as one of ten sites worldwide to be monitored for global warming impacts. That study is currently ongoing.

Included within the basin are habitats important to a number of rare, endangered and endemic species. The Mongolian Protected Areas programme currently includes over 40 per cent of the habitat considered important for these species within the country. Expansion of the network will provide additional protection. The issue of nature protection and conservation is a high priority for the current government. In addition, sustainable development is seen as a way to improve the overall living standards of the Mongolian people. It is critical that these two priorities be handled together rather than separately, since the potential for conflict is high unless the issues are thoroughly and openly discussed.

CURRENT GOVERNMENT POLICY ON SUSTAINABLE DEVELOPMENT

Sustainable development is a complex and integrated issue covering economic, social, cultural, political and environmental issues so as to meet the needs of the present, without diminishing the resources and opportunities for future generations to meet their own needs. The government has developed the legal and economic basis for achieving ecological balance. State policy aims to establish conditions for the use of natural resources through the application of waste-free, ecologically friendly, advanced technology, and the production of pure, high quality goods. The Mongolian constitution (1992) declared the human right to a healthy life and secure environment. The 'Concept on Development of Mongolia' was approved by the Ikh Hural (Mongolian parliament) in 1996, and further supports the idea of sustainable development. In 1998, the government approved the National Programme for Mongolia's sustainable development for the future (MAP-21) and has been implementing it ever since. The policy goals are reflected in economic well being, economic growth, social development, and ecological policies and provisions. For example, the goals for economic well being are:

- Improving productivity and quality of agricultural products and maintaining stable trading.
- Increasing the yield of agricultural products through the implementation of progressive technology, and the supply of good quality seeds and fertilizers.

- Introducing progressive technology in power plants, including renewable energy sources like the sun, wind and water, to achieve environmentally friendly energy sources and to reduce energy waste.
- Privatizing land ownership or establishing long-term leasing.
- Developing a competitive, open market system.

ECONOMIC CONSIDERATIONS

Prior to 1990, light industry existed in the Uvs Lake region, including wool processing/washing facilities, lumber mills and flour mills. However, with the collapse of the centrally controlled economy and subsequent privatization of facilities, most of these facilities closed down and remain inactive.

Today the raising of livestock is the main economic activity, accounting for nearly 75 per cent of the gross domestic product of the region as well as 70 per cent of the labour force. Livestock numbers have fluctuated widely in recent years, decreasing by over 3.2 million animals in the past two years alone. A variety of factors including severe winters and reduced forage are blamed for the decline. Traditional row crop farming was practiced in some areas, and intensified somewhat in the 1970s and 1980s. However, unsuitable soils at higher elevations, coupled with lack of water in lower, flatter areas, make farming a marginal activity at best. The lack of any suitable infrastructure also limits the potential for economic development in the region. Roads are poor and communication systems are inadequate. The potential for improvements along these lines is high, but the resources to carry them out are severely restricted.

IMPORTANT WILDLIFE RESOURCES IN THE REGION

An impressive number of globally important species, as well as species of special concern, occur throughout the Uvs Lake Basin. These include at least ninety-five species of mammals, such as the Argali sheep, Siberian ibex, snow leopard, Eurasian lynx, Siberian roe deer, red deer, wild boar, goittered and black-tailed gazelle, marbled polecat and Eurasian otter. There are nearly 360 species of birds, including the Relict gull, Dalmatian pelican, Eurasian spoonbill, black stork, snow egret, mute swan, Altai snowcock, ring-necked pheasant and many others of special concern. Among the twenty-nine species of fish are some found only in such salt-concentrated waters.

The wide variety of habitats and species makes the region especially interesting and important from an international standpoint, and was a major contributing factor to the selection of the basin as a World Natural Heritage Site by the UNESCO Committee in 2003.

THREATS TO BIODIVERSITY

As stated previously, the issue of conservation of nature and the environment is given a high priority by the present government. It is included in three of the eleven areas currently receiving emphasis. In addition, the government has initiated land reform in the country, and under the land ownership law enacted in July 2002 Mongolians are able to actually own land for the first time in history. As a result, Mongolian people in the twenty-first century now have the opportunity to improve their livelihoods and economic condition, using their land as real estate. Some of the environmental issues being addressed by the government are hot topics not only in Mongolia but also worldwide.

Desertification, dust storms and loss of biodiversity are major threats to the environment of Mongolia. Desertification is influenced by such activities as illegal harvesting of brushwood and other plants, overgrazing, soil erosion caused by poor agricultural practices, and drought itself. Deforestation is occurring in a number of areas as a result of illegal tree cutting as well as fuel wood collection. Even in areas where logging is allowed, poor logging technology and practices result in wasted resources and degraded forest lands. Climate change is having an as yet undetermined impact on the biodiversity of the region, and global warming has the potential to increase the desert steppe portion of the region. Habitat alteration could come from a variety of causes, including the raising or lowering of the level of Uvs Nuur itself.

Threats to animal diversity include poaching, often the result of the high poverty level of the region, poor enforcement of laws protecting wildlife species, and the increase in illegal international trade in certain animals. Over-harvesting of some species may be occurring because there is not adequate information about population levels to determine harvest quotas. Other factors include habitat degradation caused by livestock overgrazing, ‘tracking’ (off-road vehicle travel resulting in eroded soils), possible air/water pollution, and probably others that are as yet undiscovered. Threats to plants include overuse/abuse of forest resources, international trade in plants, particularly those of medicinal value, and overgrazing.

In addition a number of threats may be critical, even though not of a habitat-degrading nature. An impressive number of laws and regulations have been established, dealing with protection of lands and buffer zones, flora and fauna and so on, but are inconsistent in some cases, and at times appear to be in conflict with one another. The funding necessary to implement many of the laws is limited at best, and enforcement is often weak or non-existent. Guidelines for implementation are often lacking, and the training levels and capacity of those expected to implement and enforce the regulations are often weak. The lack of an adequate incentive framework (salaries, rewards and so on) for agents as well as local citizens is also problematic.

INTERNATIONAL ACTIVITIES IN THE REGION

A number of international collaborative activities have occurred in the region in recent years. The United Nations Development Programme (UNDP), including the Global Environmental Facility (GEF), has provided critical resources in a number of instances, as has the German Technical Assistance programme (GTZ). The Dutch government funded an Environmental Awareness effort in the late 1990s. The World Wide Fund for Nature (WWF), as part of a larger Altai-Sayan Ecoregion project, provides support for strengthening the management capabilities of protected area staff. The Greifswals University (Germany) is assisting in terms of livestock grazing studies. The Marvel Foundation (France) is assisting in a recently initiated programme designed to re-introduce Przewalski’s horse (takhi) back into the Uvs Lake region. Similar efforts, coordinated by the Mongolian Association for Conservation of Nature and Environment

(MACNE), with valuable financial assistance from the Dutch government, have proved highly successful at the Hustai Nuruu National Park in central Mongolia, and similar success is envisioned at Uvs Nuur. These and other initiatives demonstrate that others also see this region as critically important from a global perspective.

MONGOLIAN NATIONAL PROGRAMMES IN THE REGION

A number of programmes developed since 1990 are improving Mongolia's ability to protect and manage its natural resources. The Biodiversity Action Plan of 1996 has provided a framework for achieving success. National efforts to improve forest management (1998, 2001) have the potential to improve forest habitats markedly. The National Protected Areas Programme is an important element in the overall effort to conserve and protect Mongolia's most precious areas and resources. Finally, the Mongolian Action Plan for the Twenty-First Century (MAP-21) provides a vehicle for sustainable social development, wise use of natural resources, adequate environmental protection, and a means of implementation. Taken together, these efforts provide hope for a brighter future for the resources and people of Mongolia.

Many environmental issues remain unresolved, but much has been accomplished in the sustainable use of natural resources. Areas needing additional attention include the restoration of degraded lands, modernization of production technology, and application of ecologically clean methods and technology in industry. Another important issue is to initiate better management of solid and toxic wastes. Some initial actions have been taken by implementing management plans in large cities and local areas, with the assistance of major international donor agencies. The year 2004 has been declared by the government as the 'Year of Water'. Within this framework, surveys of ground and surface water will be carried out in 2004. We have some good experience to share, but there still needs to be more action to complete the principles for the wise use of natural resources.

AREAS OF CONCERN, ACTIONS NEEDED

A number of key issues need to be addressed if we are to be successful in our management of the Uvs Nuur Basin, as well as the rest of Mongolia. Resources at risk include forest lands, freshwater areas, native grasslands, keystone wildlife and plant species, and the quality of life of people who enjoy these lands.

- Protection and restoration of important habitats can occur through the expansion of the Protected Areas programme.
- Cooperation and collaboration between and among different protected area administrations can be improved.
- Promotion of the community-based management concept, including participation by local people, will help create an incentive for local involvement and the support of conservation programmes.
- Efforts towards increasing public awareness will help address the issue of poaching that is so evident in many areas.

- Support and encouragement of traditional practices and teachings on nature protection will serve to rekindle the beliefs and values held by earlier Mongolians.
- Establishment of Environmental Education Centres at protected areas and within buffer zone communities will go far towards increasing public understanding and appreciation for natural resources, and reduce the level of illegal activities.

In addition to the above, further efforts in the area of international fundraising will help generate the funds needed to implement many of the actions listed here and elsewhere. Since local governments have little experience along these lines, it is essential that international project offices (UNDP, WWF, GTZ and others) provide assistance in seeking out and obtaining these needed resources.

Finally, I highlight the following actions that need to be discussed with national and international organizations, for the benefit of regional and international development:

- Bring to the attention of donor organizations the issue of the enforcement of conventions to protect nature and the environment, and the difficulties in financing such efforts internally.
- Improve collaboration on transboundary trade, to prevent illegal trade and transfer of raw materials and wildlife products at national and international levels.
- Further cooperate and collaborate on transboundary control of forest and steppe wildfires.
- Establish transboundary protected areas, including joint development of management plans and work with neighbouring countries on nature conservation and biodiversity protection.

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8. *Peru: Huascarán Biosphere Reserve*

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LOCATION OF BIOSPHERE RESERVE

The Huascarán National Park (Parque Nacional Huascarán, PNH) was created in 1975; it was recognized by UNESCO as a biosphere reserve in 1977 and as a natural World Heritage Site in 1985. It is located in the Ancash department of the northern–centre of Peru (77° 59'–76° 42' longitude, 8° 38'–10° 18' latitude). Huascarán has an area of 3,400 km^2 with an average width of 20 km and a perimeter extending along 431,424 m. There are eighty-two landmarks among the ten provinces that make up the Huascarán National Park; they are: Huaylas, Yungay, Carhuaz, Huaraz, Recuay, Bolognesi, Huari, Asuncion, Mariscal Luzuriaga and Pomabamba.

VEGETATION ZONES IDENTIFIED IN THE BIOSPHERE RESERVE

The mountainous Andean region ranges between 1,000 m and 6,768 m along a north–south axis between the dry coastal strip to the west and the extremely wet Amazon rainforest to the east.

These lands have been intensively used with inappropriate technology for agricultural production and cattle grazing. The use of primitive production methods combined with high population growth has resulted in the destruction of the original vegetation cover; today only a few remnants of native forests survive, with most of the local species being replaced by exotic competitors.

Representative genera of shrub and lower shrub plant communities found within the reserve include: *Acacia, Spartium, Arundo, Alnus, Lupinus, Physalis, Salix* and *Eriotheca*. Hydrophilic and thallophytic plants like *Distichlis spicata*, and hydromorphic species like *Juncus* are also found, as are plants of the Cactáceae family such as *Neoraimondia*, *Browningia*, *Opuntia*, *Puya* and *Tillandsia*. Other genera include *Cestrum, Rubus, Baccharis* and *Agave*. Representative tree species include sauco, *Sambucus peruvianus* and *quisuar Buddleia spp*. Other interesting botanical species include *Brachyotum, Caesalpinia* and chinchango, *Hypericum laricifolium*.

Among examples of exotic species, the eucalyptus deserves a special mention, with *Eucalyptus globules* covering the largest forested areas in Ancash, and pine, cypress and casuarinas are found in lesser proportions.

The Gramineae, Compositae and Brassicaceae families dominate the herbaceous cover, mostly located in cultivated fields. Some of these plants can cause serious damage in agricultural lands. A example of this is the ‘kikuyo’, *Pennisetum clandestinum*, which can propagate rhizomes, seeds extremely easily and has invaded the entire area; cultivated fields have been totally abandoned in some areas and it has proved to be extremely difficult to exterminate.

Among the more common herbaceous plants we can mention: the cardo, *Cercium arvense*;

manzanilla hedionda, *Matricaria chamonilla*; tomatillo, *Lycopersicum pimpinefollium*; chamico, *Datura stramonium*; mostacilla, *Cinapis arvencis*; amor seco, *Bidens pilosa*; rabaniza, *Raphanus raphanistrum*; ortiga menor, *Urtica ureas*; and capulí cimarrón, *Nicandra phisalloides.*

The topography of the area between the glacier and the agricultural zone is very irregular, with many geological lithic formations. The vegetation cover is composed of tree and shrub forests of the genera *Polylepis, Budleia, Scallonia, Berberis, Baccharis* and *Gynoxis* that alternate with grasslands populations. Predominant genera include *Festucas, Calamagrostis* and *Stipas*, with the latter genus possessing a remarkable adaptability to the region but low nutritional value for cattle. The swamp area (cushion plants) is composed of young green vegetation throughout most all the year. Species such as *Distichia spp.* and *Distichia muscoides* and species of the genera *Oreobolus, Plántago* associated with species of the *Cyperaceae* and *Asteraceae* families.

CHARACTERIZATION OF THE SITE ABOVE THE VEGETATION LINE

Glaciers dominate this zone, with an approximate area of 611.48 km² in 1997. However, in the 1970s the area covered by glaciers measured 723.37 km², which means there has been a reduction in glacier area of 15.46 per cent. The sole life forms are the small lichens that live on dark-coloured stones in the lower limits of the glacier zone and in close proximity to the tundra formation. Some algae can also be found above the snowline.

DEMOGRAPHIC AND ECONOMIC CHARACTERIZATION OF THE BIOSPHERE RESERVE

The grassland users in the Reserve are situated in the core zone and are currently being organized into what is known as 'comités de usuarios de pastos naturales' (grassland users committees) for the co-management of grassland systems. Inside the park, local populations develop various economic activities associated with the sustainable use of natural resources. However, this concept of local users (natural resources users) is not compatible with the Natural Area objectives.

In the buffer zone, the population is grouped into sixty organizations formed by 'campesinos' (farmers) and 'pequeños propietarios' (small landowners). A total of 9,649 farmer family leaders have been identified from the approximate population of 67,543 inhabitants. The distribution of land uses and its potential inside the park are as follows: 27.47 per cent is arable land with irrigation systems; 21.55 per cent is *secano* lands (without irrigation systems, i.e. rain-fed agriculture); 2.44 per cent is forest areas and 48.54 per cent are grasslands.

The transition zone has a surface area of 6,456 km² (645,600 ha). These lands function under a communal, private or public ownership system. The provincial and departmental capital cities, with commercial and tourists zones, small businesses and mining industries (Pierina and Antamina) are all located in the transition zone; these areas form the Callejón de Huaylas and Conchucos economic corridor.

Among the economic activities developed in the park, the following should be mentioned:

- Mining. Mining activities within the Huascarán National Park are forbidden by law, although mining permits granted before the creation of the National Park are accepted and accord exploitation rights, but only in accordance with the environmental laws in force. With the recommencement of mining activities and the presence of two important mining companies, Antamina and Barrick, in the transition zone of the Biosphere Reserve, there has been a noticeable increase in claims to reactivate a number of mines and authorize new claims. The problem lies with the Mining and Energy Ministry that grants mining contracts.

- Hydroenergy. The water resource users established a group of economic units (families, private and public enterprises) and are the most demanding users of Egenor, the special projects Chavimochic and Chinecas, and the sanitation enterprises.
- Tourism. The PNH witnesses two forms of tourism: conventional and adventure tourism. Economic benefits to the PNH and the local population are measured in relation to the number of visitors (both foreign and national) and the amount of money spent in the reserve.
- Farming (agriculture and cattle raising). Local agriculture is based on irrigation and *secano* (rain-fed) systems. In areas higher than 2,900 m above sea level, the most common crops are corn, pumpkin, lettuce, cabbage and alfalfa, but there is also cultivation of wheat, barley and tubers, particularly potatoes. As regards fruit trees there are, among others, citrus, lúcumo, medlar, peach, pacae, apple, custard apple and capulí.

Between 2,900 and 3,600 m, potatoes and minor tubers (oca, olluco), legumes such as beans, and small grains (wheat, rye) are cultivated. Above 3,600 m the high Andes grasslands are used for the cattle raising activities (sheep and cattle grazing).

It is important to emphasize that inappropriate use of the land has directly contributed to the destruction and degradation of the soil. To solve this problem it is necessary to set up a production and protection programme for water and soil resources, which would have the effect of improving local agriculture while helping the local economy to recover.

ONGOING GLOBAL CHANGE PROGRAMMES AND INDIVIDUAL RESEARCH PROJECTS ADDRESSING GLOBAL CHANGE ISSUES

There are no specific programmes on global change; however, the National Institute of Natural Resources (INRENA), through its Glaciology and Hydric Resources Unit, is developing activities aimed at the study of the status and dynamics of the glaciers in Peru.

For the area around the 'Cordillera Blanca' (White Mountain Range), which constitutes the core and upper region of the Huascarán National Park, two glacier inventories have been made (1987 and 1997), with an inventory carried out in 1968 of lakes. Monitoring and measurement activities have taken place in seven glaciers, where mass balance data, front glaciers annual variation, balance line variations, glaciers speed and so on, have been determined.

AVAILABILITY OF CLIMATE, VEGETATION, HYDROLOGICAL, ECONOMIC AND DEMOGRAPHIC DATA

In 1984, the American botanist David Smith developed a botanical census of high Andes flora; this listed 799 species found in the PNH. On 26 July 1990, the first 'master plan' was agreed by the INRENA authorities; the most recent 'master plan' was endorsed on 20 December 2002.

In 1973 and 1975, the National Office of Natural Resources Evaluation (ONERN), developed studies of the soil, climate and environment in the 'Callejón de Huaylas' (Huaylas Corridor) and the 'Callejón de Conchucos' (Conchucos Corridor). These studies have been carried out in practically the entire Huascarán Biosphere Reserve. In the 1950s, the Santa Peruvian Corporation (a government organization) installed a complete hydrometeorological station in the Santa river basin, but unfortunately it is only partially operative. Other hydrometeorological stations have been installed by INRENA in five of the seven glaciers being monitored in the Cordillera Blanca.

9. *Russian Federation: Katunskiy Biosphere Reserve and Natural World Heritage Site*

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INTRODUCTION

More than 50 per cent of the territory of the Russian Federation is covered by mountains and highlands, of which there are fifteen mountain biosphere reserves (out of a total of thirty) situated in mountain massifs that represent the different environmental and economic zones of Northern Eurasia (Figure 9.1, Table 9.1). A number of them (Laplandskiy in Kola Peninsula, or Vismskiy in Central Ural, or Taimyrskiy in Taimyr Peninsula) are located in arctic belt and are affected by mining industries. Others are situated in very remote parts of Russia (Kronotskiy BR in Kamchatka, Sikhote-Alin BR in the far southeast).

Five South Siberian biosphere reserves are situated in the continental part of Eurasia; they provide good opportunities for research and for monitoring changes in the upper parts of the great Asian rivers, Ob, Enisey and Amur. There are two biosphere reserves in the Caucasus representing east Mediterranean features.

KATUNSKIY BIOSPHERE RESERVE: LOCATION AND DESCRIPTION

Katunskiy Biosphere Reserve (BR) is situated in the central part of Eurasia within the most elevated part of the Altai mountains. The highlands of the Katunskiy ridge are included in its territory. Mt. Belukha (4,506 m) – the highest peak of Altai – is part of Belukha Natural Park within the transition zone of the biosphere reserve.

The idea of creating a reserve in the central part of the Altai was first promoted by V. Semenov-Tyan-Shanskiy in 1917. Katunskiy nature reserve was established in 1991, principally to protect the snow leopard population and habitats, and in 1998 it was inscribed on the World Natural Heritage List of UNESCO as a cluster of the 'Golden mountains of the Altai' site. In 2000, it was designated a Biosphere Reserve by UNESCO's Man and the Biosphere (MAB) programme.

The core zone, with an area of 151,700 ha, includes parts of the north and south slopes of the Katunskiy and Listvyaga ridges located at heights between 1,300 and 3,280 m.

The climatic features of this territory are determined by the influence of the Asian anticyclone in winter, and in summer and the transition seasons by the western air transfer. In general, the territory

Figure 9.1
Mountain regions of North Eurasia including Russia. Mountain BRs shown as shaded rectangles

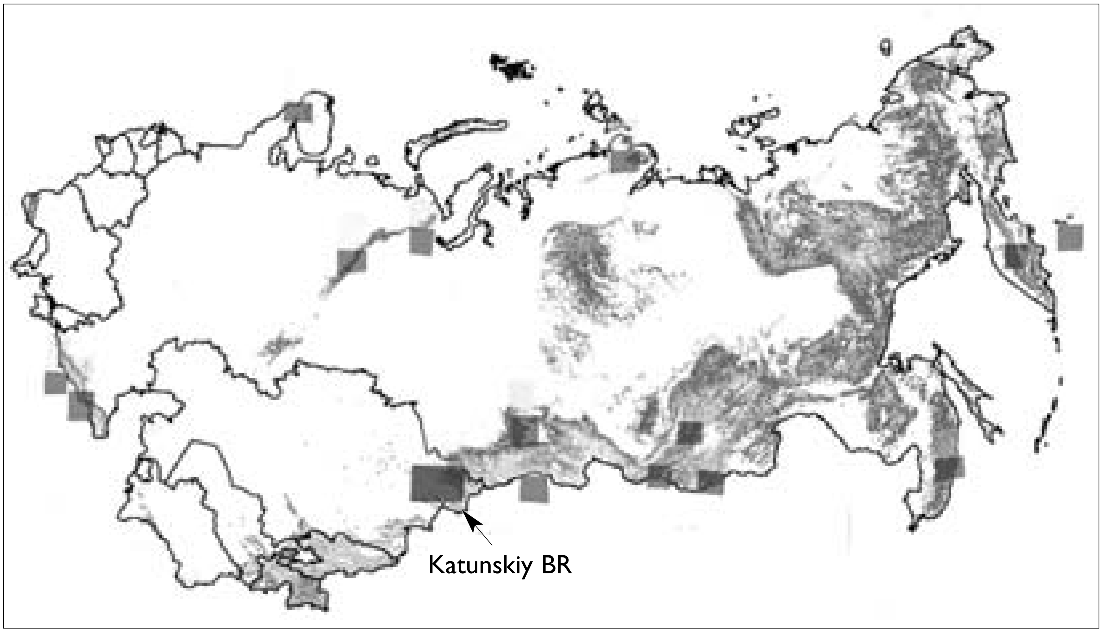


Table 9.1
Mountain Biosphere reserves and Natural World Heritage sites in Russia

No.	Biosphere reserve	Region	Status	Location/ Altitude/Size	Desig- nated
1	Kavkazskiy BR	Caucasus	Natural WH site TEMS	43°30' to 44°05'N 39°40' to 40°50'E 260 to 3 360 m a.s.l. 295 700 ha	1978
2	Teberda BR	Caucasus	Natural WH site	43°32'N 41°42'E 1 260 to 4 047 m a.s.l. 536 000 ha	1997
3	Sikhote-Alin BR	Far East (South)	Natural WH site TEMS	44°49' to 45°41'N 135°45' to 136°35'E 0 to 1 600 m a.s.l. 4 469 088 ha	1978
4	Kronotskiy BR	Kamchatka Peninsula	Natural WH site	54°09' to 55°07'N 159°38' to 162°07'E 0 to 3 528 m a.s.l. 1 142 134 ha	1984
5	Laplandskiy BR	Khibin mts Kola Peninsula		67°10' to 68°05'N 31°45'E to 32°45'E 470 to 1 115 m a.s.l. 278 400 ha	1984

6	Pechoro-Ilichskiy	Northern Urals	Natural WH site TEMS	61°58' to 63°16'N 57°47' to 59°39'E 1 183 to 1 195 m a.s.l. 1 253 753 ha	1984
7	Visimskiy BR	Central Ural Mountains		57°25'N 59°40'E 310 to 754 m a.s.l. 179 606 ha	2001
8	Taimirsky cluster BR	Taimyr Peninsula		73°01' to 74°35'N 95°47' to 101°18'E 0 to 569 m a.s.l. 2 750 291 ha	1995
9	Barguzinskiy BR	Barguzinskyi Mountain ridge SE Siberia	Natural WH site TEMS	54°20'N 109°45'E 400 to 3 000 m.a.s.l. 358 600 ha	1978
10	Baikalskiy BR	Western Sayan mts	Natural WH site	51°50'E 105°05'E 400 to 3 000 m.a.s.l. 200 524 ha	1986
11	Sayano-Shushenskiy BR	Sayan mts	TEMS	50°50' to 52°30'N 91°15' to 92°30'E 400 to 2 735 m.a.s.l. 390 368 ha	1984
12	Katunskiy BR	Altai mts	Natural WH site	49°28' to 49°65'N: 85°37' to 86°34'E 756 to 4 506 m.a.s.l. 695 262 ha	2000
13	Sokhondinsky BR	Sokhondo mts		49°28' to 49°53' 110°31' to 111°29'E 1 100 to 2 500 m a.s.l 347 000 ha	1984
14	Uvs Nuur cluster BR	Uvs Nuur Lake watershed	Natural WH site	48°20' to 51°10'N 91°19' to 94°49'E 700 to 4 096 m a.s.l. 284 300 ha	1997
15	Commander Islands	Archipelago in in Bering Sea		55°25' to 54°31'N 165°45' to 168°06'E 0 to 755 m.a.s.l. 3 648 679 ha (34 627 ha marine)	2002

Notes:
TEMS: Terrestrial Ecosystem Monitoring Site
Commander Islands may be recognized as a mountain BR

is situated within the continental-climate region. Mid-year temperatures are below zero (from –2 °C at 900 m to –6.3 °C on the tops of the ridges). The average altitudinal temperature gradient is 0.52 °C per 100 m. Precipitation increases from the foothills of Katunskiy Ridge (418 mm) towards the summit (estimated annual precipitation above the snowline is 1,600–2,000 mm). Above 3,000 m, 80 per cent of the precipitation falls as a snow.

Analysis of atmospheric circulation suggests that this is influenced by Europe, and to a greater degree of Asia. Specialist research has revealed the presence of heavy metals in the glaciers of Katunskiy Biosphere Reserve, which may be due to traces of industrial pollution from Kazakhstan. Other sources of pollution could include nuclear facilities, Semipalatinsk in Kazakhstan and Lop Nor in China, which are a short distance from Katunskiy BR. It is therefore ideally situated for the important monitoring of transboundary air pollution.

There are 135 mountain lakes within the core area. Generally, these are oligotroph moraine-dammed and kar reservoirs with a small area. About 90 per cent of the lakes are located at altitudes between 2,000 and 2,450 m above sea level. The dynamics of the lakes are under investigation by our scientific staff.

The territory of Katunskiy Biosphere Reserve is characterized by a high diversity of flora and fauna. In total, there are 663 species of higher vascular plants. Four of these are included into the Red Book of Russia: a dwarfish onion (*Allium pumilum*), a Nonfound monkshood (*Aconitum decipiens*), an Altaian rhubarb (*Rheum compactum* var. *Altaicum* (= *Rh. Altaicum*)), an Altaian gymnospermium (*Gymnospermium altaicum*). Seventeen species are included in the *Red Book of the Altai Republic*. They are: a Grapefern (*Botrychium multifidum*), a feather grass (*Stipa pennata*), an Altaian onion (*Allium altaicum*), a dwarfish onion, a Siberian kandyk (*Erythronium sibiricum*), a Whorled Fritillary (*Fritillaria verticillata*), a granulated gagea (*Gagea granulosa*), a Persian salep (*Dactylorchiza fuchsii*), an Altaian rhubarb, a peony hybrid (*Paeonia hybrida*), a Monkshood, a frost rhodiola (*Rhodiola algida*), a scarlet rhodiola (*Rh. Coccinea*), pink rhodiola (*Rh. Rosea*), an Altaian sibiraea (*Sibiraea altaiensis*), tea French honeysuckle (*Hedysarum theinum*) and an Alpic tristle (*Rhaponticum carmatoides*).

The fauna of the reserve is also rich. It includes forty-eight species of mammal and 132 species of birds. The snow leopard (*Uncia uncia*), which is in both the *Red Book of Russia* and the IUCN's Red List, occassionally enters into the territory and, as mentioned earlier, was one of the reasons for the establishment of Katunskiy reserve. Other rare species found include the river otter (*Lutra lutra*), *Vespertilio murinus*, the great cormorant (*Phalacrocorax carbo*), black

Table 9.2
Climatic characteristics of Katunskiy BR area

	Weatherstation, altitude (metres above sea level)		
	Katanda, 900	Kara-Turek, 2600	Ak-Kem, 2050
Mid–annual temperature, °C	–2.0	–6.3	–5.4
Mid–July temperature, °C	+15.2	+6.3	+8.3
Mid–January temperature, °C	–23.6	–16.9	–21.2
Precipitation, mm	418	736	628

stork (*Ciconia nigra*), Spanish imperial Eagle (*Aquila heliaca*), golden eagle (*Aquila chrysaetos*), black signature stamp (*Aegypius monachus*), saker falcon (*Falco cherrug*) and grey crane (*Grus grus*).

Due to its remoteness from settlements, Katunskiy BR was only slightly affected by human activity before its establishment as a protected area. The only human impacts were due to grazing and tourism.

Vegetation Zones

The lower zone is formed by a combination of cedar and larch (on the northern slopes) and meadows (on slopes of southern exposure). The cereal basis of the meadows includes orchid grass, couchgrass and meadow foxtale, while tall herbaceous meadows are formed near woods. In the lower part of this zone, within Katun terraces, there are unique steppe meadows where steppe, meadow and high-altitude species grow together. The lower parts of the river valleys are occupied by Siberian Spruce and larch woods. The forest ecosysytem makes up about 27 per cent of the total area.

Subalpine meadows and shrubs are found above the woods at a height of around 2,200 m. Mountain tundra within the reserve is fragmentary, and is found in combination with alpine meadows. Because of the high moisture, lichen-moss bushy tundra with *Betula rotundifolia* thrive and only occasionally do *Dryas oxyodonta* communities appear. Alpine glacial relief with steep slopes can be seen in the axial parts of the mountain ridges on the uppermost surfaces. Lichens dominate, and higher plant communities are bound by small contours. Pioneers plants are found on the upper borders.

Table 9.3
Altitude zones of Katunskiy BR (after Timoshok et al., 2003b)

Altitudinal zones		Altitude (m.a.s.l.)
Combination of steppes and woods		Fragments up to 1 600
Combination of woods and meadows		1 400–2 000
Subalpine zone	Combination of subalpine meadows and woods	1 800-2 000
	Subalpine tall herbaceous meadows and shrubs	1 900–2 200
Mountain tundra	Alpine meadows	2 200–2 500
	Lichen-moss bushy tundra with *Betula rotundifolia*	Fragments up to 2 000–2 400
	Communities of the crustaceous lichens	Above 2 400
Snow fields and glaciers		Above 2 600

Site Above the Vegetation Line

Nival complexes are spread above 2,600 m. The Katunskiy BR territory is the one of the modern glaciation centres within the Altai mountains (Western Katun centre). There are approximately eighty glaciers covering 3 per cent of Katunskiy BR; the glacier capacity is insignificant – up to 150 m. Studies of glaciation began in the middle of the nineteenth century and show a constant diminution of the area. Detailed descriptions of glaciation in this area can be consulted in Narozhniy, 1997; Narozhniy et al., 1999; Okishev et al., 2000; and Proceeding of State Nature Biosphere Reserve 'Katunskiy', 2001.

Long-term glaciological research was carried out in the massif of Mt. Belukha and in the actual area of the core zone in Mul'ta river basin (prior to the establishment of Katunskiy BR). The data indicates the retreat of glaciers. For instance, one of the larger glaciers – the Rhodzevich glacier in the Belukha massif – receded 1,800 m during the period 1938–65. Another example is the small glacier Tomich in Mul'ta river basin, which receded 61.9 m between 1973 and 1995.

Demographic and Economic Characteristics

The buffer zone encompasses lands used for different purposes, mainly forestry and agriculture (grazing lands). Recreation and tourism have been developed in several areas around Taimenye Lake and across the Mul'ta river.

The 'Terecta' transition zone is situated in land of the Terek joint-stock company, and has a total area of about 500 ha. This complex economy combines maral (red deer, *Cervus elaphus sibiricus*) farming, apiculture, agriculture, flour and bread production. There are several types of land use, including agriculture, forestry, and resident areas with kitchen gardens.

Within the Terecta zone there is one village, Terecta, with 506 inhabitants (in 2003). On average, 3.3 people make up each family unit. Most of the able-bodied population (41 per cent) work for the Terek Company. The majority of people have a part-time farm, which is the main source of income for more than 40 per cent of the population. Many local people (12–15 per cent) are engaged in beekeeping.

The transition zone covers all the high-altitude zones of Terectinskiy ridge, from the steppes of the Ujmonskaya intermountain hollow up to the mountain tundras and snowfields. The recreational resources of this territory are potentially vast but tourism is limited due to the present infrastructure and lack of advertising.

Another cluster of the transition zone – the Belukha Nature Park – comprises the massive of Mt. Belukha (4,506 m), a Natural World Heritage Site. Land uses include forestry and grazing. There are no settlements. The most developed economy in the park is recreation and tourism. Mt. Belukha is popular among alpinists; it also attracts followers of various religions as the legendary 'Belovodye country' – a land of freedom and harmony. The famous philosopher and artist N. Roerich cited Belukha as the way to Shambala. For native Altaians, Mt. Belukha is a sacred place; it is even forbidden to look at it.

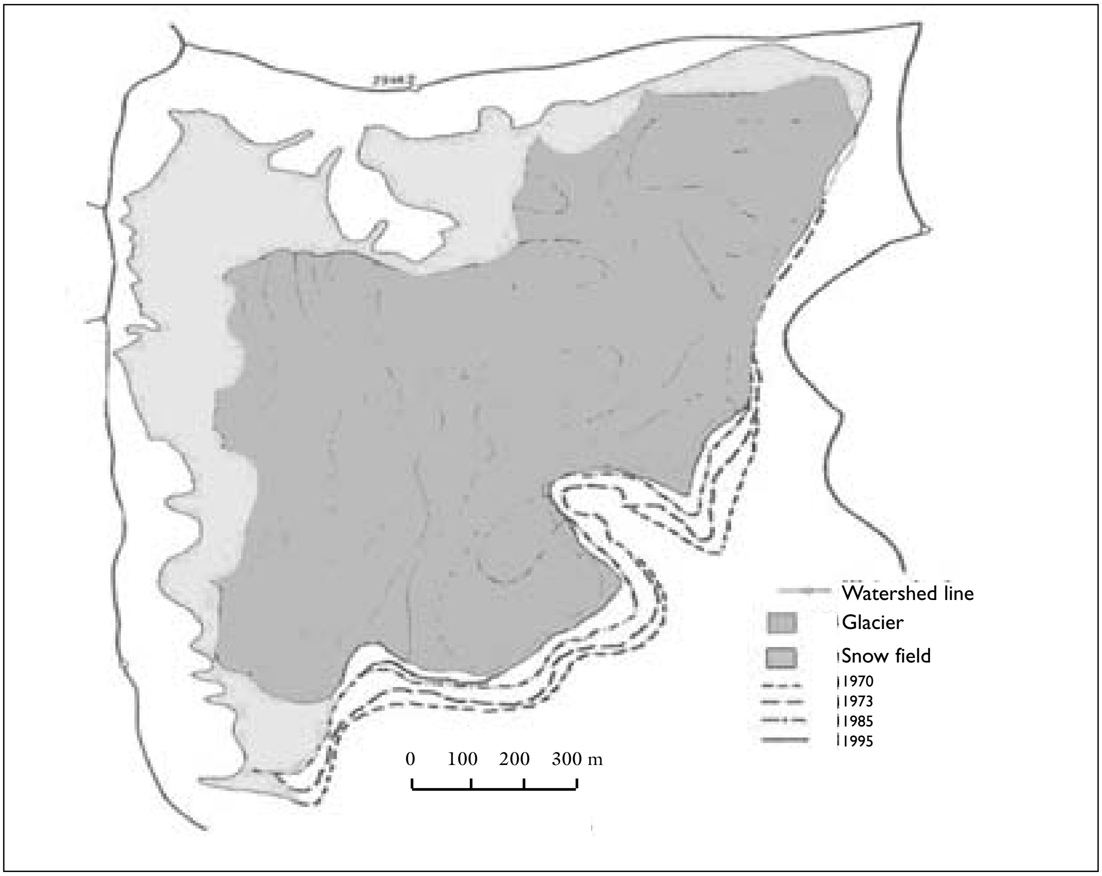


Figure 9.2
Rhodzevich glacier in the Belukha massif

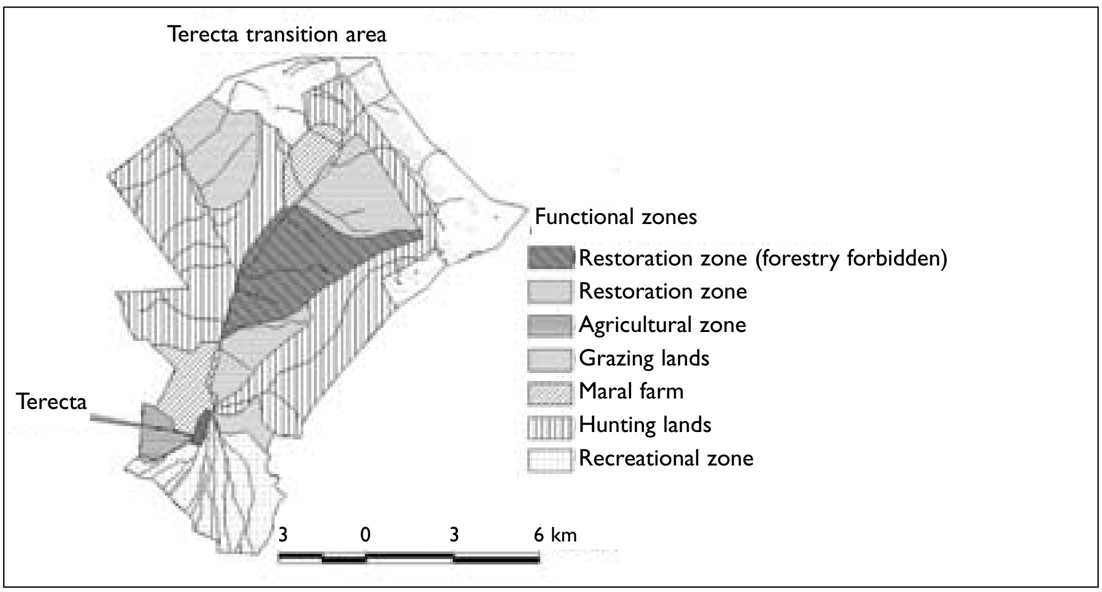


Figure 9.3
Terecta transition zone, showinng land use patterns

Ongoing Global Change Programmes

There has been a research division in Katunskiy BR since 1995. It is currently made up of a botanist, a hydrologist, two zoologists, a geographer (landscape research), an ecologist, an historian and an economist. There is also a GIS (geographic information sytem) laboratory and all cartographic information is thus organized into geo-information systems.

INVENTORY AND MONITORING

As part of the inventory work programme, annotated lists of plants and animals have been completed, and investigations carried out into water bodies, lakes and glaciers. Current work involves the completion of a landscape map. Most monitoring activities are carried out under the 'Chronicles of Nature' programme and include the following:

- *Monitoring of water bodies* (lakes, rivers). A period of five years is the standard for a hydrological observation series. Seven test lakes were selected in Mul'ta river basin at heights of between 1,670 and 2,255 m above sea level. The work also covers the autonomous high-mountain lakes fed from glaciers and snowfields. The morphology of the lakes was also studied. Parameters such as temperature regime, water level, ice conditions and ichthiofauna have been monitored since 1998. In addition, analytical data for these test lakes are available. It is important to highlight that these are the only monitored lakes within Katunskiy ridge and neighbouring lands. This data is complementary with hydropost network monitoring.
- *Monitoring of geomorphic processes* (avalanches, mudflows, rockfalls) within ten years. Observations will be carried our by a routing way, which practically covers the entire territory of the core zone. Systematically we get new data and summurize it into 'The Chronicles of Nature'.
- *Monitoring of vegetative communities* on the stationary sample plots over a period of five years. There are twelve static sample plots, which are located in different altitudinal zones in Mul'ta and Zaychikha river basins.
- *Zoo-monitoring of large mammals and birds* over a period of five years. Bird observations are being carried out in Mul'ta river basin while large mammal observations occur throughout the entire territory of the core area.

Results of the above studies are issued annually in the volumes of the ' Chronicles of Nature'.

The other aspect of our research concerns assistance to sustainable development of the region. Within the framework of this study the system of planning and building the expertise of maral farms is being developed and a recreational land survey of Ust-Koksa district is being completed.

Models of sustainable development for the Terecta transition zone are also being developed. In cooperation with the Biodiversity Conservation Centre in Moscow we provided the microcredit for ecologically friendly honey production. Currently under consideration is the project 'Conservation of biodiversity in the Terecta transition zone', which takes into account the economic aspects of maral farming intensification. In addition, socio-monitoring of the transition area is being carried out to determine its social and economic situation.

CURRENT ACTIVITIES

- Inventory and monitoring within the framework of 'The Chronicles of Nature'.
- Completion of a landscape map of Katunskiy BR.
- Monitoring of geomorphic processes, flora and fauna, lakes and rivers.
- Organization of cartographic information into GIS.
- Determining the system of apimonitoring within Katunskiy BR.
- Study of the digressional processes within maral farming (Terecta transition zone) and implementing the system of economical intensification in accordance with ecological limits.

AVAILABILITY OF ADDITIONAL DATA

Meteorological data are available for the period since the 1930s. Two weather stations are located within the territory of the Belukha Nature Park cluster. One of these, the Akkem, is situated in a valley of the same river at a height of about 2,000 m above sea level; the second, Kara-Tyurek, is on a watershed surface at a height of 2,600 m. This is the highest weather station in the region. In the 1930s, for a period of only four years, the Katun weather station was situated upstream from the Katun river, in the core area.

There is also a network of hydrological posts within the reserve and in adjoining lands. Hydroposts on the rivers Terecta (in the transition zone), Katun, Koksa, and Kucherla have also been operational since the 1930s. They provide information on river levels and rates and other hydrological characteristics.

For global change research it is possible to obtain meteorological and hydrological data from weather stations and hydroposts online. It is also possible to obtain long-term data (since the 1930s) for the above-mentioned stations and posts. In addition, there is an opportunity to expand the system of stationary sample plots for vegetation monitoring. Data sources from other scientific organizations carrying out regular observations in the reserve's territory are also accessible. This is mostly in the form of glaciological and hydrological information from Tomsk and Altai universities.

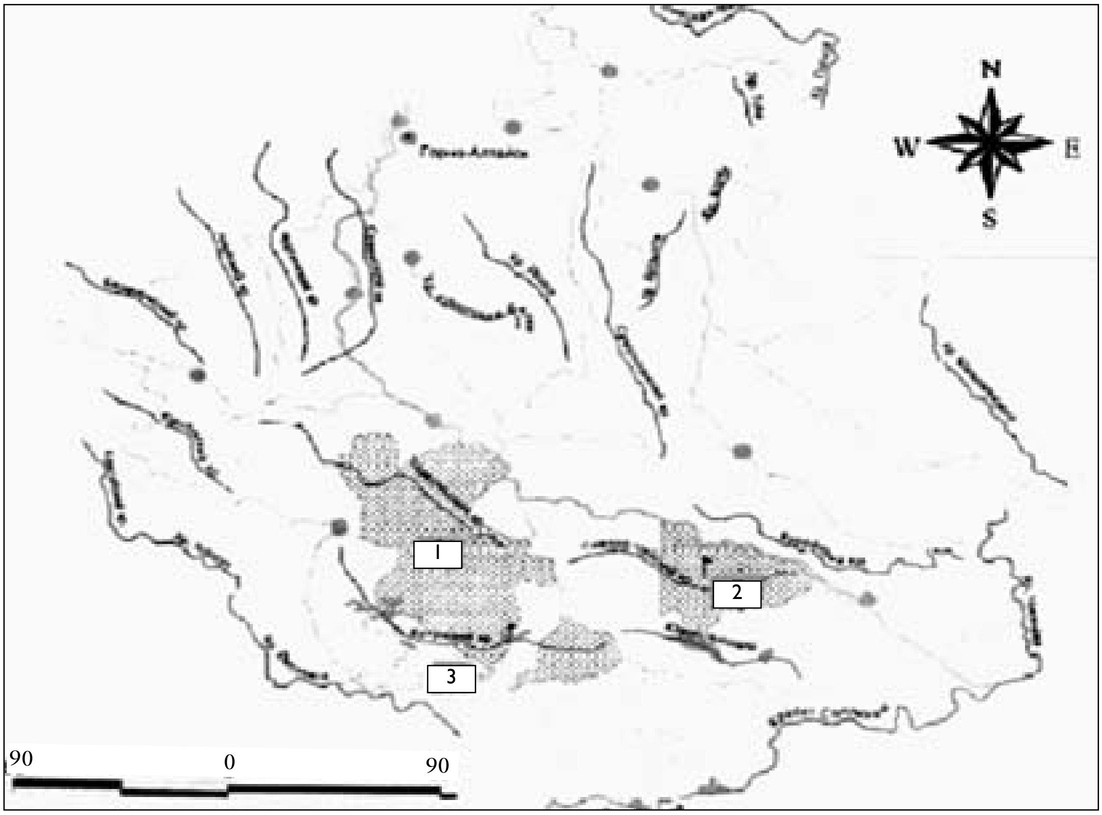
Hydrogeological monitoring is carried out in the neighbouring area; the data covers the chemical composition of springs and hydrological study of surface waters among other aspects. Social and economic data are collected on a regular basis by the local authorities within the Terecta transition area. The data collected over the last thirty years can be added to the sociomonitoring results.

LOCATION AND DESCRIPTION OF THE ASSOCIATED AKTRU CLUSTER

The associated Aktru cluster is located in the glacier basin of the Aktru river, on the northern slope of the Severo-Chuisky Range in Central Altai. It ranges in height from 1,800 to 4,073 m above sea level. In the high-elevation Aktru geographical station (2,150 m) of Tomsk State University, comprehensive glaciological, hydrological, climatic and geomorphological studies have been carried out by the university's scientists since 1957, and changes of vegetation and soil biota have been studied by scientists of the Filial of V.N. Sukachev Institute of Forest, Siberian Branch, Russian Academy of Science since 1998.

The Aktru glacier basin covers 40 km^2, and about 38 per cent of this consists of five large

Figure 9.4
Katunskiy BR spatial structure
1: Katunskiy BR
2: Aktru associated cluster
3: Berlukha Natural Park



(Levy Aktru, Pravy Aktru, Maly Aktru, Kupol and Vodopadny) and two small (Stazher and Uchitel) glaciers.

A combination of high mountain summits (elevation up to 4,073 m above sea level), large high-altitude plateaux (2,800–3,000 m) and the steep slopes of the river valley are characteristic of the Aktru glacier basin relief. The slopes are asymmetric and because of glaciation activity the northern slopes are sharper than the southern ones.

Continental, sea and Mongolian steppe air masses exert an effect on the Altai. These masses are characterized by contrasting temperature and precipitation. In Aktru the winter weather (from October to April) is determined by the strong and stable Asian anti-cyclone. In spring a cool polar front is experienced. Cyclones move to the north. In summer, anti-cyclone weather with convective cloud cover often occurs in the daytime. Southern and southwestern winds dominate in winter, and western and northwestern winds in summer. In the mountains there is a local air circulation (for example, slope, valley and glacier winds).

In the Aktru glacier basin the mountain brown soils (mountain metamorphosical cryozems) with permafrost at a depth of 50–100 cm are typically found in the mountain forest zone, and primitive mountain tundra soils in the mountain tundra zone. Primary soils are formed in the nival-glacial zone on the moraine ecosystems (Vorobjev et al., 2001).

All types of high altitudinal landscapes are represented here, from steppe to glacial, including forest–tundra ecotones, moraine communities, sections of relic Siberian stone pine (*Pinus sibirica*) forests, and younger forests with Siberian larch (*Larix sibirica*).

In the Aktru glacier basin several single measurements of the glacier end fluctuations were begun in 1911 and continued until 1952 by Professor V. Sapozhnikov of Tomsk University. Since 1952 annual measurements have been taken, and between 1936 to 1957 Professor M. Tronov of Tomsk State University began the study of the mass balance and its components, a study that continues to the present day. A comprehensive study involving the observation of the main climatic parameters was begun in two permanent and six seasonal weather stations in 1957, using five permafrost meters, five hydrological sites, twelve terrestrial sample areas, nine precipitation meters and many pits, thermal wells and ablation rods. The components of the nival-glacial complex are comprehensively investigated, with studies of glacier mass balance, dynamics, area and volume change, snow cover, hydrotermic regime, pollution, and water-balance observation as well as geomorphological, cryolitological, dendrochronological and landscape studies.

The Aktru glacier basin has the longest-running series (in the Altai-Sayan mountain area) of indicators: glacier dynamics, river discharge, temperature, precipitation, permafrost and terrestrial ecosystem dynamics; the latter series, for instance, has been running for about 600 years in relic forests and over 150 years on glacier moraine.

This area can be considered a natural model because the dynamics of the terrestrial ecosystems at the upper forest line can be analysed using the climatic data measurements of the Aktru weather station taken over fifty years, and climatic data over a period of 400 years can be reconstructed using dendroclimatological methods. Thus we have available a unique series of observations that can be used for monitoring of the high altitudinal environment in the Altai.

Vegetation Zones in the Associated Aktru Cluster

Formation of the modern vegetation cover and distribution of vegetation communities in the Aktru glacier basin give rise to mountain relief, climatic conditions and ancient and present glaciation. The following zones are found in the Aktru glacier basin (Timoshok, 2000):

- The mountain-tundra zone. This lies between 2,800 and 3,100 m above sea level. Stone tundras with rare plants are prevalent in the upper part of the zone, and tundra communities with *Dryas oxyodonta*, *Betula rotundifolia* and green mosses are present in the lower part of the zone. The tundras with *Dryas oxyodonta* and lichens lie on the gently crushed stone fragments of high mountain plateaux with thin snow cover, and the tundras with *Betula rotundifolia*, mosses and lichens occupy parts with thick snow cover.
- The nival-glacial zone. This is found from 2,200 m to 4,073 m. The Maly Aktru, Bolshoy Aktru (Pravy Aktru and Levy Aktru since 1958), Vodopadny and Kupol glaciers and their moraine ecosystems are found here (the younger ones date from the Little Ice Age from 1400 to 2003 while the older ones date from about 1,000 years ago).

In the Aktru nival-glacial system the relic Siberian stone pine forests with dwarf shrubs and green mosses are preserved under the moraine of the Bolshoy Aktru glacier (2,400 m above sea level).

Two sections are interesting to examine for evidence of global change in terrestrial ecosystems. The first consists of Siberian stone pine forest with green mosses and *Betula rotundifolia* (2,350 m) with two Siberian stone pine generations in its overstorey (250 and 420 years old). This segment has been preserved since the fourteenth century, through the two later glacier advances in the seventeenth and nineteenth centuries. These forests, unique in Altai, represent the climatic type of high altitudinal primary forests. The average age of the trees is over 550 years. The second section consists of Siberian stone pine forest with green mosses, lichens and *Betula rotundifolia* (2,200 m) with two Siberian stone pine generations (200–530 years old) and two Siberian larch generations(260–535 years) in its overstorey. Both the forest sections have been growing since the fourteenth century and were preserved during the period of great fire in Altai in the nineteenth century.

- *The forest-tundra ecotones*. These lie from 2,400 to 2,800 m above sea level, and consist of sparse Siberian stone pine forest with green mosses and *Betula rotundifolia*, Siberian stone pine and Siberian larch tree groups and trees, and small segments of subalpine meadows. In the Aktru river valley there are forest-tundra ecotones (modern forest and tree lines), and the climatic type of lines on southern slopes (2,400–2,500 m) in competition between the trees, herbs and shrubs, and the edaphic type of lines on northern slopes (2,200–2,300 m) with moving stone screes, and where there is no competition between trees and other plants.
- *The mountain forest zone*. Its elevation is from 1,800 to 2,400 m above sea level. It consists of Siberian stone pine/Siberian larch and Siberian larch/Siberian stone pine forests of post-fire origin. Fragments of relic Siberian stone pine forests with green mosses and *Betula rotundifolia* survived in the upper zone after the fires in the late nineteenth century. In the Aktru valley slopes there are younger Siberian larch/Siberian stone pine forests with shrubs, herbs, grasses and *Carex*.

Characterization of the Site Above the Vegetation Line

The vegetation of the moraine complexes in the Aktru glacier basin, as with other basins in Altai, is sparse. It started to develop around the mid-nineteenth century when the regressive phase of the modern glaciation began. Today the vegetation is a combination of communities at different stages of post-glacial succession, from pioneer species on deglaciated areas to dense Siberian stone pine and Siberian larch forests.

On the moraine complexes (the Little Ice Age) of the Maly Aktru, Levy Aktru, Pravy Aktru and Kupol glaciers, all the stages of post-glacial succession of vegetation (without a competition) are represented in the actual forest, tundra and nival-glacial zones (2,200–3,050 m).

Using glaciological observations of the glacier retreat, from 1850 up to 2003, we divided the deglaciated area of the moraine complex of the Maly Aktru glacier (2,200–2,300 m above sea level, modern forest zone) into twenty area plots characterizing five-year boundaries of the retreating glacier. Each of these plots was studied to describe the formation of primary ecosystems.

More than 140 species of vascular plants (four species of ferns, six species of gymnosperms and 130 species of angiosperms) can be found in these ecosystems. Figure 9.5 demonstrates the increasing age of the ice-free area plots from 3–8 to 90–150 years ago, and the number of species of vascular plant increases, from twenty-four to seventy-eight. We have distinguished three stages of post-glacial succession, described below:

- The first was a pioneer (initial) stage covering about thirty years (1968–2003). Herbaceous plants (*Crepis nana, Draba cana, Braya aenea, Neotorularia humilis, Poa glauca, Calamagrostis pseudophragmites, Trisetum mongolicum* etc.) were typically dominant at this stage. The total coverage of flowering plants and mosses increased from 1 to 10 per cent. We observed the first young Siberian stone pine individuals.
- The second (herb-moss-willow) stage of primary succession continued for about sixty years (1911–1968). Various herbs and species of *Salix* (*S. saposhnikovii. S. glauca, S. berberifolia* and *S. vestita*) dominate this stage. The first layer may contain virginal Siberian larch and Siberian stone pine trees, which slightly rise above the shrub (willow) layer.
- The third stage – herb-moss-willow-ground birch with various herbs (*Astragalus alpinus, Bergenia crassifolia, Pyrola rotundifolia, Oxytropis strobilacea, Hedysarum neglectum, Poa sp., Festuca lenense, Trisetum mongolicum* etc.), *Salix* and *Betula rotundifolia* individuals – continued for about sixty years (1850–1911). A thin tree layer at this stage of succession consists of uneven-aged young larch and Siberian stone pine and, less frequently, spruce (*Picea obovata*) trees. The generative phase of larch and pine appear for the first time, together with numerous uneven-aged pregenerative individuals. This suggests that larch and pine expand to younger moraine fragments, and this occurs not only through the transfer of seeds from the larch/Siberian stone pine forests adjoining the moraine complex, but also through seed reproduction of young generative larch and pine trees growing on the moraine proper.

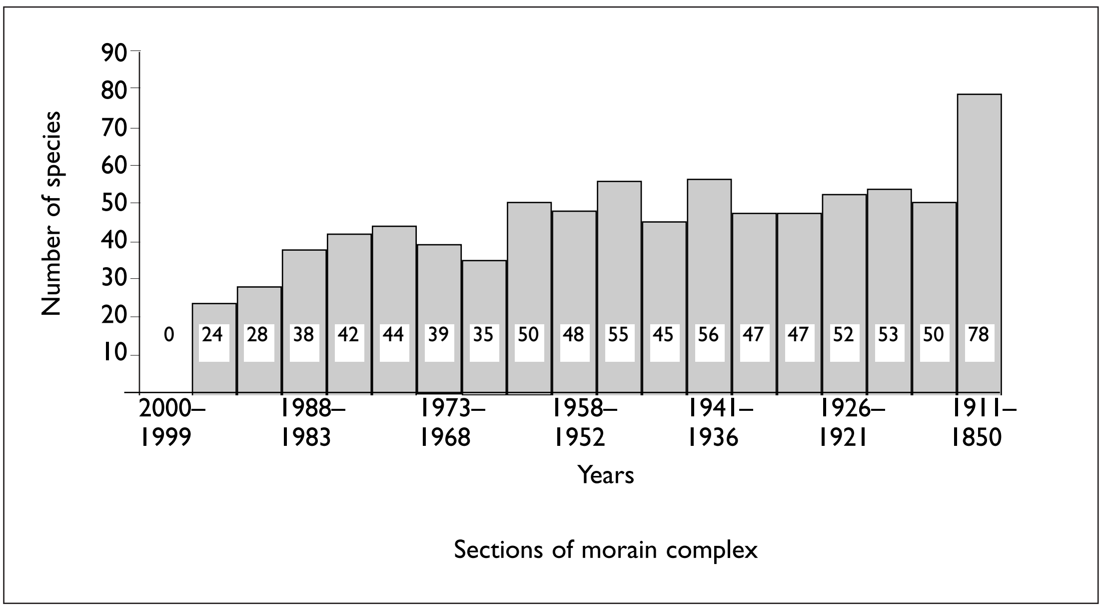


Figure 9.5
The number of species occupying the moraine complex of the Maly Aktru glacier (1850–2000)

Ongoing Global Change Programmes and Research Projects

THE CLIMATE DYNAMICS

A data bank has been produced for all the Altai weather stations, and the main climatic parameters (air temperature and precipitation) have been analysed. Significant warming (about 1.7 °C over the last forty years) has been detected during the winter period, mainly under constant precipitation.

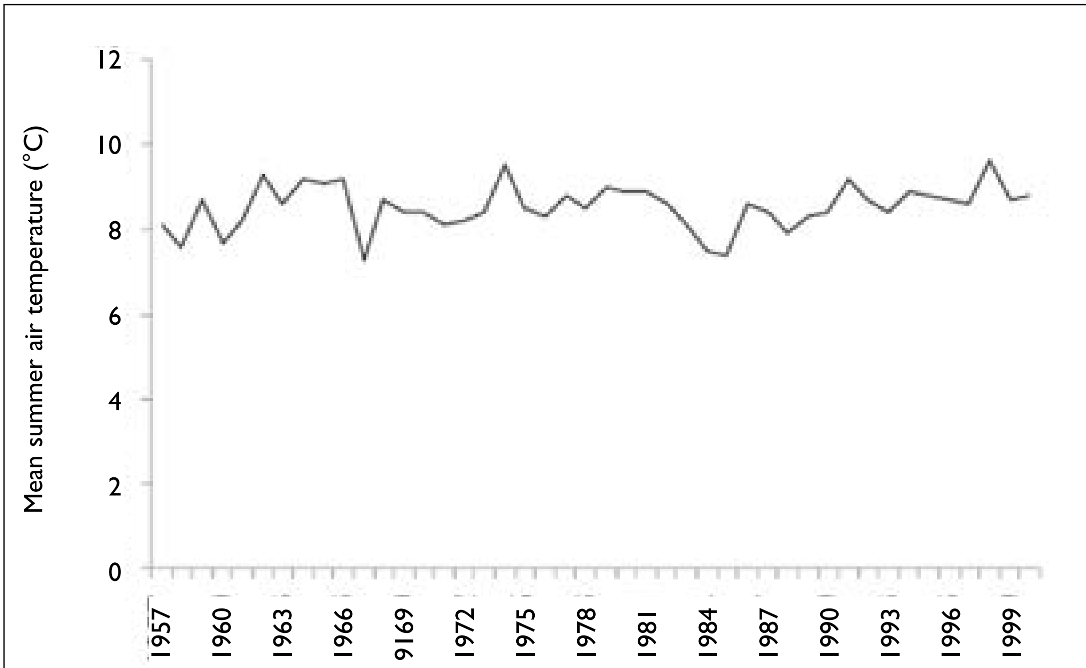
The dynamics of summer (June to August) air temperature and precipitation in the Aktru glacier basin can be seen in Figures 9.6 and 9.7 (based on data from the Aktru weather station from 1957 to 2003). In the basin, the mean annual air temperature is –5.2 °C and precipitation is 563 mm, about 65 per cent of which is in summer. The mean summer air temperature is 8.6 °C (see Figures 9.6, 9.7, 9.8 and 9.9).

Using a Siberian larch tree ring-width chronology and data from the Aktru weather station, we were able to reconstruct the summer air temperatures over the last 110 years in the Aktru glacier basin (Figure 9.9). Significant decreasing air temperatures were observed in the early nineteenth century (1910–23) and in the 1960s (1958–62), and less significant but decreasing temperatures in the 1980s (1983–7). In the late twentieth century (1987–2003) increasing air temperatures were observed.

GLACIATION DYNAMICS

The present glaciation in the Aktru glacier basin occupies about 16 km^2 of the total area. There have been many long-term series of observational data on the mass balance and fluctuations of glaciers, and so we can determine the main trends of glaciation change over a long period (Figure 9.10).

Figure 9.6
The dynamics of annual average summer temperatures in the Aktru glacier basin (1957–2000)



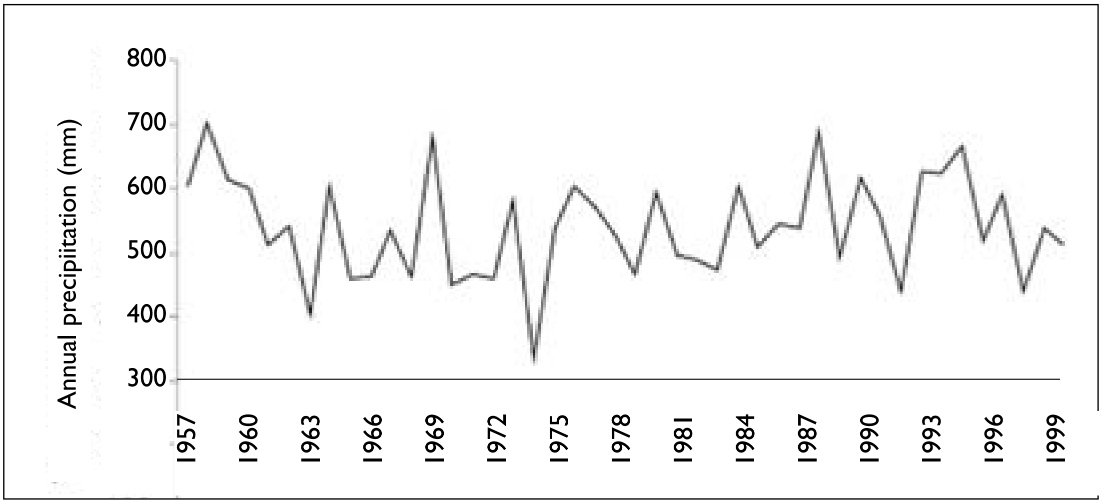


Figure 9.7
The dynamics of precipitation in the Aktru glacier basin (1957–2000)

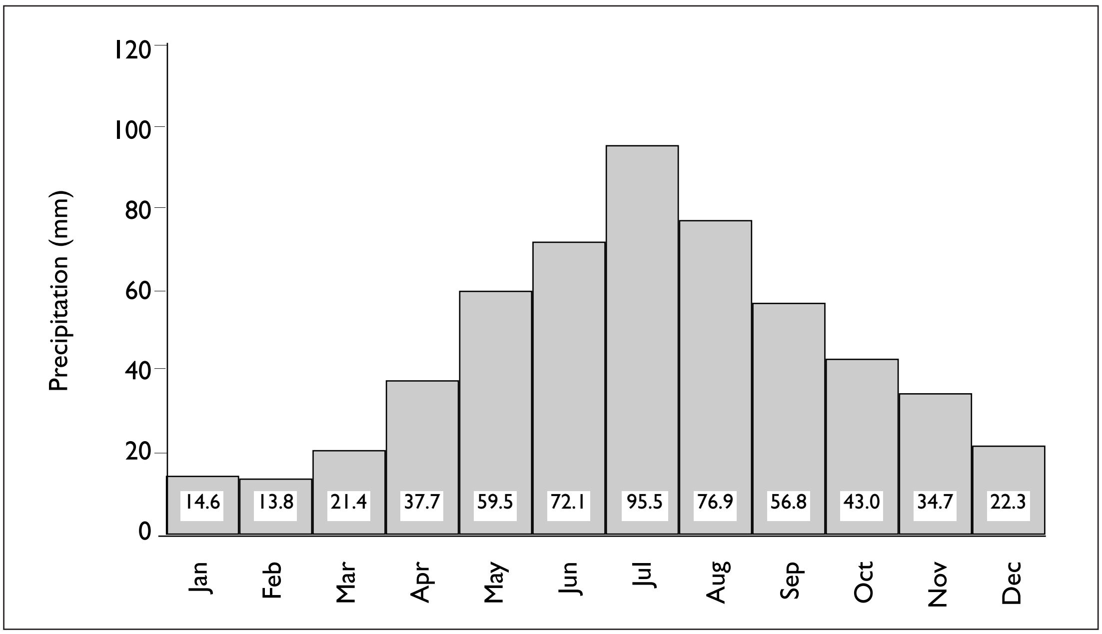


Figure 9.8
The monthly distribution of precipitation in the Aktru glacier basin (annual average 1957–2000)

On average, a deficit of glacial mass has been documented over the whole period of observations (1957–2003) (Narozhniy, 2001). The mass balances of individual glaciers differ and they occasionally even demonstrate opposite trends. Nevertheless, in the actual year, deviations of mass balance from mean values are similar for all the glaciers. They follow the same trends but often differ in values. This fact may be seen as evidence of the common features in the behaviour of all glaciers in the region. The amplitude of long-term variation of mass balance decreases from the west to the east of this region.

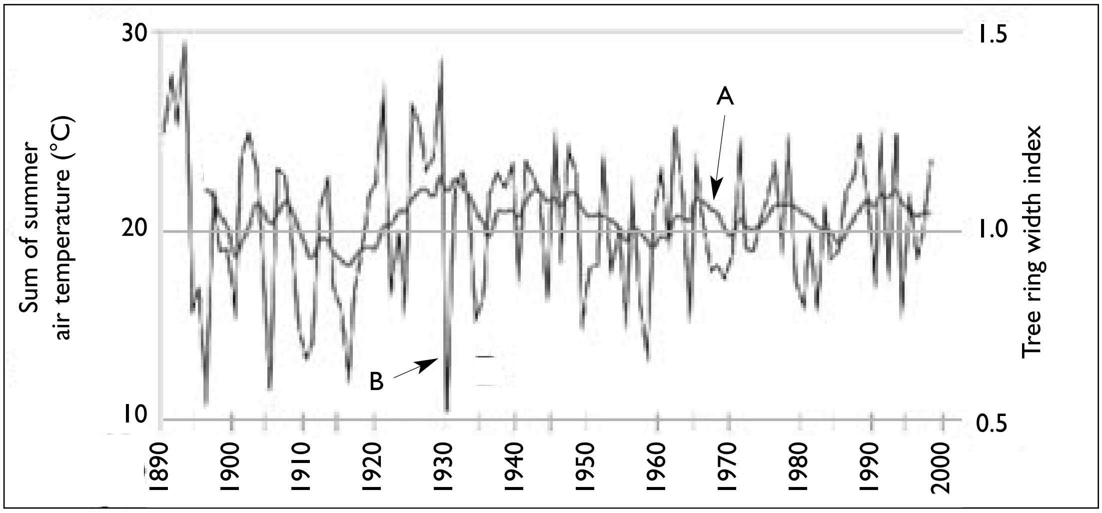


Figure 9.9 *Reconstructed sum of summer air temperature (seven-year runnin mean) (A) and Siberian larch tree ring width index chronology (B) in the Aktru glacier basin*

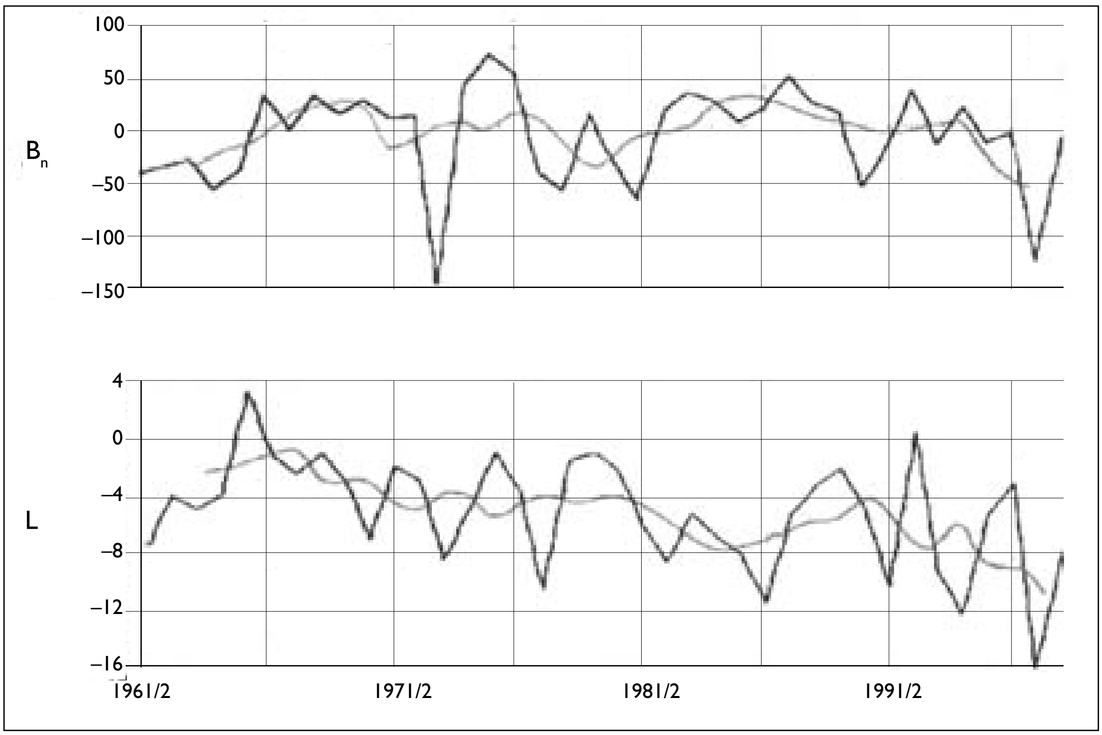


Figure 9.10 *Annual variation of mass balance B_n and rate of front retreating L of the Maly Aktru glacier in 1962–2000 (1: annual variations; 2: average by mean five-year cycles)*

The total glaciation retreat is about 4 per cent for the period 1957–2003, and 11.5 per cent since the mid-nineteenth century (Figure 9.11). Certain cycles of retreat intensity may be found as a common condition of decreasing glacial area; retreat intensity shows a tendency to slow down and in some cases to stop briefly. For example, the first wave of such slowing down and even glacial advancing (from about 2 to 7 m per year) appeared in 1988 while a second one, in

1993 was more comprehensive. Synchronism in temporal variations of regime and dynamic characteristics is most obvious in anomalous years when climatic differences between different parts of the region studied become less expressive. In such years the deviations of the retreat intensity from mean values are the same for almost all the glaciers.

The glaciers of the basin are included in the network of the World Glacier Monitoring Service. Measurements of the dynamics and mass balance of some glaciers in Altai were published by Yury Narozhniy in seven volumes of 'Fluctuation of Glaciers' and six UNESCO bulletins of 'Glacier Mass Balance Bulletin' (led by Wilfried Haeberli).

CHANGES IN VEGETATION AND SOIL BIOTA

In the present era of global warming and glacier retreat in the high altitudinal Altai ice areas, interesting modeling is being carried out in test areas to study changes in mountain terrestrial ecosystems, and particularly vegetation and soil. Studies of these changes enable us to collect new data on the recolonization of trees on both mountain slopes outside of the modern glacier areas (near glaciers) and the deglaciated areas (moraine complexes).

The Aktru glacier basin has a number of highly sensitive high mountain ecosystems, ranging from forest-tundra ecotones in the upper forest line, and primary ecosystems formed 100–150 years ago on the glacier moraines, to relic Siberian stone pine forests. There are two types of forest line. The first is the climatic type of line on the northern slopes (2,200–2,300 m above sea level) of the Aktru river valley. Competition between trees, herbs and shrubs is intense. Climate is the limiting factor of tree and shrub growth (temperature, snow cover and wind; the other climatic variables are less significant). The second line is the edaphic type on the southern slopes (2,400–2,500 m) of the valley where there is no competition between trees and other plants. The principal reason for the limited growth and development of trees and shrubs is due to the regular fall of stone and rock material. Climate changes are less significant for plants. Recent warming has caused tree lines to move upwards by about 600 m along a slope, or vertically by more than 100 m.

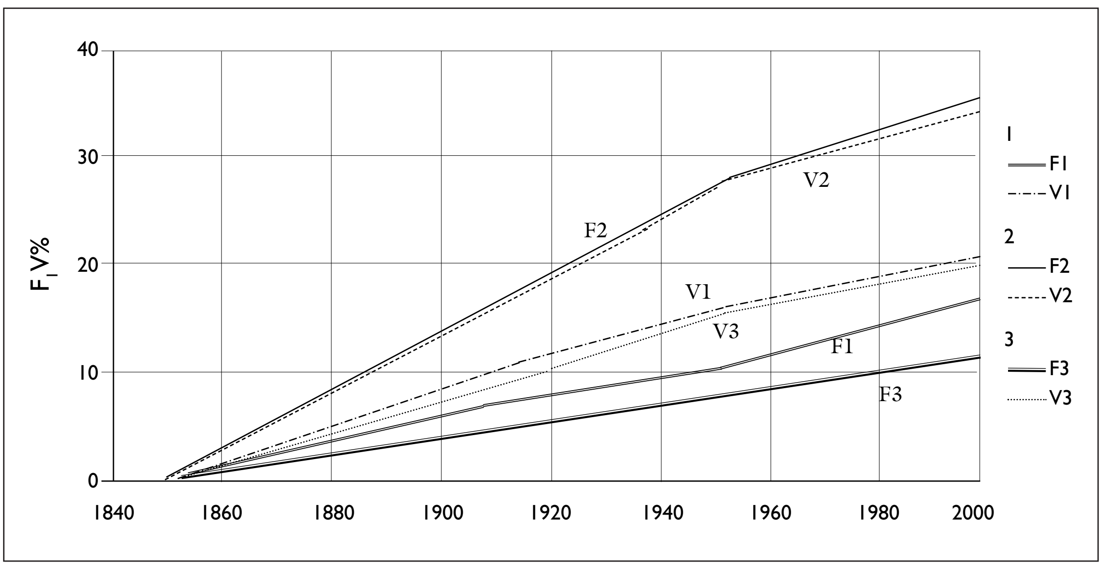


FIgure 9.11
Rate of glacier area reduction F and volume V in the Aktru glacier basin.
1: Maly Aktru glacier
2: Vodopadny glacier
3: Total (1 - F1, 2 - V1, 3 - F2, 4 - V2, 5 - F3, 6 - V3).

Changes in vegetation and soil biota are related to changes of climate and some glaciers (the Maly Aktru, Pravy Aktru and Levy Aktru) over a period of decades or even several centuries.

During the Little Ice Age (1400–1850) there were three great advances of the Aktru glaciers when temperatures were at their lowest: in the first part of the sixteenth century, the late seventeenth to early eighteenth centuries, and late eighteenth to mid-nineteenth centuries. The latter period saw the greatest advances when the glaciers reached their maximum size in the last millennium.

Following the maximum glacier advance, scattered areas of Siberian stone pine forests survived under the glacier moraines; before the glacier advance these had been a unified forest. Trees in these areas are more than 550 years old. These Siberian stone pine forests, unique in the Altai, are typical of the climatic type of high altitudinal primary forests with preserved soil cover. Due to the current warming, the forests contain many cone-bearing trees of different generations and reveal active Siberian stone pine and Siberian larch regeneration

Analysis of the vegetation distribution and condition on the moraine complexes of some glaciers in Altai indicate the development of communities of herbaceous plants dominate, with shrubs and trees in the moraines distributed as follows: individual plants; small plant microgroups and individual shrubs (willow); plant microgroups, shrubs (willow and ground birch) and individual trees (larch, and Siberian stone pine); plant microgroups, shrubs microgroups and open woodland (these larch and pine trees bear cones. This indicates that their populations are self-maintained and sustainably developed).

SUMMARY

Katunskiy BR has a wide range of landscapes, from steppes of intermontane hollow (in the Terecta transition zone) to snowfields and glaciers. The nature of the core and buffer zones has been only slightly changed by human activity, and can be considered as almost pristine.

The location of Katunskiy BR makes it possible to trace air pollution originating from China and Kazakhstan at glaciers and autonomous high-altitude lakes.

Sustainable development models for Ust-Koksa district are employed for various traditional types of economic activity: maral farming, apiculture and recreation. They are for the most part directly connected with global change issues; apiculture, for example, is an excellent indicator of the well being of the environment (apimonitoring), because of its particular sensitivity to climate change (i.e. air pollution).

There is a wealth of scientific information available for the study of global change, and we actively cooperate with various Russian universities and institutes, including Gorno-Altaisk, Barnaul, Tomsk, Saint Petersburg, Moscow State Universities and the Central Siberian Botanic Garden among others.

For the Global Change Research Programme we propose several topics:

- Long-term monitoring
  - of autonomous high-mountainous lakes as indicators of environmental state (global changes of environment)
  - of snowfields and glaciers (monitoring of transboundary air pollution from China and Kazakhstan)
  - of social and economic aspects within the Terecta transition area.

- Sustainable development
  - Apiculture: a traditional economy type and an example of sustainable development. assess the resource potential of the territory, influence on the environment and indication of environmental condition (apimonitoring)
  - Development and organization of sustainable tourism within the Terecta transition zone and Belukha Nature Park.
  - Development of a system of maral farms for the sustainable use of biological resources (influence on the environment, establishing a monitoring system for farming, developing intensification).
- Process study
  - Studying the rehabilitation rate of mountain ecosystems in the changing environment; twelve years ago the anthropogenic load (recreation and grazing) was eliminated within the core zone. It is therefore possible to estimate the rehabilitation rate following a change in recreational and grazing activities. The collected data can be extrapolated and applied to other, similar ecosystems during the planning, examination and regulation phases of economic activities.

ACKNOWLEDGEMENTS

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10. *Switzerland: Swiss National Park Biosphere Reserve*

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INTRODUCTION

Founded in 1914, the Swiss National Park (SNP) was designated a biosphere reserve in 1979 and was, at that time, the first biosphere reserve in Switzerland. Today, the Biosphere Reserve consists mainly of the National Park area, which is completely protected from anthropogenic pressure. In 2000 the failure of an attempt to create a peripheral zone around the Park caused the National Park authority to change its strategy. Currently a project is in preparation to create a Biosphere Reserve National Park/Müstair Valley in cooperation with the regional board of the Müstair Valley. The Müstair Valley, and notably the medieval Abbey of Müstair, is one of four sites in Switzerland on UNESCO's Cultural World Heritage.

LOCATION

The Swiss National Park (SNP) has a surface area of 172 km^2 and is located in the Central Alps, in the most eastern part of the Switzerland in the canton of Grisons. It consists of mountain ranges and valleys situated between the Inn valley (1,000 to 1,800 m above sea level) in the north and the Italian border to the south. The SNP boundary embraces the Italian border and the Italian Stelvio National Park. The planned Biosphere Reserve, SNP/Müstair Valley will create a large contact zone between SNP and Stelvio National Park and enhance conditions for international cooperation within both Parks.

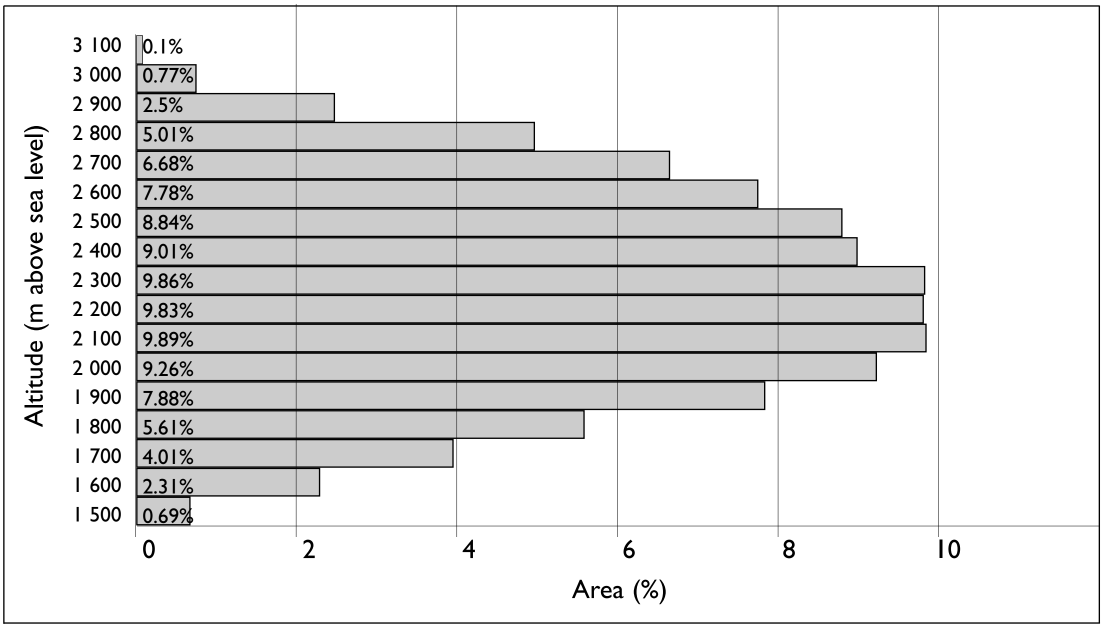
The SNP includes subalpine, alpine and nival zones, from 1,400 m up to 3,173 m above sea level with a permafrost zone above 2,500 m. As shown in Figure 10.1, most of the Park area is located between 1,700 m and 2,800 m. From a geographical point of view, the Park includes portions of six main valleys and a series of ranges and peaks within the altitudinal range of 2,600 and 3,100 m, most of which are composed of limestone or dolomite.

Human impacts are associated with two linear features that cross the SNP: the road from Engadine to Müstair Valley and the River Spöl, which is managed by a hydropower company. It must be emphasized that human impacts on in the National Park and its surroundings are not intensive and external effects of these activities on the Park are very low.

VEGETATION ZONES

The main vegetation types in the Swiss National Park are subalpine forests (dominant: *Pinus mugo*;

Figure 10.1
SNP area by altitude



28 per cent), alpine grassland (dominant: calcerous; 21 per cent) and rocks/debris (51 per cent). The vegetation of the larger region is more varied and includes a montane zone, agriculturally formed vegetation and silicious vegetation (see Table 10.1).

CHARACTERIZATION OF THE SITE ABOVE THE TREE AND VEGETATION LINE

The natural treeline in the SNP is situated at a height of 2,300 to 2,400 m, but in some areas it has been depressed by former cattle grazing. There is no clear climatically determined vegetation line. In many cases, areas with sparse vegetation on rocks and debris occur due to morphodynamic processes and continuous erosion. However, areas above 3,000 m generally lack vegetation.

Ecosystems above the treeline are dominated by calcerous/dolomitic bedrock and corresponding geomorphic processes (debris formations, karst, soil formation). Permafrost is widespread above 2,500 m (several rock glaciers, earth streams and so on) but there are no true glaciers in the park.

DEMOGRAPHIC AND ECONOMIC CHARACTERIZATION

Swiss National Park

There are no permanent residents within the National Park, though two hotels open during the holiday season employing a total of about twenty staff (the SNP is closed during the winter). Tourism generates added value for the regional economy, adding CHF17 million per year (4.25 per cent of the GDP), which ensures full-time employment for 120 (minimum) to 200 (maximum) people (Küpfer, 2000).

	km²	% belt	% area
Montane: subalpine belt			
Forest	295.5	64.8	22.8
Hedges	3.3	0.7	0.3
Grassland, dry	2.4	0.5	0.2
Pastures, low fertility	86.4	18.9	6.6
Pastures, high fertility	39.2	8.6	3.0
Fields	0.8	0.2	0.1
Wetland	3.5	0.8	0.3
Rocks and debris	25.0	5.5	1.9
Total zone	456.1	100	35.2
Alpine: nival belt			
Heathland	29.5	3.5	0.3
Grassland	290.3	34.4	22.4
Calcerous	75.9		
Calcerous/silicious	95.8		
Silicious	118.8		
Wetland	3.5	2.4	0.4
Rocks and debris	517.7	61.6	39.7
Total zone	841.0	100	64.8
TOTAL	1 297.1		100

Table 10.1 *Vegetation in the SNP-region, Lower Engadine, Müstair Valley (Zoller, 1995)*

Neighbouring Region

Tourism is the most important economic sector for the sixteen neighbouring communities, which are part of three administrative regions: the Upper and Lower Engadine, and the Müstair Valley. These communities have a permanent population of 8,800 inhabitants (1999), with 5,074 in full-time employment (1995). In economic terms, the primary sector accounts for 8.1 per cent of full-time employees and 5 per cent of the regional GDP; the secondary sector for 27.3 per cent of full time employees and 19 per cent of regional GDP; the tertiary sector for 64.5 per cent of full time employees and 76 per cent of regional GDP (Küpfer, 2000).

In the sixteen communities, there are 3,900 beds in hotels, 5,300 beds in apartments and 2,700 beds in group lodgings. In addition, there are almost 900 camping places. During the summer season tourists spend in total 603,000 nights (1998) in the region, which corresponds to 51 per cent of total nights annually.

ONGOING GLOBAL CHANGE PROGRAMMES AND INDIVIDUAL RESEARCH PROJECTS

Global change issues in the SNP are addressed mainly by long-term monitoring programmes as well as associated individual research projects that explore specific aspects of political or scientific relevance.

A significant component of the independent research projects deals with the modeling of future changes and developments. Research is concentrated in two main areas, the area of Il Fuorn and the Trupchun Valley, so as to protect other areas from long-term disturbance by scientists.

Long-Term Monitoring Programmes

Table10.2 lists all the long-term projects and monitoring programmes undertaken in the SNP. There are almost fifty programmes and projects being carried out, covering most aspects of geological and biosphere related research (although there is a lack of socioeconomic monitoring). A number of programmes (vegetation, forest, ungulates, climate) began shortly after the foundation of the Park and have been providing data for more than fifty years. Most of the programmes have been operational for a period between ten to fifty years. Newly installed programmes (post-1990) focus on zoology, interdisciplinary monitoring projects and sites affiliated with global monitoring programmes.

A significant advantage of these monitoring programmes is the high security of permanent plots and monitoring instrumentation situated in the Park, which ensures the long-term continuity of data.

Of a total of fifty programmes and projects, some thirty-five are of relevance for detecting global change phenomena, and fifteen of them are highly relevant and important. Two programmes particularly worth noting are part of the global monitoring programmes, GLORIA (Global Observation Research Initiative in Alpine Environments) and IMP, which is part of the LTER (Long-Term Ecological Research) network. Six of the programmes are part of national monitoring programmes or networks. Although most of the programmes were designed and established specifically for the Swiss National Park, they are carried out with the use of scientifically accepted monitoring methods as far as possible.

Research Projects

In addition to the monitoring programmes, some twenty to thirty research projects are currently being carried out in the Park annually, many of which are led by young scientists (PhD thesis, diplomas) or within the framework of international projects (EU-FRP, Interreg). Some ungulate projects are carried out in common with the Stelvio National Park (Italy). A wide range of topics is covered by the individual projects, which vary from year to year.

Integrated Research Programmes of the Swiss National Park

Since 2000, research in SNP has been focused on four interdisciplinary research programmes. Within the next ten years, the relevant scientific issues and expertise should be well established and synthesized for the following topics:

- issues of global change in the National Park region
- ungulates in alpine habitats

- the role of disturbances in ecosystem evolution
- Interactions between the Swiss National Park and society.

Organization, Resources, Implementation

Research in the SNP is managed by the SNP Research Council in close cooperation with the Park's administration. For research coordination and GIS (Geographic Information Systems), two full-time employees have been engaged, one by the Research Council and one by the SNP.

Financial running costs (including personnel) amount to US$350,000 annually. Collaborating research institutes and institutions finance the majority of the monitoring and research projects at an estimated cost of US$750,000 annually. In total, approximately US$1.1 million is invested in SNP research. Research findings are used in National Park management of tasks such as regulation of ungulate populations, slope stability/risks, restoration of the dammed River Spöl, planning (fire control), and information dissemination.

Availability of Data

Permission is required from the Swiss National Park to carry out monitoring programmes and research projects, and thus all data originating from the research is considered to be the property of the Park. A significant body of past data exists, chiefly in paper or published form; many appear in the series *Nationalpark – Forschung in der Schweiz* (National Park – Research in Switzerland); so far ninety-one issues have been published. Copies can usually be obtained in the archives of the National Park Centre in Zernez or at the Museum of Nature in Chur. In an unpublished report dated 1986, all known data sources prior to 1986 are listed.

The storage of information by electronic means has only been instigated in recent years. To achieve this, the SNP has developed its own spatial data system, GIS, and is in the process of integrating data into GIS-related databases.

Important rock samples (specimens, rocks, etc.) from SNP are for the most part deposited in the Museum of Nature in Chur while others are sent to other specialized Swiss institutes or museums.

Table 10.2
Monitoring and long-term programmes in the Swiss National Park

Source: Research Council of the Swiss National Park

(Key on page 92)

Programme	Number of stations/plots	Leading house	Start of data series
CLIMATE			
METEOROLOGICAL STATIONS			
ENET-Station Buffalora 1900m	1	MeteoSwiss	1917
IMP Stabelchod Forest 1900m	1	WSL	1996
IMP Stabelchod Pasture 1900m	1	WSL	1996
Munt Chavagl 2400m	1	FoK	1969/1998
Trupchun 1800m	1	SNP/FoK	1992
PRECIPITATION/SNOW			
Annual precipitation	3	MeteoSwiss	1918/1955/1973
Forest Avalanches	Park	SNP/SLF	1996
Snow level records	5	SNP/SLF	1996
PHENOLOGY			
Plant Phenology (Stations)	30	MeteoSwiss/ SNP	1995
VEGETATION/ TERRESTRIAL ECOSYSTEMS			
FOREST			
Stock stability	5	WSL	1925/1933
Stock growth	12	ETHZ	1979
C: IMP (Integ. Monitoring Programme)	1	WSL	1996
Swiss Forest Inventory	55	WSL	1990
PHANEROGAMES AND KRYPTOGAMES			
Vegetation plots	160 plots	WSL	1917/1939
C: Burnt Area of Il Fuorn	13 plots/1 Trans.	FoK	1952
Mosses (Forest)	1 with 20 plots	FoK	1954
Sowed banks (plots)	10 sites	ETHZ	1969
C: Exclosures SNP	27 sites	FoK/GR	1992
GLORIA-SNP	8 summits	FoK	2002
Lichens			interrupted
EARTH AND LANDSCAPE			
SOIL			
Swiss Soil Monitoring Prog. (2300m)	1	FAL	1993 (every 5 years)
PERMAFROST, ROCK GLACIERS (RG)			
Earth Streams Munt Chavagl	1	FoK	1969
RG Val Sassa	1	ETHZ	1917
RG Val da l`Acqua	1	ETHZ	1930
RG Macun	1	Uni Jena	1968

Table 10.2
Continued

Programme	No. of stations/plots	Leading house	Start of data series
LANDSCAPE			
Inventory of natural events and disturbances	Park	SNP/FoK	1987
Landscape Monitoring (remote sens.) (HABITALP)	Park	SNP/FoK	2002-2005
Landscape perception	1Parcours	WSL	1999 (first cut only)
FAUNA			
UNGULATES (RED DEER, CHAMOIS, CAPRICORN, ROE DEER)			
Stock of ungulates	Park	SNP	1914
Activity pattern of Ungulates Species	2 areas	SNP	1995
Use of living space by ungulates	3 areas	SNP	1990
BIRDS			
Subalpine forest	2	SV Sempach	1998
Alpine pastures	1	SV Sempach	1996
Gypaetus		GWB	1991
Snowgrouse	1	SNP	1995
Black grouse	1	SNP/GR	1990
Trans-section Champlönch	1	-	interrupted
Route assessment Schifferli	80 km	-	interrupted
INVERTEBRATES			
Ant colonies	2	FoK	1954
Monitoring of rare species	Park	SNP	1960
Rapid Biodiversity Assessment alp.	2	WSL	2000 subalp./2004
Butterflies	5	SNP	2000
Biodiversity-Monitoring CH	3	BUWAL	2002
HYDROSPHERE/WATER ECOSYSTEMS			
HYDROLOGICAL STATIONS (RIVERS)			
Punt dal Gall/Spöl	1	BWG/LHG	1952
La Drossa/Ova Fuorn	1	BWG/LHG	1960
Ova Cluozza	1	BWG/LHG	1961
HYDROBIOLOGY			
C: Monitoring river ecology	9	FoK	1996
C: Experimental floods in Spöl	6	FoK	1990, 1995, 2000–2
C: Monitoring of the Macun Lakes 2400m	5	SNP/FoK/EAWAG	2002
C: Monitoring Springs Fuorn		Uni Berne/EAWAG	in prep.
Water mites Bluogls	1	-	1977–88 interrupted

Table 10.2 Key

Programmes in italic type are of direct relevence for global change monitoring.
Programmes in bold type are the most important montoring programmnes for global change issues.

SNP	Swiss National Park
FoK	Research Council of the Swiss National Park
WSL	Swiss Research Institute of Forest, Snow and Landscape
SLF	Swiss Research Institute of Snow and Avalanches (incorporated in WSL)
ETHZ	Swiss Federal Institute of Technology
BWG/LHG	Swiss Agency of Water and Geology / Hydrological Service
BUWAL	Swiss Agency of Environment
SV Sempach	Swiss Institute of Ornithology Sempach
GR	Canton of Grisons
EAWAG	Swiss Federal Institute for Environmental Science and Technology
Uni	University
GWB	Society for the Reintroduction of the Gypaetus

11. *Sweden: Lake Torne Biosphere Reserve*

Christer Jonasson, Abisko Scientific Research Station, Sweden

LOCATION

The Lake Torne Biosphere Reserve, designated in 1987 and the only biosphere reserve in Sweden, is situated in the northern part of Sweden at 68°25'N 19°00'E. The establishment of the biosphere reserve was to a large extent due to the presence of Abisko Scientific Research Station, which has been located in the area since 1912 and has been owned by The Royal Swedish Academy of Sciences since the 1930s. Today, the Abisko research station can host up to 100 visitors; some 500 to 700 scientists, mainly in the fields of ecology and geo-sciences, visit the station each year.

The Biosphere Reserve is made up of core areas in the form of national parks and nature reserves. When the decision to designate the area as a biosphere reserve was taken in 1987, the focus was very much on the research component and there was little attention paid to the opportunities to create zonations of the area. The area is very heterogeneous; the National Parks are situated at a long distance from each other and there are no obvious transition zones. When the area was established, no attention was paid to the 'man' component of the 'Man and Biosphere' concept. At that time there were fewer than fifteen people living permanently within the Biosphere Reserve area (this is still the case today).

The administration of, and activities within, the Biosphere Reserve during the period 1986–96 was relatively limited. In 1997, the Abisko Scientific Research station hired a project leader on a part time basis, but In 2002 it was announced that the research council, who were financing the post, could no longer continue with its support. Today, the Abisko Scientific Research Station is carrying out MAB-activities from its own budget and duties.

The Biosphere Reserve is now under threat because of the difficulties encountered in allocating zones and because so few people live in it. Furthermore, there is to some degree a lack of local and regional engagement (particularly from a financial perspective) – a requirement of the Seville Strategy. Ideally national, regional or local authorities should take economic responsibility for the area, but it is not certain that this will happen.

VEGETATION ZONES IDENTIFIED IN THE BIOSPHERE RESERVE

The area is situated in a mountainous area around Lake Torneträsk. The Biosphere Reserve has an area of 96,500 hectares, with the core areas (national parks and nature reserve areas) making up 11,000 hectares. About a quarter of the area is taken up by Lake Torneträsk. The reserve ranges in altitude from 340 to 1,600 m.

The area has a varied topography, geomorphology, geology and climate, as well as a wide range of flora and fauna. The area below the treeline includes the subalpine birch woodland belt, which is an oceanic variety of the circumpolar taiga. The major ecosystem types within the biosphere reserve are tundra communities and barren arctic deserts. The major habitat and land cover types are, from lowlands to mountains: subarctic mountain birch forest, alpine and subalpine heaths represented by heather and bilberry, and meadows and mires with Salix. The flora is locally very rich because of calcareous soils.

CHARACTERIZATION OF THE SITE ABOVE THE VEGETATION LINE

Approximately 60 per cent of the area is situated above the treeline. This area consists mainly of thin till-covered or bare rock communities, nutrient-poor lakes, snowfields and some glaciers. It is likely that vast areas (above approximately 1,200 m above sea level) have permafrost conditions.

DEMOGRAPHIC AND ECONOMIC CHARACTERIZATION OF THE BIOSPHERE RESERVE

Principal land-use activities in the area and the surroundings include reindeer herding, tourism and research.

The aboriginal population, the Saami people, have been in this area for thousands of years and have domesticated reindeers for several centuries. Although the number of reindeer herders among the Saami people is quite small, the herding is in many ways important for the area. The landscape is affected to a great extent by the reindeer's grazing and trampling. Without the reindeer herds, which move from one place to another throughout the year, biological diversity in the region would probably be less. The Saami accompany their animals as they move from summer grazing areas in the mountains to winter grazing sites in the forests further east. The Biosphere Reserve is a major calving area for the reindeer.

Tourism first became important in the early twentieth century with the construction of the railway between Kiruna and the Norwegian coast, and the first national parks in the surrounding areas were established at about the same time. Today, tourism is one of the more important activities in the whole region, and is certainly its fastest growing economic activity. The hotels in and near the biosphere reserve play host to about 100,000 people a year. Tourism is mainly concentrated during two periods: the late summer and spring time. In summer, tourist activities include walking, fishing and so on, while in winter the chief pursuits are driving snowmobiles, fishing and downhill and cross-country skiing. There is also increasing tourism linked to hunting during the autumn months.

The Abisko Scientific Research station is one of the major employers in the region and the biggest one within the Biosphere Reserve. The station is open throughout the year and research activity during the winter is increasing, particularly that related to global change issues.

Other economically important activities are trade and transport. A relatively large store (at least from a north Swedish point of view) is situated in Abisko, a small village of 160 inhabitants just outside the Biosphere Reserve. Its size can be explained by its closeness to the border with Norway, with Norwegian visitors responsible for more than 90 per cent of its activities.

The railroad and the fairly recently constructed road (completed in the 1980s) require some tens of people for their maintenance throughout the year.

ONGOING GLOBAL CHANGE PROGRAMMES AND INDIVIDUAL RESEARCH PROJECTS THAT ADDRESS GLOBAL CHANGE ISSUES

A good deal of research related to global change is now being carried out in the biosphere reserve at the Abisko Scientific Research Station. There are three major fields of activity.

First, there are the research projects that the station staff themselves are involved in. Results from these activities are generally available. Over the last year the in-house researchers have been involved in several projects on global change, mainly within the fields of plant ecology, climatology and geosciences. Major projects include: STEPPS (Snow in Tundra Environments: Patterns, Processes and Scaling Issues), PINE (Predicting Impacts on Natural Ecotones) and BALANCE (Global Change Vulnerabilities in the Barents Region: Linking Arctic Natural Resources, Climate Change and Economies).

For several years the Abisko Scientific Research Station has been one of the worlds leading centres for large-scale experiments on environmental changes. For more than a decade it has been carrying out ecologically oriented field experiments, aiming to investigate changes caused by increased air and ground temperature, increased atmospheric carbon dioxide and increased UV-B radiation.

The station is also involved in a number of international projects and networks. SCANNET (Scandinavian/North European Network of Terrestrial Field Bases) consists of about ten terrestrial field research stations, all situated in northern Europe. The network, coordinated from the Abisko Station, aims at creating an overall understanding of how future changes in climate and land-use will affect flora and fauna. Abisko Scientific Research Station is also one of the leading institutes in ACIA (Arctic Climate Impact Assessment), which aims to evaluate and synthesize knowledge on climate variability, climate change and increased UV-B radiation and its consequences for nature and people. The Station also has a major role within CEON (Circum-arctic Environmental Observatories Network). CEON aims to promote environmental observation in the Arctic and its dissemination to arctic researchers whilet encompassing and building on the strengths of existing networks in the Arctic.

The second major field of activity comprises the work of independent and visiting scientists who carry out a number of research projects. Over the last few years, about 400–500 scientists have come and worked at the Station. Since those who conduct research at Abisko always send their research findings to the library, there is now a collection of more than 2,700 scientific publications from the Abisko area. An updated bibliography is available by clicking on the homepage: www.ans.kiruna.se.

Third, there is a long series of monitoring programmes at Abisko that are generally run by the station, where the collected data is generally available. There are also some monitoring missions that are being carried out by the station in collaboration with other authorities: again data from these programmes is available at the station.

The major monitoring programmes are shown in Table 11.1.

LEVEL OF FUNDING FOR RESEARCH

The level of funding for research is highly variable. The in-house research staff are engaged in projects financed both by national research councils and the European Union. The station is also a part of several networks. The major research funding sources for the in-house researchers are:

- EU
- Vetenskapsrådet (Swedish Research Council)
- Swedish Environmental Protection Board
- The Göran Gustafsson Foundation
- NERC, Great Britain
- FORMAS (The Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning)
- H.M. The King's Wallenberg foundation
- Anna Greta and Holger Crafoords foundation
- Hierta-Retzius foundation
- Other local and regional sources.

Visiting scientists to Abisko Scientific Research Station tend to come with their own research grants.

AVAILABILITY OF CLIMATE, VEGETATION, HYDROLOGICAL, ECONOMIC AND DEMOGRAPHIC DATA

Economic and demographic data are available from local and regional authorities. As the information and data are for the most part considered 'official' information in Sweden, from a legal point of view, they are generally available and accessible to everyone.

Table 11.1 *Major monitoring programmes*

(continued next page)

Variable	Period of observations	Frequency
Monitoring activity and existing databases: climate		
$14C/CO_2$	Late 1950s onwards	
Air humidity	1913 onwards	
Air pressure	1913 onwards	
Air temp: max/min	1913 onwards	Every 3rd hour
Evaporation	Early 1950s to 1973	
Global radiation	1973–86	
Ground and soil temp in peat	1950s onwards	
Ground and soil temp in till	1955–81	
Long wave radiation	1984 onwards	Daily
PAR radiation	1984 onwards	Daily
Precipitation	1913 onwards	
Radiation, Bellani pyranometer	Late 1950s to 1975	
Snowdepth	1913 onwards	Daily
Snow structure	1960s onwards	
Soil temperature (5, 20, 50, 100 cm)	1984 onwards	Every 10 mins
Sunshine hours, heliograph	1913 onwards	
UV radiation	1994 onwards	
Wind direction	1913 onwards	Every 3rd hour
Wind speed	1913 onwards	Every 3rd hour
Monitoring activity and existing databases: physical environment		
Date of ice formation and break up	1904 onwards	
Geomagnetism	1929 onwards	
Ground water level	1955 onwards	
Permafrost	1978 onwards	
Ice thickness	1904 onwards	Weekly
Water level lake	1904 onwards	
Water level river	1985 onwards	
Monitoring activity and existing databases: biotic environment		
Birch forest		
Chironomids		
Dendrochronology		
Diatoms		

Table 11.1
Continued

Variable	Period of observations	Frequency
Phenology key		
Photo phrenology	1978 onwards	
Pollen		
Small rodents		
Tree line		
Monitoring activity and existing databases: chemical environment		
Atmospheric dry downfall	1972–85	
Atmospheric wet downfall	1988 onwards	
Water chemisry	1970s onwards	
Monitoring activity and existing databases: upper atmosphere		
Riometer registrations	1975 onwards	

12. *USA: Glacier National Park, Biosphere Reserve and GLORIA Site*

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INTRODUCTION

The National Park Service of the United States has 388 designated protected areas and parks that include historic and cultural sites as well as 'natural resource' parks set aside for their unique and outstanding natural features. Early efforts to create parks were focused on areas of beauty or unusual features but later efforts increasingly aimed to protect biodiversity and intact ecosystems. Protected areas in the National Park Service are found in nearly all the fifty states from Florida to Alaska, with examples of preserved natural environments ranging from coral reefs to the icy summit of Mt. McKinley in Alaska, at 6,187 m. Many of the larger parks have been designated as Biosphere Reserves under the United Nations Educational, Scientific and Cultural Organization (UNESCO) Man and the Biosphere Programme.

The area now managed as Glacier National Park was first set aside as a Forest Reserve in 1897 and then designated as a national park in 1910, six years before a national park service was created to oversee the growing number of parks that the US Congress was establishing. Waterton National Park was created by Canada immediately north of the US–Canada border during the same period. In 1932, a joint lobbying effort by private citizens and groups convinced both the United States and Canada to establish the world's first trans-boundary park to explicitly underscore and symbolize the neighbourly relationship between these two countries. This became the world's first 'peace' park and was named Waterton–Glacier International Peace Park. The combined park is managed collaboratively on many issues but each national park is separately funded and operates under different national statutes and laws. It was, however, jointly named a Biosphere Reserve in 1976 and a World Heritage Site in 1995. There have been recent efforts to significantly increase the size of Waterton National Park by adding publicly owned forests on the western side of the continental divide in British Columbia, Canada. For the purposes of this chapter, I will emphasize the US portion of the Waterton-Glacier International Peace Park and refer to it as the Glacier Mountain Biosphere Reserve (MBR).

LOCATION AND DESCRIPTION

The Glacier MBR is in the northern Rocky Mountains of northwestern Montana, USA, along the US–Canada border. It is a 4,082 km^2 mountain wilderness that straddles the continental divide of North America and contains 175 named summits of up to 3,150 m elevation. It contains 762 lakes as deep as 150 m and 563 streams and rivers. Sedimentary rock layers that are as old as 1.3 billion years have been dramatically reshaped by repeated glaciation to form relatively flat-bottomed valleys, steep headwalls, numerous cirque basins and pyramidal peaks. Approximately 60 per cent of the Glacier MBR is covered in conifer and deciduous forests. It is managed as a wilderness area, and only the Going-to-the-Sun Road traverses the park over the continental divide. Short roads and nearly 1,000 km of trails provide access to the majority of the MBR's landscape. There are approximately 1,270 vascular plant species, 880 mosses and lichens, and 130 non-native plant species. The Glacier MBR is home to 272 bird species, 23 fish species and 63 mammal species that include the endangered or threatened grizzly bear, grey wolf and lynx.

The Glacier MBR is bordered by US Forest Service lands that include large, designated wilderness areas to the south and west. To the east is the Blackfeet Indian Nation reservation that shares Chief Mountain, a sacred site to many Plains Indian tribes. To the north are Waterton National Park in Alberta, Canada, and Crown Forest Lands in British Columbia. Relatively small towns (with populations of around 3,000–12,000) lie outside the MBR in nearby valleys but much of the region is undeveloped or mostly natural landscapes. This region has been described as the 'Crown of the Continent Ecosystem' in recognition of its interconnected and intact characteristics.

VEGETATION ZONES IN THE BIOSPHERE

Climatic regimes are distinctly different on the eastern and western sides of the MBR owing to the continental divide that bisects this landscape. The western side is strongly influenced by maritime moisture from the Pacific Ocean and displays moderate temperature variation. The eastern side is dominated by a drier, continental climate with frequent strong winds and more extreme temperatures. This is reflected in the vegetation types and plant communities found on the either side of the divide.

The lowest elevation in Glacier MBR is 985 m on the western side, where moist coniferous forests are common on valley bottoms and lower slopes. These forests are dominated by western red cedar (*Thuja plicata*), mountain hemlock (*Tsuga heterophylla*), western larch (*Larix occidentalis*), and Engelmann spruce (*Picea engelmannii*). Drier sites, or areas that have been historically burned, are dominated by lodgepole pine (*Pinus contorta* var. *latifolia*), a fire-adapted species common throughout the Rocky Mountain western states. Drier forests are more widespread on the eastern side. Deciduous species, such as cottonwood trees (*Populus spp.*), dominate riparian areas and various shrubs are common on slopes where there is frequent disturbance such as snow avalanches. Deciduous trees, such as aspen (*Populus tremuloides*), are also common on the eastern border of the park where they are interspersed with grasslands. Most of the grasslands are found on the eastern side and at low elevations where they merge with the Great Plains of central North America. However, there are some high elevation grasslands on ridges from the east-facing mountains, which are important winter ranges for bighorn sheep and other ungulates.

At mid-elevations (2,000 m), the conifer forests are dominated by subalpine fir (*Abies lasiocarpa*), and where the canopy begins to thin subalpine meadows and high-elevation wetlands are interspersed with patchy subalpine fir forests. Higher still, krummholz forms of subalpine fir become common and soon give way to alpine tundra at an elevation of approximately 2,500 m.

The treeline, or alpine treeline ecotone, is greatly influenced by the diverse topography and geomorphic dynamics. Consequently, the variation in treeline elevation is greater than for other mountain areas. Alpine tundra represents less than 3 per cent of the vegetation communities in this MBR.

For the land surface of this MBR, 34 per cent is lowland, moist, coniferous forest; 16.3 per cent is dry, coniferous forest; 6.6 per cent is deciduous trees and shrubs, 5 per cent is moist, herbaceous vegetation, and 7.1 per cent is dry, herbaceous vegetation. Barren rock, snow and ice cover the remaining 31 per cent of the terrestrial surface.

CHARACTERIZATION OF THE SITE ABOVE THE VEGETATION LINE

The Glacier MBR is a snow-dominated environment with approximately 70 per cent of the annual precipitation falling as snow. Snow covers all elevations of the MBR for four or five months of each year and the highest elevations (2,800–3,000 m) above the vegetation line are snow-free for only two months of the year. According to a remote sensing survey, the area above the vegetation line has approximately eighty perennial snowfields and small alpine glaciers. There are an estimated twenty-seven glaciers remaining. Rock and snow avalanches, debris flows, solifluction lobes, patterned ground, talus slopes and frost-shattered rock above the vegetation line all reflect cold, harsh conditions that prevent or slow plant colonization. Much of the terrain above the vegetation line is composed of steep cliffs, ridges and headwalls that surround the summits.

DEMOGRAPHIC AND ECONOMIC CHARACTERIZATION OF THE BIOSPHERE RESERVE (INCLUDING LAND USES)

The cultural history of the MBR dates back at least 10,000 years and includes the prehistoric and historic use of the land by Native Americans and their contemporary descendents. The first Europeans to explore the area were fur trappers in the 1730s. By the 1880s, a few transitory mining camps and hunting expeditions were begun but economic development did not start until 1892 when the arrival of the Great Northern Railway spurred homesteaders to claim land within the future park boundaries. The railway company was instrumental to the development of the tourist industry for the fledgling park and a number of hotels and backcountry chalets were constructed. The National Park Service purchased most of the private homes after the park was created but approximately thirty 'in holdings' still exist. These homes are used as summer homes as most businesses and services are closed during the winter months. Tourism is the only economic activity within the MBR and only a few National Park employees reside permanently within the park. The MBR maintains several visitor centres, numerous campgrounds, roads and trails, it also provides law enforcement and search and rescue services. Licensed concessionaires provide hotel lodgings, park guides and other facilities within the MBR boundaries. There are 1.7 million visitors annually and numerous hotels, restaurants, shops and services have been established outside the MBR to cater to their needs, primarily between the months of June and September. Winter use has increased over the last decade but remains less than 20 per cent of the total number of visits yearly. The MBR generates significant economic activity for the region, estimated at $1.1 million per day in tourist-based revenues. In addition, there has been a 26 per cent increase in the population of the nearby valley during the past ten years as retirees and others move into the area. Most of these newcomers are encouraged by the presence of the MBR. The role of the MBR in driving demographic and economic patterns in the region has increased as other activities, such as mining, manufacturing and timber harvest, have decreased.

ONGOING GLOBAL CHANGE PROGRAMMES AND RESEARCH PROJECTS

Scientists were prominent among the early supporters of Glacier National Park's creation and various scientists played roles in exploration, management and research during the first half of the twentieth century. In 1967, a full-time scientist was hired as a member of the park's staff and a research division eventually formed as more scientists joined. In 1990 the Glacier MBR successfully competed to host a global change research programme sponsored by the National Park Service as part of the US Global Change Research Program newly created by Congress. A global change research coordinator was hired and over the past thirteen years a diversity of research projects have been initiated with numerous collaborators from other federal agencies, universities, non-government organizations, and from other countries. After several reorganizations, global change research at the Glacier MBR is now conducted through the US Geological Survey, the primary research arm of the Department of the Interior. Funding levels range from $235,000–$595,000 annually and have been greatly leveraged through partnerships, graduate student programmes, and the use of interns to increase the research intensity on addressing how mountain ecosystems respond to climate change. Currently, the Glacier MBR global change programme employs an ecologist, two physical scientists and a biological technician working on site on a full-time basis. Active partnerships currently exist with nineteen scientists at eleven universities and five federal agencies with partial or full support to seven graduate students. A similar level of collaboration has existed during the thirteen years of the programme. The programme and individual projects are periodically renewed through intense competition so the future of the Glacier MBR global change research is not assured.

CURRENT ACTIVITIES

Climate

A network of remote, automated climate stations has been placed at sixteen (mostly) high-elevation sites within the Glacier MBR for various periods to monitor trends and to provide data for parameterizing purposes and for improving computer models. These augment long-term, permanent climate stations, with data going back to 1896, at low elevations in the MBR and in the adjoining valleys. Real-time access capabilities are a recent addition with radio links to hosted websites. Nine climate stations are currently maintained and additional sensors have been added to two snow monitoring sites (SNOTEL) operated by another federal agency. A high-precision Climate Reference Network station (with triple redundant sensors) and a spectrophotometer have recently been added by other agencies. Historic climate data have been compiled and statistically reviewed from nearby sites and a comprehensive regional climate database is nearing completion. Through collaborators, a climate extrapolation process has been developed that provides proxy climate data for mountainous terrain at a 30 m resolution for the past eighteen years.

Snow

Since 1993, monthly snow depth and snow water equivalence measurements have been taken at 110 sites within two 500 km^2 watersheds. This spatially distributed dataset augments daily data collected at a single site since 1979 and annual data collected from seven sites since 1922. Maximum snowpack accumulation trends have been correlated with sea surface temperature anomalies in the Pacific Ocean that have consistent multi-decadal patterns. A trend toward later maximum snowpack accumulation has been noted along with earlier snowmelt, potentially creating more intense spring run-off and flooding. Several models of snow distribution in complex topography have been devised and tested and a new study has been initiated on forest canopy cover interception of snow. As snow controls a great number of ecosystem processes in Glacier MBR, these research activities all aim to translate the impact of past and future climate change on the spatial and temporal dynamics of snow.

Snow Chemistry

Since 1980, atmospheric deposition has been monitored at a single, low elevation site in the Glacier MBR as part of a national network. Orographic uplift brings tremendous quantities of snow to the higher elevations of the MBR. Up to nine months of atmospheric deposition is contained in the annual snowpack at high elevations, which is released during spring melt. As climate change affects the timing and quantity of snow, since 1998 a series of research projects have examined the spatial distribution of major ion snow chemistry in the Glacier MBR with respect to elevation and the different climatic regimes on either side of the continental divide. These studies are nested within a larger scale study of the Rocky Mountains. Two recent projects have evaluated the presence of persistent organic pesticide residues in snow. These residues may have been transported from as far as Southeast Asia and the atmospheric transport system may be greatly affected by climate change.

Snow Avalanches

Up to 50 per cent of some high elevation watersheds in the Glacier MBR show the impacts of snow avalanches on vegetation. The magnitude and frequency of likely avalanches will be affected by shifts in snow deposition induced by climate change. Research projects are testing the effectiveness of remote sensing technologies for detecting and measuring snow avalanche impacts on plant communities, estimating the movement of carbon within the ecosystem (including carbon inputs to aquatic systems), compiling historic avalanche frequency and establishing statistical correlations to precursor meteorological conditions, developing Intelligent Sensor Array approaches for collecting avalanche data, and increasing our understanding of wet-slab avalanches. Some of this information is being collected through an avalanche hazard-forecasting programme for the alpine section of the road that traverses the MBR over the continental divide. Safety and engineering standards will be influenced by long-term changes in snow avalanche potential. The regional economy is directly affected by changes in road closures due to snow avalanches. Thus, for this MBR, changes in snow avalanche frequency and magnitude are a direct and measurable consequence of climatic change.

Glaciers

Small alpine glaciers are rapidly disappearing in the Glacier MBR. Historic data on recession have been captured and analysed in geographic information systems, and chronosequences have been produced that show over 72 per cent of the largest glaciers have disappeared over the past century. Geospatial modeling techniques were applied that suggest that all glaciers will disappear by 2030. Repeat photography, utilizing the 18,000 images from the Glacier MBR archives, has provided visual evidence of glacial recession to diverse audiences. Website and ftp access to these images has proved to be critical in communicating the impacts of climate change on a MBR such as Glacier. Ongoing studies include various remote sensing efforts to monitor changes in ice area; use of ground-penetrating radar to determine volumetric changes; global positioning system surveys and the re-establishment of stream gages to measure glacier discharge. Consequences of glacier disappearance for downstream fauna have also been assessed.

Alpine Studies

A suite of ongoing research projects aims to assess rates of change, and those mechanisms controlling change, in high elevation environments near the alpine treeline ecotone. New remote sensing data sources at 1-m resolution and spatial analysis techniques are improving plant community classification as well as characterizing spatial patterns of tree invasion into alpine tundra. Cellular automata examine the strength of various positive and negative feedback in establishing trees and creating observed spatial patterns. Climate monitoring and modeling at several spatial scales examine the role of wind, snow, soil depth, microtopography and tree patch modification of microclimates in determining size, shape and distribution of tree 'fingers' and islands in the alpine tundra. Soil nutrient distribution, carbon balance modeling, disturbance by animals and the underlying template of treads and risers resulting from patterned ground are being evaluated as drivers of pace and pattern in tundra invasion by trees. The post-Little Ice Age history of tree colonization is being tied to instrument records of climatic trends and modeled snow deposition. Paleoclimatic data are being reconstructed from tree-rings in order to look at climatic pulses over the past 480 years, relating these to the timing and extent of alpine processes. Approximately 200 plots, used in an earlier vegetation classification study, are being monitored for long-term changes in species composition and cover in alpine tundra areas throughout the

MBR. Responses to climatic change in the alpine zone are being separated from disturbances caused by changing levels of human use. Repeat photography is being used to visually document changes in the alpine areas, and digital aerial photography has documented the expansion in area and increases in biomass, of the alpine treeline ecotone. These integrated studies will collectively allow us to understand and predict the degree and direction of change in alpine areas of the MBR as continuing global changes are manifested.

GLORIA

The Glacier MBR has joined the GLORIA (Global Observation and Research in Alpine Areas) worldwide network that identifies suitable summits for long-term monitoring of alpine vegetation change in response to climatic variability. Two summits were established and inventoried during the summer of 2003 and an additional two summits will complete the study in 2004.

Forests, Fire, and Ecosystem Modeling

Since its inception, integrated ecosystem modeling has been a cornerstone of the global change research programme at Glacier MBR. An evolving system of modeling has successfully accounted for the major processes of biogeochemical cycling, hydrology, forest succession and disturbances such as fire. These models have been validated using a variety of monitoring programmes that include: extensive fire histories of the MBR, a network of over 200 forest study plots, a decade of hydrologic monitoring, and updated vegetation mapping. The models have been used to examine and project the ecological consequences of different climatic scenarios for a period of up to 500 years into the future. Results, such as an increase in grasslands on the eastern side of the MBR under a likely future scenario, are mapped and conveyed to managers and the public using a variety of visualization technologies.

Hydrology

As the water towers of the world, mountains provide significant benefits to humans and downstream ecosystems through stream and river discharge. Since 1993, daily discharge and temperature and frequent water chemistry and biological inventories have been monitored at one 500 km^2 watershed. This data has been used to parameterize and validate ecosystem models, and determine the relative contribution of the MBR to regional rivers; it has been related to climatic and snowpack trends so that future climate changes can be translated into changes in regional water supply.

Floodplains

Riverine floodplains are major nodes of biocomplexity and biogeochemical cycling in mountains, but relatively few intact floodplains exist for study. Past and future climatic change will directly impact on floodplain dynamics through hydrologic and landscape changes that interact in complex ways. A major ongoing effort with other collaborators is a multidisciplinary investigation of one floodplain that will result in a coupled terrestrial–aquatic model with which we can assess relative impacts of climate change.

Regional Scaling

Recognizing that Glacier MBR is not a discrete ecosystem and that the surrounding landscapes provide critical inputs, we have expanded the spatial scale of the research programme several times. Regional snow and climatic datasets have been analysed for the Crown of the Continent Ecosystem, described earlier, that encompasses other relatively unaltered mountain landscapes along approximately 400 km of the spine of the Rocky Mountains in Canada. The US Ecosystem modeling and monitoring, including three years of intensive field studies, have been extended along a transect from the Glacier MBR to the Pacific Ocean and includes two other national parks, Olympic and North Cascades. This 800 km transect spans three distinct mountain ranges and a variety of land uses, and modeling studies will be used to respond to questions concerning the interaction of climatic change and growing human populations in mountain regions. The Western Mountain Initiative has been conceptually described and proposed to link existing mountain research programmes across all the mountain areas of the western United States, and to find common, and different, responses of mountain ecosystems to climate change. These mountain programmes are geographically well distributed across the different mountain ranges and include both arid and temperate rainforest extremes in climate and vegetation communities. Finally, Glacier MBR is part of the GLORIA network (as described above), as well as the World Network of Biosphere Reserves (WNBR), it will also participate in the UNESCO–MRI (Mountain Research Initiative) Global Change Research in Mountain Biosphere Reserves project.

AVAILABILITY OF CLIMATE, VEGETATION, HYDROLOGICAL, ECONOMIC AND DEMOGRAPHIC DATA

Climate data was first systematically collected in 1896 in the nearby town of Kalispell, Flathead Valley. Since 1896, additional weather stations have been established around the perimeter of Glacier MBR as part of the US National Weather Service. The first climate data within the MBR was collected in 1913, but more reliable data has been acquired since 1932. A growing network of climate data stations (as previously described) has provided for more complete spatial coverage, and additional sensors and instruments have been added. Climatic data products (for instance, DAYMET) provide geospatial extrapolation of climate variables, and several web-based data clearinghouses ensure that access to climate data is easier than ever before.

A land cover map for Glacier MBR was first produced in 1898 as part of a forest resources inventory. Other contributions to the vegetation database include: improved mapping, a 1936 vegetation survey, analysis of the first aerial photos in 1945, establishment of a herbarium and museum collections, creation of a naturalist division in Glacier MBR, programmes to control infectious plant diseases (for example, blister rust), independent research projects, and a comprehensive baseline map in 1968. A number of botanists and plant ecologists have devoted much of their careers to improved understanding of the biodiversity and ecology of vegetation in Glacier MBR, and a comprehensive floristic summary was recently published. Following a four-year effort, a detailed vegetation classification and digital map is nearing completion for the entire park using combinations of aerial photography, remote sensing, and extensive ground truthing. A full-time plant ecologist, seasonal staff and a native plant nursery manager have been resident for over ten years. Numerous university collaborators continue to study fire history, grasslands, alpine vegetation dynamics and other topics.

Hydrological data include the US Geological Survey gauging stations on major rivers, which are part of a national network of many thousands of stations, from which real-time data can be accessed from the web. In Glacier MBR, they have been augmented by automated gauging stations located on streams in two watersheds so as to provide more finely scaled data. These stations are downloaded several times per year and a decade-long database of the daily discharge has now been collected. Another recent addition is the Hydrologic Benchmark Network site with periodic water quality sampling and additional instrumentation to measure conductivity. Several surveys have been made of lakes to detect regional changes in water quality, and a five-year baseline for water quality was established for four backcountry lakes in the MBR. Finally, the intensive floodplain study, described earlier, has hydrological data for both surface and ground waters covering at least ten years.

Economic and demographic data has been recorded in Glacier MBR ever since the area was first proposed as a park. The data is kept in a museum collection that contains over 361,000 catalogued archival items and a park library with over 15,000 titles. Several administrative histories and a number of books have been published that describe, among other topics, the economics of the tourism industry from 1910 to the present day. Most of the privately held properties within the MBR have been purchased by the National Park Service and have been included in the public land base. There are virtually no permanent residents in the MBR but several small communities live just beyond its border; the largest of these numbers 300 people but larger communities of 3,000 inhabitants are found 24 km away. Annual reports, filed by the MBR superintendent, describe detailed budgets, contracting activities and financial impacts on local businesses. The county government has maintained demographic and economic information for the areas adjoining the MBR for the past 100 years and there have been several recent analyses of population and economic growth to guide community decision-making. A recent summary entitled *Gateway to Glacier* specifically examines the economic impact of the MBR on the regional economy and the increasing interdependence between them.

Summary

The Glacier MBR is an excellent place to assess the impacts of global changes on mountain ecosystems. Its size, relatively pristine condition, and the natural landscapes around it suggest that many of the documented changes can be attributed to climatic change rather than local disturbances. Glacier MBR has a diversity of biological communities, a variety of physical indicators of climatic change (for instance, glaciers), strong environmental gradients and two distinct climatic regimes. Furthermore, its position in North America provides opportunities to scale up research studies from local to continental scales. The Glacier MBR has a relatively robust science infrastructure, a history of studies to draw from and access to a rapidly increasing wealth of data that are becoming increasingly organized. Management issues which are likely to become more important to Glacier MBR in coming years include developing responses to extreme climate fluctuations (for example, drought and forest fires followed by heavy snowpacks and floods), shifting expectations of the MBR by the public and politicians, and rapidly increasing regional landscape fragmentation, which may undermine ecosystem resilience in the face of continuing global change.

13. GLORIA (The Global Observation Research Initiative in Alpine Environments): Alpine Vegetation and Climate Change

G. Grabherr, H. Pauli, D. Hohenwallner, M. Gottfried, C. Klettner and K. Reiter

INTRODUCTION

High mountain ecosystems, that is, the alpine life zone above the treeline, are determined by low-temperature conditions. Hence, alpine ecosystems are considered particularly sensitive to the impacts of climate change and are thus vulnerable to climate warming. Mountain regions are often 'hot spots' of biological diversity, caused among other reasons, by the compression of thermal life zones (Barthlott et al., 1996; Grabherr et al., 2000). For example, about 25 per cent of European flora is concentrated on high mountains, although they cover only 3 per cent of the continent's area (Väre et al., 2003). In some mountain systems, a high level of endemism is characteristic of the upper elevation belts. Many mountain environments are far less altered by human land use than lowlands. However, the effect of a rapid change in climate can be expected to affect alpine life severely; plants adapted to cold environments will suffer habitat losses and will, in many cases, have nowhere to migrate to as the climate becomes progressively warmer (Grabherr et al., 1995; Kundzewicz and Parry, 2001). Moreover, the alpine life zone is the only terrestrial life zone found from polar to tropical latitudes (Körner, 1999). Ecological climate impact research is thus a global priority for high mountain environments.

Evidence of the upward migration of alpine plants has been found in the European Alps (Grabherr et al., 1994, 2001; Pauli et al., 2001). Treelines have shifted upwards significantly in several European mountain ranges, such as those in Bulgaria (Meshinev et al., 2000) and the Urals (Moiseev and Shiyatov, 2003). A particularly high risk of critical biodiversity loss is anticipated for isolated mountains with high rates of endemism, for example, the Sierra Nevada of Spain (Pauli et al., 2003a), the Snowy Mountains of Australia (Good, 1998; Pickering and Armstrong, 2003) and for mountains in New Zealand (Halloy and Mark, 2003).

Standardized *in situ* monitoring is a crucial and much-demanded requirement in the assessment of climate-induced biodiversity and habitat loss, as shown in a large number of recommendations and work programmes (for example, Becker and Bugmann, 1997, 2001; EEA, 1999; Heal et al., 1998; Price and Barry, 1997; UNEP-WCMC, 2002). Yet, standardized observation sites are to a large extent nonexistent, which led to the initiation in 2001 of the Global Observation Research Initiative in Alpine Environments (GLORIA).

THE GLORIA APPROACH

GLORIA adopts two approaches: first, a worldwide multi-site long-term monitoring network aligned on summit habitats of different elevations (the multi-summit approach), and second, a network of a few GLORIA master sites in each continent, based at existing mountain field stations. At the planned master sites more extensive monitoring, field experiments and modeling studies, which would be too expensive for every site in the network, are to be conducted as a synergistic complement to the multi-summit approach. The research site at Mount Schrankogel (Central Eastern Alps, Austria) represents one such master site (for results please consult Gottfried et al., 1998, 1999, 2002; Grabherr et al., 2004; Keller and Körner, 2003; Pauli et al. 2004b;).

The multi-summit network is already established in Europe, with sites in thirteen countries between southern Spain and the Russian Polar Urals. In addition, GLORIA sites in New Zealand, the Australian Snowy Mountains, the Peruvian Andes, and in the United States (Montana Rocky Mountains) are already active. In order to establish an effective network with a large number of sites the GLORIA approach was designed with the following considerations: comparability, simplicity and low costs.

To represent an altitudinal gradient, four summits at different elevations from the treeline ecotone upwards, are used as monitoring sites in each GLORIA target region (see Figure 13.1a). The standardized sampling design consists of different

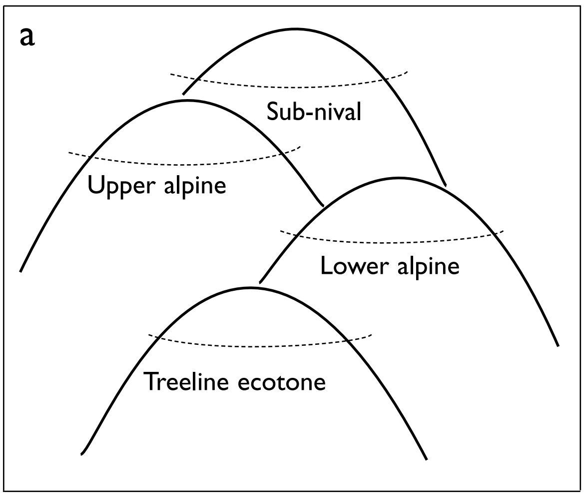
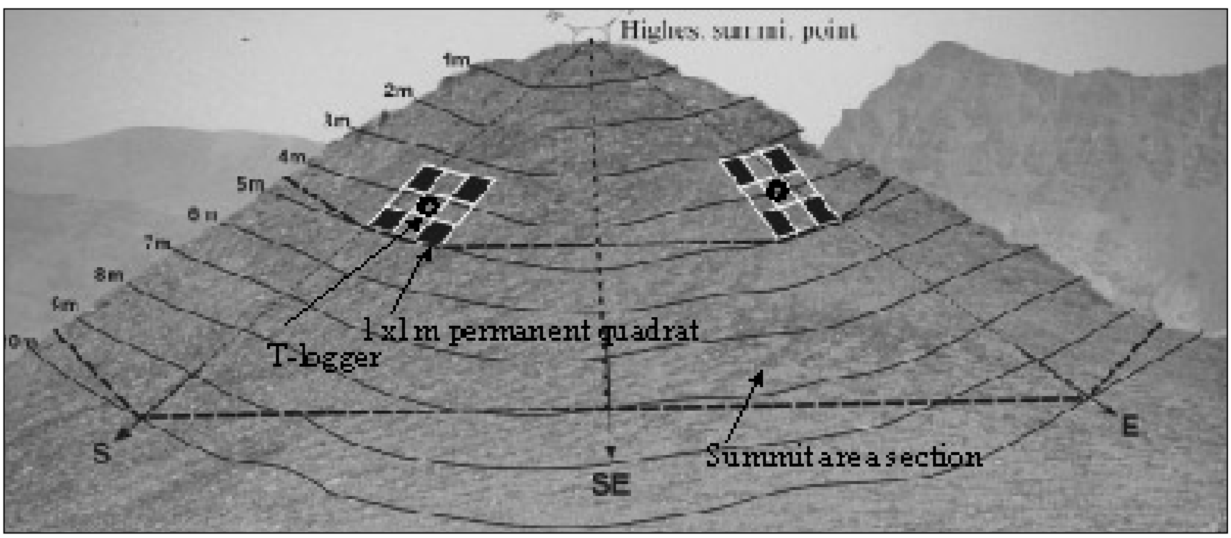


Figure 13.1
The Multi-Summit approach. (a) Altitudinal arrangement of summit sites (b) Sampling design for an observation summit (for details see the GLORIA field manual at www.gloria.ac.at)



plot types arranged around each summit to record species cover and frequency on different scales (see Figure 13.1b). Continuous measurements of soil temperature are conducted to compare temperature and snow regimes.

A detailed field manual provides the complete guidelines for site selection, the set-up and documentation of permanent plots, and for data recording and management (Pauli et al., 2003b; Pauli et al., 2004a). Electronic tools for the data input into the central GLORIA database and for plot documentation can be downloaded at the GLORIA website: www.gloria.ac.at

THE WORLDWIDE IMPLEMENTATION OF GLORIA

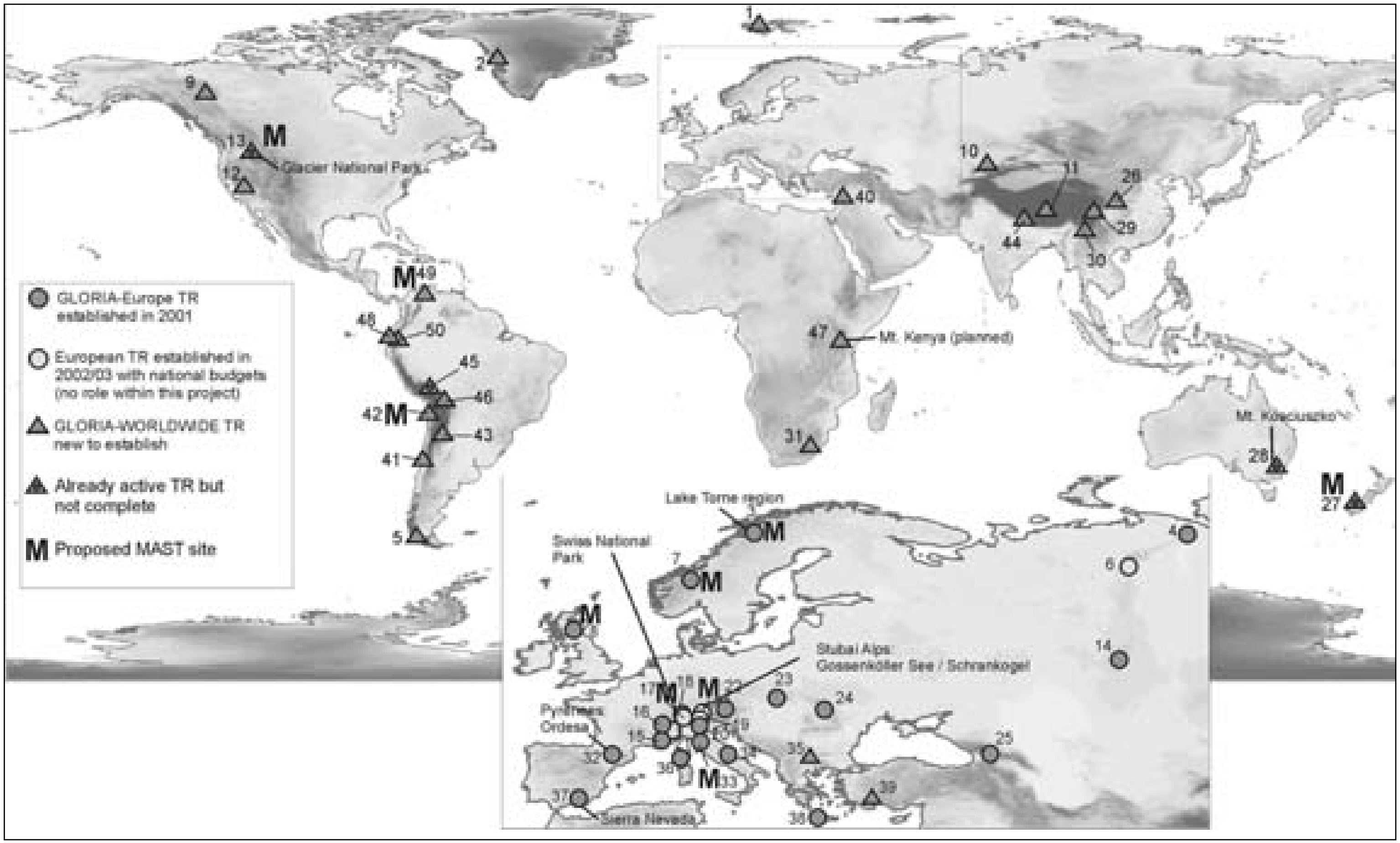
The Fifth Framework Programme (FP-5) research project GLORIA-Europe of the European Commission (from 2001 to 2003) was a successful pilot project for the global extension of the monitoring network. Over the coming years, GLORIA target regions, each with four summit sites, are being planned in all major life zones between the polar and tropical latitudes. In order to balance their global distribution, the geographical arrangement of these target regions will follow a three-fold approach (see Figure 13.2); it takes into consideration the pattern of mountain systems across all populated continents and across the major vegetation zones (compare Walter, 1985; Richter, 2001) and is in keeping with global circulation models (ECHAM4 circulation model; Roeckner et al. 1996). Moreover, this major effort includes the establishment of GLORIA master sites in all major lifezones. Following this first implementation phase, the network may consist of fifty GLORIA multi-summit target regions and ten GLORIA master sites.

GLORIA SITES IN UNESCO-MAB BIOSPHERE RESERVES

At the Mountain Research Initiative, MRI/UNESCO-MAB workshop in November 2003, Entlebuch Biosphere Reserve, Switzerland, which saw the launch of the GLOCHAMORE (Global Change and Mountain Regions) project, the topic of future monitoring strategies within a world-wide network of Biosphere Reserves in mountain regions was a key item of discussion. Monitoring in biosphere reserves is recommended at the international, national and individual reserve level of the Seville Strategy and is consolidated by the Biosphere Reserve Integrated Monitoring (BRIM) project. The core zone of biosphere reserves may provide ideal sites for monitoring the effects of climate change on biodiversity and vegetation patterns. The GLORIA strategy, in particular the establishment of multi-summit sites, is among the favoured approaches to be adopted in applicable biosphere reserves, due to its low set-up and maintenance costs, its standardized methods and its world-wide dimension. The legal protection status within the often-pristine core zones of biosphere reserves would provide ideal conditions for long-term ecological climate impact monitoring. Furthermore, the structure of biosphere reserves into core, buffer and transition zones is such that it would allow an immediate comparison of impacts related to climate change with those caused by human land use.

Linking GLORIA sites to biosphere reserves is thus a highly recommended extension to the existing and planned GLORIA network. Currently, seven active GLORIA target regions already lie within or in the close vicinity to biosphere reserves (see Figure 13.2).

Figure 13.2 *GLORIA target regions*



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14. Global Environet: A Coordinated Environmental Observation System Linking Mountain Biosphere Reserves

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General circulation models of temperature changes that can be expected with increased levels of greenhouse gases show large changes near the surface at high latitudes, but also at higher elevations in lower latitudes (Figure 14.1).

Much attention has been given to the expected changes at high latitudes, and indeed observations of reduced sea-ice extent, melting of permafrost and so on indicate the significant warming currently underway in those regions. Less attention has been paid to the expected changes in mountain regions at lower latitudes, yet there is much evidence that temperatures have also risen markedly in these regions (for instance, Vuille et al., 2003). In many areas, this has led to the dramatic recession of glaciers and ice caps, with negative consequences for regional water supply and hydroelectric power generation, while creating hazards from newly created glacier-dammed lakes (for example,

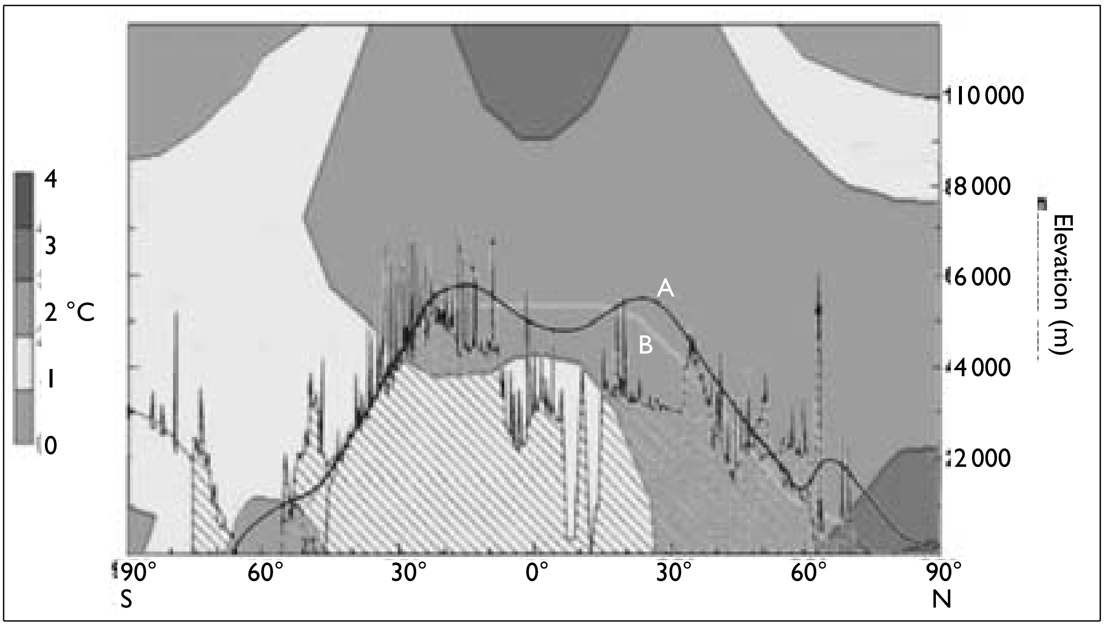

Figure 14.1
Zonally averaged mean annual temperature changes under 2 x CO_2 conditions, compared with control simulations. Results are the average of six general circulation model simulations used in the Intergovernmental Panel on Climate Change 2001 (IPCC) report. Topography along the American Cordillera is shown by line A. The mean freezing level is shown by line B. (Modified from IPCC, 2001).

Thompson et al., 2003). Currently, there are few meteorological stations operating at high elevations, and those that do are generally not included in readily accessible global data inventories (such as the WMO's Global Historical Climatology Network, GHCN).

To improve the quality of global climate observations an improved network is being established, the Global Climate Observing System (GCOS), but this plan includes very few high-elevation stations (Figure 14.2). For example, there will only be two GCOS stations above 3,000 m in all of South America. It is important that a future network be configured to assess meteorological conditions in those regions that are most sensitive to future change, and to locate stations monitoring climate change in pristine areas away from the effects of growing cities and large-scale land-use disturbances.

To achieve these objectives, we propose a coordinated environmental observation system ('Global Environet') that would link observations across a network of high elevation pristine sites around the globe and provide a measure of the 'background' global changes taking place. At higher elevations, measurements are above local temperature inversions where pollutants are often trapped, affecting conditions over a wide area. We propose that the Global Environet sites be among UNESCO's World Network of Biosphere Reserve (WNBR) in mountain regions (or similar isolated nature preserves, so as to provide a globally distributed network) where measurements will not be influenced by local human influences. The measurements will thus take the 'pulse of the planet' in those areas that remain as pristine as can be found on Earth today.

Standardized measurements will be made at each site (using the same instruments and protocols) and relayed via satellite to a base station where the data will be processed and freely displayed on the Internet. At a minimum, each station will record hourly measurements of aspirated air temperature and humidity, ground temperatures, wind speed and direction, precipitation, incoming solar radiation and air pressure. Other measurements, such as air chemistry and water quality could

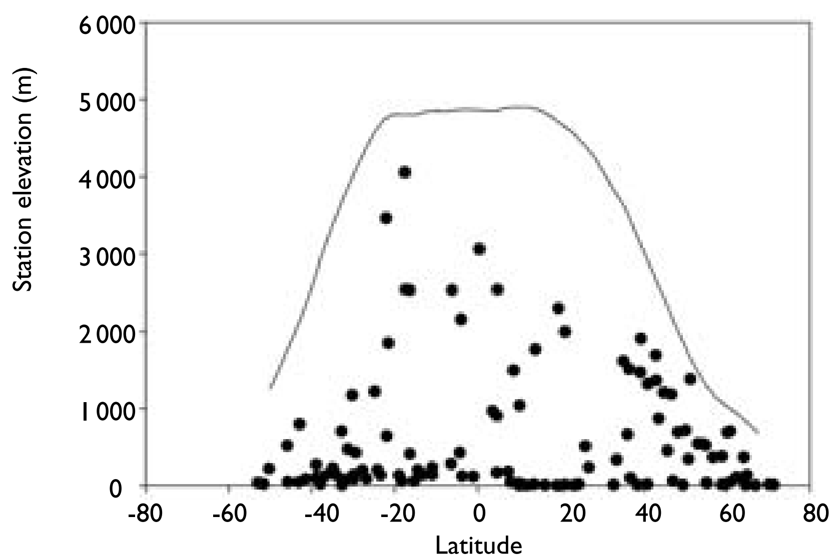

Figure 14.2 *GCOS stations planned for the western Cordillera, and their distribution with elevation. The mean annual freezing level is shown by the thin black line (compare Figure 14.1). A large 'data gap' exists at high elevations from ~ 40°N to 50°S.*

be made at a sub-set of locations, where such measurements were appropriate.

Measurements at high elevations present logistical constraints (access, lack of power) and potential environmental limitations (high snowfall, high radiation loading on instruments). However, over the last few years we have carried out meteorological measurements in some of the most extreme environments on earth and have demonstrated that reliable, high-quality data can be recovered (for instance, Hardy et al., 1998, 2003). High levels of incoming solar radiation provide abundant power for instruments, and stations can be configured to provide multiple back-ups, ensuring that no data are lost. Data can be relayed via GOES or ARGOS satellite systems for near real-time observations (Figure 14.3).

Figure 14.3
Schematic diagram of satellite linked Mountain Biosphere Reserve network (the Global Environet) relaying data via satellite to a base station.

Establishment of the Global Environet will enable a more comprehensive view of global climate change to be obtained in those areas where computer models project that future changes will be large. It will also improve our understanding of the causal mechanisms that are driving significant environmental changes across the globe.

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15. *Regional Atmospheric and Hydrological Models*

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ABSTRACT

Modeling regional climatic changes in mountain regions is a difficult task. The problem is twofold: on the one side there is the difficulty in obtaining reliable climatic data needed to validate the models, and on the other hand Regional Climate models are not always reliable. Several factors may contribute to climate change. In mountain regions the different climatic types and their associated changes may be a function of altitude (i.e. changes in temperature), but there are a range of mechanisms to be considered. In this paper some of these effects are listed and briefly discussed. A concise description of the main features of regional climate models and hydrological models is give, together with some simple applications. The purpose is to encourage the interest of the GLOCHAMORE (Global Change in Mountain Regions) community, a European Commission-funded project.

PROCESSES AFFECTING CLIMATE IN MOUNTAIN REGIONS

Besides the possible effects related to the increase of greenhouse gases such as carbon dioxide and methane, there are several other important factors to take into consideration in mountain regions. An excellent review is given in the paper by Pielke (2001), from which some of the points considered below are taken.

Landuse Change Effects

Anthropogenic landscape changes include deforestation, overgrazing, agricultural activities, urbanization and reforestation. Evidence shows that the process of land use change began around 1900 and is accelerating. Mountain regions will be affected in different ways depending primarily on their accessibility and altitude.

Biogeochemical Effects

The biogeochemistry of vegetation may be altered by an increase in carbon dioxide concentration as well as anthropogenic nitrogen deposition. Possible effects due to temperature changes must also be considered. The change in vegetation may have an effect on the climate on a regional scale.

Indirect Effect of Aerosols

The role of atmospheric aerosols originating from pollution in promoting precipitation is currently being debated. However, evidence seems to indicate that the effects may depend on the chemical nature of the particles. Combined with the direct effect of increased CCN on albedo, the net result of the spatially and temporally variable anthropogenic input of aerosols into the atmosphere may be important

Biogeographic Effects

The movement of entire biomes and the feedback that can occur due to changes in vegetation species composition may be an important factor in the climate system. In mountain regions this effect is demonstrated by altitudinal change.

HYDROLOGICAL MODELING

On an annual time scale, the analysis of climatic and hydrologic processes is generally based on the assumption of constant conditions. While this assumption may be reasonable over a short time scale (a few decades, depending on the particular case), empirical evidence shows that most hydroclimatic processes deviate from constancy in the long term. To some extent the assumption of constancy has persisted because most historical records have been too short to accurately detect inconstancy, and because of the lack of mathematical frameworks for analysing and modeling the dynamics of non-stationary processes. However, as record lengths have increased, trends, oscillatory behaviour and sudden shifts have been observed in sample records.

A possible alternative approach to observed time series analysis is the simulation of hydrological cycles using a numerical model. Figure 15.1 demonstrates a general classification of

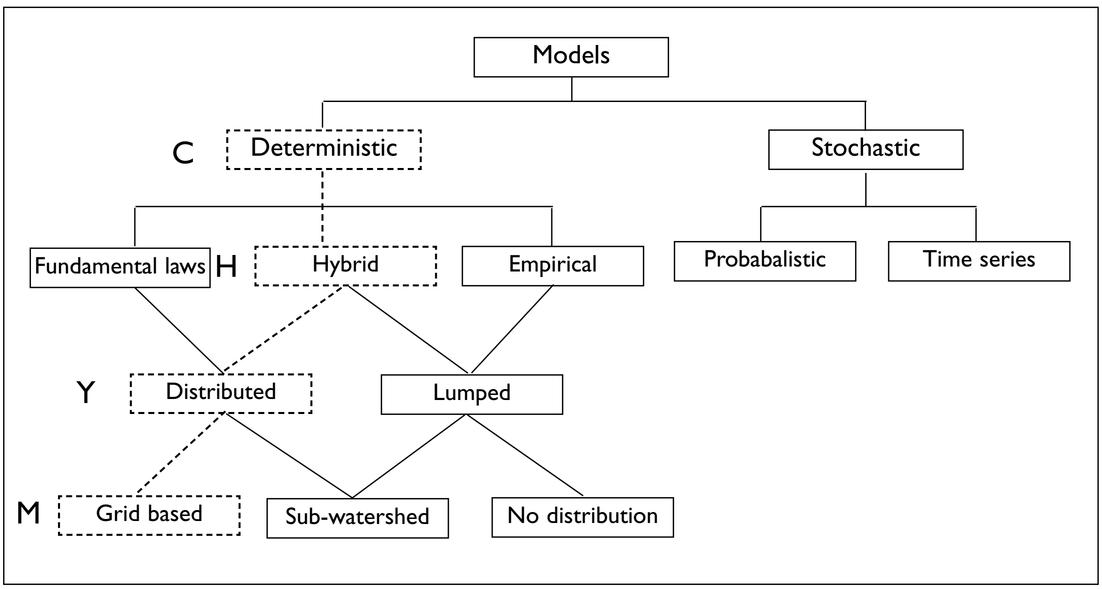

Figure 15.1
Classification of hydrologic models Taken from J. Kepner (Miller et al., 2002)

hydrological models (Miller, 2002). A first distinction is usually made between a deterministic and stochastic model. In the former, fundamental laws are used to simulate the main attributes to the hydrological cycle, while an empirical approach is often suitable for reproducing an observed time series of some hydrological variable, for instance flow rate discharge. Another important distinction is between lumped and distributed models. In the former, the simulation is performed to predict the behaviour of a whole river basin, while in the distributed model hydrological parameters are usually defined on a two-dimensional spatial grid.

Space resolution of hydrologic models depends heavily upon the size of the river basin that has to be simulated. Flow rate discharge can be well predicted with horizontal resolution spanning from 1 km to a few hundred meters for most implementations. As an example, a short description of the Centre of Excellence (CETEMPS) at the University of L'Aquila, and its hydrological model is given, which includes a short discussion of case-study results.

REGIONAL CLIMATE MODELS AND THEIR VALIDATION

There are two principal ways of downscaling a large-scale prediction to a regional scale. The first is dynamic downscaling, which combines a regional climate model (RCM) with a general circulation model (GCM hereinafter) output. The second is statistical downscaling, in which statistical properties of the region are used to constrain the GCM predictions. While this method is particularly appropriate for weather prediction, it presents several limitations for RCM as argued by Pielke (2001). These limitations can be summarized as follows:

- There is no feedback upscale to the GCM from the regional model, even if all of the significant large-scale (GCM scale) anthropogenic disturbances are included.
- The GCMs do not have a level of spatial resolution that is adequate to define the lateral boundary conditions of the regional model clearly. With numerical weather predictions, the atmospheric observations used in the analysis to initialize a model retain a component of realism even when degraded to the coarser model resolution of a global model. The validity of such data persists up to a week or so, when used as lateral boundary conditions for a regional numerical weather prediction model. This is not true with the GCM climate change experiments where observed data are not available for the same job.

Statistical downscaling from large-scale climate change experiments, besides requiring that the GCMs give accurate predictions of the future, also requires that the statistical equations used for downscaling remain invariant under changed regional atmospheric and land-surface conditions. There is no way to test this hypothesis. In fact, it is unlikely to be valid since the regional climate is not immune to larger-scale climate conditions, but is expected to change over time, both due to direct human-induced changes, and in response and feedback to the larger-scale atmospheric conditions.

A more appropriate procedure for using regional climate models is to apply them as sensitivity experiments where the relative effect of regional human disturbance is investigated (e.g. the radiative and biological effect within the regional climate system of increased CO_2; land use change – both historical and projected future possibilities; the radiative and biogeochemical effects of air pollution, such as ozone or nitrogen deposition). Knowledge of 'sensitivity' data would be much more useful than the existing downscaled regional climate results, which are inappropriately reported as projections. Since many decisions are regional and local in scale, a more effective methodology would be to understand the involvement of the regional climate system within the entire spectrum of environmental change and variability (and not just the radiative effect of increased CO_2 and aerosols).

AN APPLICATION OF A HYDROLOGICAL MODEL FOR FLOODING ALERT MAPPING

The Cetemps Hydrological Model (CHYM) is a deterministic grid-based model developed for predicting floods. It can be used in any geographical domain and with any resolution up to the implemented digital elevation model (DEM) resolution. For typical applications, the DEM and hydrological variables are given on an equally spaced grid and the number of grid points (usually called cells) is in the order of magnitude of a few hundred for each dimension (lat–lon).

A graphical representation of the DEM is shown in Figure 15.2. Starting from the DEM, a flow direction map is built, calculating for each cell the direction for which the slope is maximum; this corresponds to the assumption that flow occurs with a strong preferential direction. For practical purposes, the definition of the flow direction for each grid point is not simple, because of the local minima in the DEM matrix due to the finite resolution: in addition, these local minima occur mainly along the riverbed where the slope is lower. In order to avoid an unrealistic simulation of the drainage network a careful numerical manipulation of these singularities must be carried out. It should be noted that many hydrological models acquire the flow scheme from other commercial software, usually referred to as a GIS (geographic information system). In our case, the explicit choice of calculating the flow scheme is justified by the ability to run the model in any geographical domain and at any resolution.

The next step is to verify that the drainage network is simulated realistically, and for this purpose we implemented a sort of game that we call rolling stones algorithm (RSA). A quick description of this algorithm is given here because it will also be required later for a simple application of the model. RSA can be schematized as follows:

1. Starting from each cell, a stone rolls up to the river's mouth.
2. Each time that the stone goes though a cell, a counter is incremented by one for this cell.
3. If a quantity A is associated with each stone, where A is equivalent to the surface where the stone was situated initially, for each cell the upstream drained surface can be computed (see Figure 15.3).

Using this procedure the model is now able to calculate the path of the main river; the graphical representation of this result is shown in Figure 15.3. However, the drainage network as rebuilt by the model may be not realistic. This is often due to the wrong choice of resolution; this occurs, for example, if we try to simulate a river basin with resolution that is greater than or similar to the river cross section.

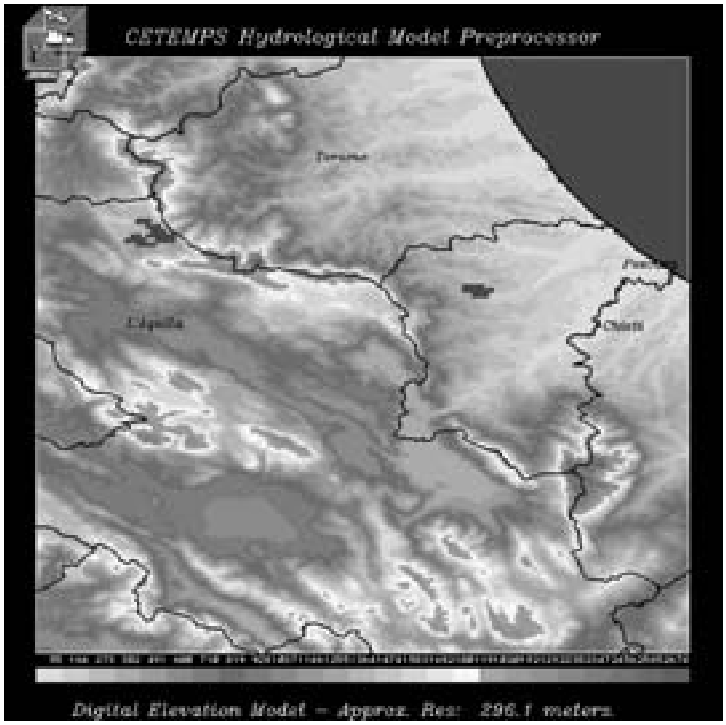

Figure 15.2
Digital Elevation Model

Figure 15.3
The drainage network as rebuilt by the CHYM model

The RSA described above, or comparable procedures, can be used for many simple and interesting applications. For instance, when defining an irregular geographical domain, in practice we can calculate all the cells that belong to a given river basin and then perform a simulation for those cells only. This drastically reduces the number of cells that are actually simulated and consequently the CPU time needed for the simulation.

Another application might be the mapping of pollution sources. Suppose for example a strong gradient of a pollutant – a nitrate or pesticide – is measured along a river. If measurements are taken within a few hours after heavy rainfall, pollution is mainly attributable to surface runoff. In this case, the RSA approach can easily be used for delimitating the area that is the source of the pollution, which coincides with the area drained by that segment of the river.

Finally, we present a simple application for flood alert mapping. Suppose that for each cell of our domain we are able to estimate the accumulated rain for a time interval of one or two days; the matrix representing this estimation can now be used to calculate the total amount of rain drained by the upstream surface for each cell, and then we can define an alarm index as:

$$\frac{\sum_{i=1}^{N} R_i}{\sum_{i=1}^{N} R_i} = AI$$

The numerator represents the total drained rain and the denominator represents the total drained surface; in fact this index measures the average accumulated rainfall in the upstream domain. What seems interesting for practical purpose is that the AI index actually highlights the likely area to be flooded. This has been verified in a couple of case studies. The alarm index calculated previously is shown in Figure 15.4. In order to better understand the plot, only those cells representing a total drained area of at least 10 km^2 are mapped. The case study refers to an event on 24 January 2003, when a typical winter frontal system was observed that produced intense precipitation in about thirty hours of continuous rain. Many relatively large floods have been observed in the zone close to the Maiella Mountains, as was correctly predicted using the alarm index defined above.

METEOROLOGICAL EFFECTS OF LAND USE CHANGE: A SIMULATION USING THE MM5 MODEL

As mentioned in the first section, evidence has shown that the process of land use change due to human activities, like overgrazing and agricultural activities, may affect the climatic system.

The use of a Regional Climate Model for studying these effects present several drawbacks that are essentially linked to the one-way feedback between GCM's and RCM's (see the earlier section on Hydrological Modeling). In order to get around these difficulties we carried out a simple experiment to study how the consequences of a typical meteorological situation could change as a result of the drying out of Fucino Lake in the Central Italy. With an area of about 150 km^2, Fucino Lake was the largest reservoir of fresh water in the Abruzzo region of Central Italy, but was drained at the end of the nineteenth century. A complete description of the

Figure 15.4
Alarm index map

Figure 15.5
Lake Fucino, which was formerly situated in central Italy

hydro-meteorological effects of this transformation is given in Tomassetti et al., 2003. They show how the presence of the lake induces a complex redistribution of humidity at both a horizontal and a vertical scale. An example of these results is shown in Figure 15.6, where the differences for the total accumulated rain between perturbed (no lake) and unperturbed (with lake) simulations are plotted.

The figure clearly highlights how differences can be observed at a noticeable distance from the area where land use change occurred. This study could be useful in determining whether a given area can really be defined as protected. For the reason shown in the previous case study, change of land use in one place can influence climate in another, quite separate area. Therefore, it only makes sense to define a protected area if that area is sufficiently big to contain all the possible sources of perturbation.

CONCLUSION

A general discussion of the use and value of regional climate models and hydrological models has been given, together with some example of their application. The RCM has been applied in order to study the perturbation in the meteorologic regime after land use has been extensively changed. It has been shown how the use of a hydrological model can provide very useful flood warning information in complex terrain and also for mapping pollution sources.

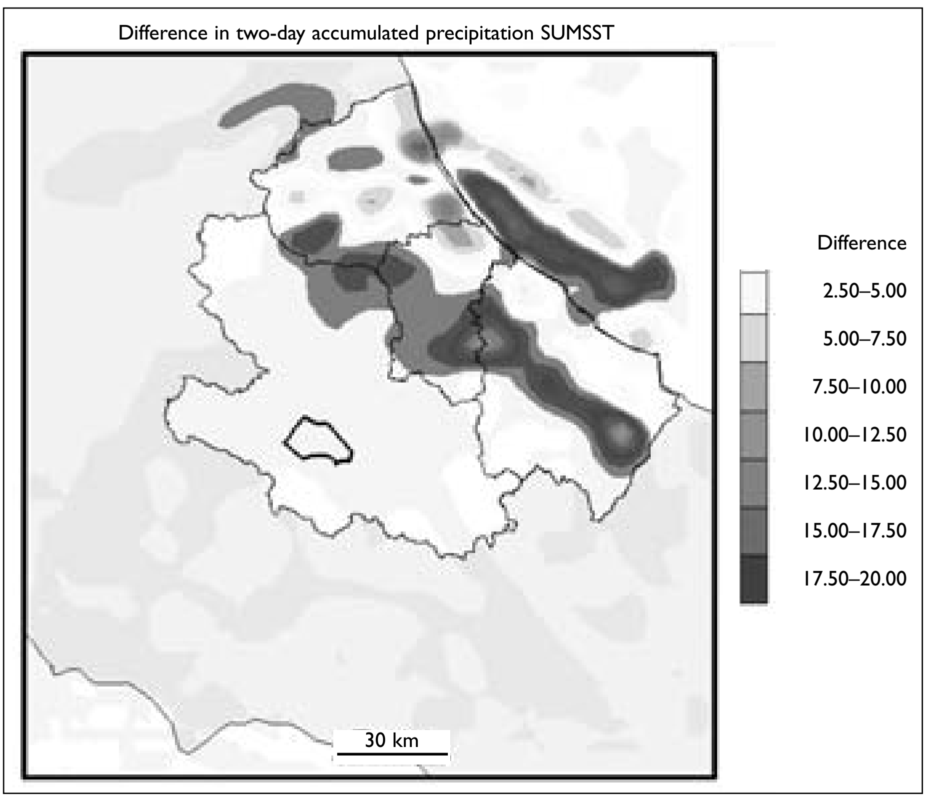

Figure 15.6 *Differences in precipitation field between perturbed (no lake) and unperturbed (with lake)*

NOTE

The colour figures originally prepared for this paper provide more precise statistical information; the authors will be happy to provide these details upon request (Marco.Verdecchia@aquila.infn.it).

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16. *Mountains and Mountainous Areas: A Field for Trans-Disciplinary Research and for Promoting Participatory Approaches to Mitigate Negative Effects of Global Change*

Daniel Maselli, Coordinator and Research Scientist, and Urs Wiesmann, Co-Director, NCCR North–South, Centre for Development and Environment (CDE), Institute of Geography, Berne University, Switzerland

The following short paper states the rationale for addressing mountains and mountainous areas (M&MAs) by research in general. It attempts to give a broader perspective with regard to the manifold specific concerns that are frequently being tackled by various single scientific programmes, institutions or persons. As such, it can be considered as a line of argument vis-à-vis policy makers who generally tend to pay more attention to urban areas, and where the economic, political and institutional stakes are considered far more important.

BASELINE ARGUMENTS

The question of how to justify research in marginal, frequently less-densely populated and mostly neglected areas must be considered in the context of 'sustainable development' (SD). This particularly applies with regard to the sustainable use and management of natural resources – a key feature and often also one of the key challenges of these areas. Furthermore, SD 'makes sense' only if related and embedded in a concrete spatial context corresponding to the regional dimension of sustainable development.

CONTENT-BASED JUSTIFICATION

These two considerations provide a starting point for a number of content-based lines of reasoning for considering mountains and mountainous areas as major focal spatial geographical element(s) of research:

- M&MAs are characterised by a (potentially) high degree of heterogeneity – spatial, social,

cultural, political etc.– composed of a multitude of rather small subsystems (e.g. single valleys, catchments, watersheds); they all require context specific approaches to SD.
- M&MAs represent highly complex and demanding ecosystems; through the connectedness of their subsystems, through their inter-relationships in the manifold processes and the frequently high dynamics in these areas.

These characteristics in themselves represent a particular challenge for SD. Thus, they should also be considered as a particularly challenging field of SD-oriented research. This is especially true when regarding the challenges of transferring and implementing research results.

- M&MAs can therefore be considered as an ideal – and very demanding – learning ground for research and reflection regarding SD (in terms of general understanding, processes, approaches, difficulties in outreach and the like).
- M&MAs can, or even must, be considered as being potentially both favourable and unfavourable zones for human beings; both types are closely connected and frequently ambivalent, depending upon the various standpoints of observation, judgements or types of utilization (e.g. internal versus external view); in addition, the appraisal depends heavily upon the nearby non-mountainous areas (lowland systems) which often act as (economic and socio-political) references.
- In M&MAs issues of protection, use and development are closely intertwined. Productive and reproductive aspects, functions and/or activities have to be considered from different standpoints. They influence any SD-oriented understanding.
- The (frequent) marginality of M&MAs, their (normative) positioning as favourable or unfavourable zones, and the need for a regionally based SD require appropriate social (societal), political (including institutional) and economic responses. This is where modalities of external solidarity and corresponding compensation mechanisms intervene to support development efforts that call for political and economic support from the exterior.

ADDITIONAL ARGUMENT

In addition to these content lines, a number of additional reasons or explanations for tackling SD in M&MAs can be added:

- Many people and/or institutions have acquired considerable competence/ experience over the years when dealing with M&MAs. This experience and relationship should not be neglected or put aside.
- M&MAs are focus areas for certain development donors, who consider rural and marginal areas as important fields for their activities in poverty reduction. Being active in M&MAs is therefore both a political opportunity and a dimension for research.
- Many researchers have developed strong personal and emotional bonds with and links to M&MAs. This influences their personal motivation and commitment to carrying out research in these areas and explains their support for relevant, high-quality findings.

- Sometimes we can identify the historical beginnings of single individuals' or institutions' activities as steering, pushing or initiating powers, which later developed into a particular tradition of tackling M&MAs issues. Hence there is a need to better capitalize on these experiences gained over years and decades.
- M&MAs are a common subject of interest reflected in the foreign policies of small countries, which frequently maintain close relationships with foreign M&MAs (see, for example, Switzerland's role representing the Central Asian mountain countries in the Bretton Woods Institutions).
- M&MAs cover about 20 per cent of the land surface of the world. This is an important amount, yet these areas tend to be neglected by the mainstream of economic, political and social development on a global scale.

STRATEGIC INTEREST OF CDE AND NCCR NORTH–SOUTH

From the above statements, the strategic interests of the Centre for Development and Environment (CDE, www.cde.unibe.ch), as the leading house of the NCCR North–South 'Research Partnerships for Mitigating the Syndromes of Global Change' (www.nccr-North-South.unibe.ch), can be derived as follows:

- M&MAs are acknowledged as a major geographical core focal zone of the CDE (not exclusively). At present roughly 50 per cent of the human and financial resources are allocated to these zones.
- M&MAs are considered as an ideal learning ground for research, training and capacity building, and implementation/application/transfer activities. These three elements are complementary and contribute to an integral competence with regard to such areas.
- M&MAs are one of the three syndrome contexts considered within the NCCR North–South; they can be considered as the most prominent.
- Partnerships and networks established in relation to M&MAs and built up over years and decades should be maintained and enforced (following the principle of building on achievements).
- M&MAs embody the potential for the CDE/NCCR North–South to distinguish itself as a centre for competence in this field both at a national and an international level.

KEY ISSUES AND TOPICS (TO BE) ADDRESSED

The following issues and topics are considered to be of relevance for the CDE and the NCCR North–South in relation to the SD of M&MAs:

- (un)sustainable use of natural resources (e.g. 'hot-spots of unsustainability'/'bright spots of sustainability')
- sustainable land management (SLM; sustainable soil/water management, vegetation, livestock, protected areas, biodiversity etc.)
- degradation and conservation processes, soil and water conservation (SWC; WOCAT www.wocat.org)

- highland–lowland interactions (including centre–periphery issues, gradients and aspects of imbalance) and their societal impacts
- watershed development
- change processes and their dynamics
- integrated, trans-disciplinary methods and methodological approaches (including issues of up and down-scaling) to overcome the tendency of accumulating ideographic examples hindering the typing and detection of patterns (cf. notion of syndrome)
- conservation and regional development
- community development, empowerment and gender aspects.

RESULTS ACHIEVED SO FAR

A series of methods, methodological approaches, and tools have been developed through activities implemented by the CDE in M&MAs such as:

- multi-level/multi-stakeholder approach (MuLMuS)
- autodidactic learning for sustainable development (ALS)
- trans-disciplinary research and knowledge transfer mechanisms
- sustainable development appraisal (SDA)
- impact monitoring (IM) etc.

The general understanding of various processes and dynamics, and the involvement of concerned stakeholders – in particular at community and local administration level – has increased considerably. Furthermore a number of special programmes or activities have been assigned to the CDE: WOCAT, CAMP, ESAPP, MRD and similar organizations.

GENERAL CONCLUSIONS

There is a basic agreed need for action with regard to M&MAs. In order to keep them high on the agenda at all levels and in different fields – in research, development cooperation, international policy dialogue and so on – CDE intends to adopt a more proactive attitude. In concrete terms this might encompass the following activities or tasks:

- To jointly produce a worldwide competence map based on specific fields of competence of major institutions involved in M&MAs research and development activities.
- To create an internal working group on M&MAs in order to preserve, enhance and apply the competencies related to M&MAs; this will explicitly include the better use of existing internal capacities.
- To secure the internal and external exchange of innovative approaches and to provide the necessary funds to tackle issues of an over-arching nature related to M&MAs (mainly working time of the internal personnel involved).
- To encourage multi-level lobbying for M&MAs (local, national, regional and international)

and to make use of or support relevant networks and initiatives such as the 'International Partnership for Sustainable Development in Mountain Regions'.

- To establish strategic alliances with complementary like-minded partners.
- To elaborate and communicate (internally and externally) a profile of CDE (and NCCR North–South) related to its commitment to and involvement in M&MAs.

Bearing these points in mind, the CDE and the NCCR North–South intend to improve the unequal level of attention paid to M&MAs with a view to ultimately contributing to a more sustainable development of these fascinating regions of our world.

17 *Globally Important Ingenious Agricultural Heritage Systems (GIAHS), Global Change and Mountain Biosphere Reserve Management*

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INTRODUCTION

Human beings interact with the ecosystem through concrete practices, which are determined by changing spatial and temporal cultural perceptions. There is wide recognition across the globe, and disciplines, that regions of ecological importance exhibit a symbiotic relationship between their habitat and the culture within (Ramakrishnan, 2001). This demonstrates the symbolic relationship between culture and environment throughout human evolution, and up until the beginning of industrialization. The cultural concept of 'the sacred' is an intangible entity that has embedded itself into the ecological paradigm, not only because human societies have traditionally looked at nature with awe and reverence but also because of their heavy dependence on the natural environment to meet their livelihood needs (Ramakrishnan, 1992; Ramakrishnan et al., 1998). The concept of culturally valued sacred species, groves (ecosystems) and landscapes (landscapes) falls into this category. As activities seeking to exploit the environment are rapidly replacing traditional value systems and associated traditional management practices, the need to understand the drivers of this change becomes an increasingly interesting area of study (Heer, 1975; Hughes, 1998; Ovsiyannikov and Terebikhin, 1994; Sanders, 1960).

The World Heritage Convention of 1972 is a unique international instrument for conserving cultural and natural heritage of outstanding universal value. It provides an opportunity to protect natural and archaeological sites that are outstanding from a historical, ethnobiological or aesthetic perspective. The World Heritage Convention recognizes three categories of cultural landscapes: first, 'clearly defined landscapes designed and created intentionally by humans', such as garden and parklands; second, 'organically evolved landscapes' that may still continue to evolve, or their remnants; and third, 'associative landscapes', defined by virtue of religious, artistic or cultural associations, and considered as intangible heritage (Rossler, 2001). The cross-cutting dimensions of ecology, economics and ethics (Ramakrishnan, 1998) across a variety of disciplines are becoming more and more relevant in natural resource management. In the contemporary context, these cultural entities not only provide intangible benefits that enable humans to enjoy a harmonious relationship with nature, including leisure, but also provide tangible benefits from the biodiversity that is conserved and managed through human actions.

In the context of 'global change' (Walker et al., 1999) from an ecological perspective, and 'globalization', from an economical perspective, (Daly and Cobb, 1989; Dragun and Tisdell, 1999), we note the rapidity by which traditional approaches were left behind. There is an urgent need for interaction between the ecological, social and cultural dimensions of a given environmental problem; there is a need to look into the wider context of how societal perceptions differ and how the same environmental issue is often perceived differently by various cultural groups. In fact, this may form the basis for managing the greater environmental uncertainties arising from 'global change' and 'globalization' (Ramakrishnan, 2001). Mountain societies in developing countries still consider themselves as part of a cultural landscape, and this forms the basis for the more recently evolved 'biosphere reserve' concept, which aims to link conservation with the sustainable development of societies. It is in this context that the 'globally important ingenious agricultural heritage systems' (GIAHS) become significant.

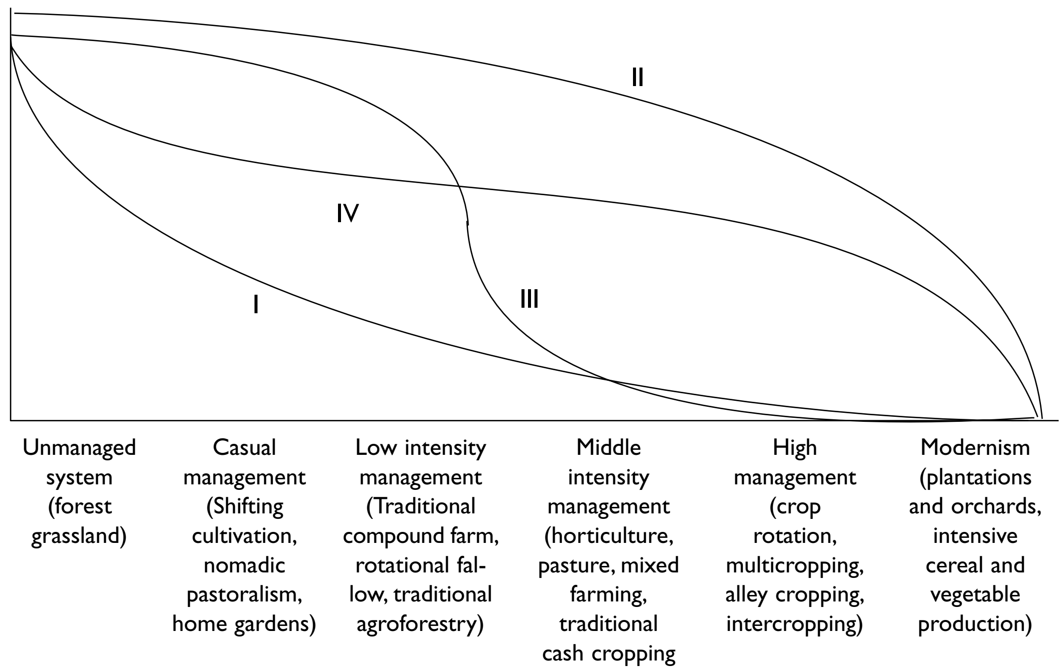
WHAT ARE GIAHS?

'Globally important ingenious agricultural heritage systems' (GIAHS) are multi-species (including cultivars), complex agroecosystems that are maintained and managed at low intensities by traditional societies based on a value system (Figure 17.1). They form an integral component of a cultural landscape, having strong sociocultural interconnections with the landscape in which they are placed. They are continually evolving products of eco-cultural interactions occurring in space and time.

Eco-Cultural Interactions

Humans are relative newcomers to a complex environment in which evolution driven by natural forces has shaped a complex set of constraints; understanding these sets of complex interactions, and the responses by indigenous forest people, may help in understanding the possible sustainable use of forest resources (Ballee, 1989). The domestication of the landscape with crop species planted at random within a forested area, often referred to as 'domiculture' by archaeologists and ethnobiologists (Hynes and Chase, 1982), is an attempt by aborigines in Australia, and many other indigenous societies elsewhere in Papua New Guinea (Groube, 1989), to manage biodiversity of economic value as part of overall landscape management. This is the necessary first step towards better organized agriculture of domesticated plant/animal populations. Such an attempt to domesticate the landscape around traditional societies is different from intensive agriculture whereby the emphasis is placed on the modification of individual crop species and the organization of those species in agricultural plots. While 'domiculture' may lead to more organized agricultural development (Lathrap, 1977), this may not always be the case (Yen, 1989).

The transition to casually managed shifting agriculture (Figure 17.1), where economically selected crop species and crop cultivars are part of a multi-species complex agroecosystem, is simple



Curve I and Curve II represent two extreme (and improbable) possibilities
Curve III is a softer version of ecologists' expectations
Curve IV seems to be the more likely and more interesting scenario from a biodiversity conservation perspective.

Figure 17.1 *Biodiversity changes (four patterns) related to agro-ecosystem types and management intensity. Efforts for the sustainable development of these traditional agroecosystems should be based on conserving agricultural biodiversity within a system of resilience that takes productivity into account (Swift et al., 1996).*

to contemplate as part of the overall landscape organization. The shifting agricultural system, essentially based on 'farming the forest' (Ramakrishnan, 1992), is the next important step in the socio-ecological evolution of 'domiculture'. Furthermore, cultural diversification could lead to more intensely managed multi-species complex agroecosystems (a variety of agroforestry systems, home gardens, compound farms and so on), while still maintaining the overall integrity of the landscape unit (Swift et al., 1996). These traditional food production systems are less energy intensive as they are largely dependent upon resource recycling from within the surrounding landscape.

Significant changes in biotic composition or agricultural practice are evidence of a local response to local necessities or modified goals. Modifications brought about in traditional agroecosystems imply an adaptive evolution in many of them. In this process, there is a decline in interactions between proximal drivers of land use/cover change such as land degradation linked to biodiversity loss and soil fertility, and an important role is played by more distant drivers such as market forces and governmental policies, which determine deforestation (Ramakrishnan, 2001).

The current situation, represented by the intense industrialization of agriculture during the period after the Second World War, can be observed extensively throughout the world and represents the ultimate reduction in biodiversity. In view of this development, landscape-level heterogeneity, ensured by traditional societies and still prevalent in the more remote areas of the world, is crucial for the sustainable management of natural resources.

GIAHS AS 'NATURAL WORLD HERITAGE' SITES

If GIAHS are to be developed as 'natural world heritage' sites, this should be done in the context of:

- A unique socio-ecological context; for example, the agri-pastoral system characteristic of the cold mountain desert of Ladakh (Kaushal, 2001).
- An agricultural system representing traditional ecological knowledge, such as integrated wet rice–pisciculture cultivation of the Apatanis in Arunachal Pradesh (see Box 1).
- A rich culture of 'traditional ecological knowledge' (TEK) – a heritage that is important from both a structural and functional perspective.
- Innovative traditional technology, like the traditional water harvesting technologies of arid land agriculture in Iran (Talebbeydokhti et al., 1999) or India (Agarwal and Narain, 1997); associations between unique religious and cultural heritage, as in the shifting agricultural calendar of tribes such as the 'Garos' in northeast India, with their elaborate dance and music forms (Ramakrishnan, 1992).

Need to Conserve GIAHS

Traditionally, agricultural scientists have largely been involved with increasing global/national food production through modern agriculture using a high energy input. Only in more recent times have traditional agricultural systems been receiving attention, and only from a limited number of agroecologists interested in designing sustainable agriculture models (Altierie and Liebman, 1988; Gleissman, 1990; Ramakrishnan, 1984, 1992). A consequence of the neglect of these traditional systems has been an attempt on the part of the agricultural scientific community, and developmental agencies, to transplant an agricultural model and thus impose a value system that is alien to the traditional sociocultural value system of the local communities, often with disastrous consequences to GIAHS, and without achieving any sustainable agroecosystem(s) (Ramakrishnan, 2001).

Many of the GIAHS are dependent upon the natural ecosystems in the landscape; large-scale deforestation and land degradation have made these traditional systems untenable. The factors that lead to land degradation stem from a variety of external pressures in which the local community has only a very limited role, or none at all. There is now increasing evidence to suggest that national policies, national and international market forces, institutional interplay and inter-institutional conflicts play a major role in the degradation of land and associated GIAHS (Lambin et al., 2001; Ramakrishnan, 2001; Indian National Science Academy et al., 2001). In a socio-cultural context, an important driver is the change in the value system of local communities, as seen in northeastern India over the last century with the introduction and spread of Christianity in the region. Many traditional practices linked with nature worship and animistic religious practices were branded primitive, with a consequent decline in the traditional value system (Ramakrishnan, 1992). In addition, increasing population pressure within a given region, and the large-scale migration of male members of the family, as in the Central Himalayan region,

Box 1. *Wet rice cultivation of the Apatanis: a unique and highly organized land use system in northeast India*

- The Apatanis, make effective use of their irrigated land by planting early- and late-ripening varieties of rice. With an elaborate water management system using bamboo tubing, and with the recycling of village waste and pig dung, they establish a graded system of soil fertility, with nutrient-rich plots closer to the village and nutrient-poor plots further away.
- Closer to the village is a late-maturing variety of rice, which is combined with pisciculture. Fish culture in plots closer to the village synchronizes well with the late ripening rice variety, making harvesting both easy and manageable.
- Early-maturing rice types are sown further away from the village, where disturbance by wild animals, the low nutrient status of the soil and poorer irrigation facilities are major constraints.
- Rice is supplemented with *Eleusine coracana*, cultivated on elevated partition strips between the rice plots. The yield per hectare of such Eleusine coracana was greater in early-variety plots than in those of the late variety.
- The early-maturing variety of rice revealed a greater density but with a reduced basal area, compared with the late variety. Economic yield per plant and per unit area of the early variety was significantly lower than the late variety. However, when combined with fish yield, the total per unit area was much higher than the late-maturing variety.
- With human labour as the major input (both men and women participating), the Apatanis obtain a high energy output. Labour input for rice/rice + millet where the early variety of rice is grown was greater than for the late variety of rice. The Apatanis obtain an exceptionally high output from the system, which is comparable to the traditional rice cultivation systems in the plains of the country. The economic and energy efficiencies, and output per unit labour hour, were greater with late-maturing variety of rice than with the other.
- The exceptionally high energy efficiency of this valley land agroecosystem (sixty to eighty units per unit energy input) is markedly different from the values discussed for the other rice systems of the Indian plains, which have an energy efficiency value of about nine (Mitchell, 1979), from other traditional mountain systems in the region where the value is within the range of nine to fifty (Ramakrishnan, 1992), or modern 'green revolution' agriculture where it is less than one.
- Plots are widened by digging adjacent higher ground to an irrigable level.
- Though the Apatani system is unique in many ways, the agroecosystem offers opportunities for improvement by appropriate crop rotation and the productive use of land during the winter season. This village ecosystem is thus a good example of economic self-sufficiency in a traditional agricultural society that practices ecologically sound sedentary agriculture in the northeastern hill region of India.

(Kumar and Ramakrishnan, 1990)

often creates a gender imbalance (Ramakrishnan et al., 2000). The net result is the breakdown of these traditional systems and the marginalization of the traditional societies.

GIAHS are important from two major perspectives – for conserving agricultural and even natural biodiversity. Protecting cultural diversity from the gradual homogenization of societies by globalization is important (Ramakrishnan, 1998). Equally important is crop biodiversity, which not only ensures the livelihood of traditional societies themselves but also ensures the general health of 'modern agriculture'. This is particularly the case when we realize that the lifespan of a given crop variety in modern agriculture is often no more than five to six years and hence it needs to be frequently replaced through traditional breeding or through biotechnological tools. The challenge for the scientific community, conservationists and development planners is to ensure the conservation of cultural with biological diversity and, at the same time, ensure the sustainable development of these sociocultural systems (Ramakrishnan et al., 1996).

Criteria for Selection

During the discussion of the concept of GIAHS, the FAO identified the following criteria:

- A number of *systems-related criteria* were identified such as that related with (a) systems ingenuity and remarkability, (b) outstanding characteristics, (c) proven history of sustainability, and (d) global significance.
- The *contextual criteria* determined for selection of GIAHS, during the conceptualization of GIAHS, are related to (a) representative nature, (b) external threats, (c) policy and development relevance.

It is in this context that we need to take on board the following sociocultural and ecological issues.

DOES IT FALL INTO THE 'ASSOCIATIVE LANDSCAPE' CATEGORY?

Of the three landscape formations of the World Heritage Convention mentioned previously, GIAHS could be viewed as falling under the 'organically evolved/evolving associative landscapes', with intangible religious, artistic or cultural associations. The implications of this are, first, that GIAHS should have a strong sociocultural connotation and therefore intangible benefits should be an important consideration for declaring sites as GIAHS. The intangible elements translate as being part of a unique socio-ecological system connected to a 'place', as in the Demojong landscape of the Tibetan Buddhists (Box 2), which could then be evaluated in more tangible terms such as its outstanding value. Moreover, due attention should be paid to human–nature interactions.

UNIQUENESS OF LINKAGES OF GIAHS AS PART OF A CULTURAL LANDSCAPE

Since GIAHS are connected to a 'place', and there is resource flow into it from the landscape, the spatial dimension of the GIAHS should encompass both the natural ecosystem(s) and the social system(s) in which it is placed. In other words, it may often be necessary to identify GIAHS as part of a cultural landscape, for instance the Demajong landscape (see Figure 17.2) of the Tibetan Buddhists of Sikkim (Ramakrishnan, 1996; Ramakrishnan et al., 1998).

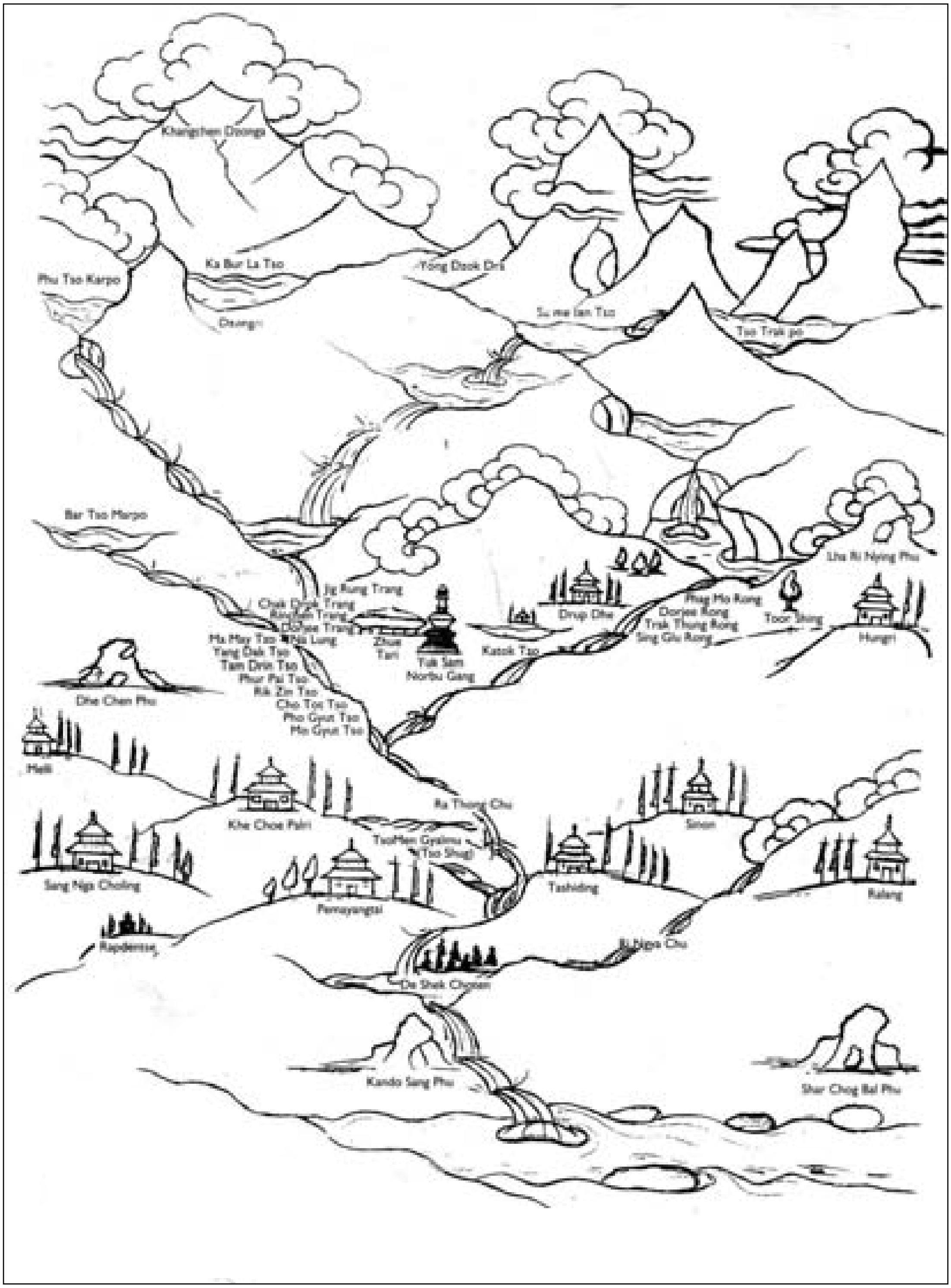


Figure 17.2 *Pictorial depiction of the Demojong landscape of hidden treasures – a sacred landscape of the Tibetan Buddhists of Sikkim Himalaya, India, and stretching from the Khangchendzonga peak to sub-tropical forests below. 'Tso' means Lake; 'Chu' means River (from Ramakrishnan et al., 1998)*

Box 2. *Examples of GIAHS linked to sacred landscapes around the world*

- An example of a 'diffused sacred landscape' (one which has a wide geographical range in terms of its influence throughout the Indian subcontinent and for Hindus the world over) is the landscape along the course of the Ganga river system in India, originating at Goumukh in the higher reaches of the Garhwal Himalaya, through the northern plains of the states of Uttar Pradesh, Bihar and West Bengal, before draining into the Bay of Bengal in the east. The sacred land of river tributaries, human dwellings and the natural and managed ecosystems together represent a cultural landscape of which GIAHS forms an important component. Large portions of the GIAHS in mountain regions are composed of *Quercus spp*. (oaks), which are culturally valued 'sacred species' (Ramakrishnan et al., 1998).

- Padmasambhava, who is worshipped by Sikkimese Buddhists, is considered to have blessed Yoksum, and the surrounding sacred land and water bodies in the West Sikkim District in eastern Himalaya are said to contain a large number of hidden treasures ('*ter*'). It is believed that these treasures will eventually be discovered and revealed only to enlightened Lamas. Conserving these treasures, protecting them from polluting influences, is considered important for human welfare. The area below Mount Khangchendzonga in West Sikkim, referred to as 'Demojong', is the core of the sacred land of Sikkim. Offerings are made to the protector deities but this is no longer possible if the land and water are desecrated. Village level activities on land and water resources are permitted, but any large-scale disturbance in the Yoksum region would destroy the hidden treasures, *ters* (the last such discovery was said to have occurred 540 years ago). Any major perturbation to the river system would disturb the ruling deities of the 109 hidden lakes of the river. Indeed, the very cultural fabric of Sikkimese society is dependent on the conservation of the entire sacred landscape. A variety of traditional agricultural systems interlinked with nomadism, such as that of the 'Bhutias' tribes, makes this an interesting GIAHS system.

- The Buddhist Dai (T'ai) tribe of Xishuangbanna in Yunnan province, southwest China, recognize many holy hills, 'Nong Ban' and 'Nong Meng' that belong to a village or a cluster of villages spread over a large area and contain hundreds of forested reserves. Agroecosystems and village systems interspersed throughout the region have close connections with the sacred mountain landscape in which they are situated.

- The forests in the Sierra Nevada de Santa Marta in northern Colombia are sacred to the indigenous Kogi, Arhuaco and Wiwa cultures.

(Messerli and Ives, 1997; Ramakrishnan, 2000;
Rodriguez Navarro, 2000)

UNIQUENESS OF SOCIO-ECOLOGICAL SYSTEM ATTRIBUTES

Both within and outside GIAHS, the unique driving forces determining ecosystem/landscape-level processes in turn determine structural and functional attributes of the landscape in general, and GIAHS in particular. Therefore, the interlinked and biophysical and human dimensions of related attributes of the given socio-ecological system would become an important criterion for evaluating GIAHS.

OBVIOUS AND NOT-SO-OBVIOUS TEK LINKED WITH BIODIVERSITY

GIAHS may be the basis for a rich heritage in 'traditional ecological knowledge' (TEK), which may operate at a purely socio-economic level in terms of its human dimension. More interestingly, TEK may be linked with ecosystem processes and functions – playing an important role in nutrient management, sustainability of soil fertility, nutrient cycling attributes of the ecosystem(s) and keystone value of species that are often socially selected, and be linked with associated biodiversity and ecosystem/landscape integrity (Ramakrishnan, 2001).

TEK linked with biodiversity management may determine the overall integrity of the system itself, at the ecosystem/landscape level. Crop diversity at species/sub-specific levels and even associated biodiversity (weed management rather than weed control for resource conservation) may often play a role, as was recognized by the Apatanis (see Box 1), or for swidden farmers (see Box 3). Such a system may also be linked with unique eco-technological attributes such as water harvesting and distribution systems using bamboo pipes, as carried out by the Apatanis or the Ladakhis in the trans-Himalayan cold desert region of India (Agarwal and Narain, 1997; Ramakrishnan, 2001).

SOCIOCULTURAL INSTITUTIONS PROMOTING EQUITY AND GENDER CONSIDERATIONS

GIAHS are a sociocultural institution and thus it follows that social institutions play a pivotal role in conserving GIAHS through community participation. Institution building and the manner in which it is accomplished is an important criterion for GIAHS conservation, but it is also an important indicator in the sustainable management of these systems. For instance, TEK was integrated into institution building in the sustainable management of the traditional slash and burn agroecosystem in the State of Nagaland in northeast India (see Box 4).

REVITALIZING AND SUSTAINABLY MANAGING GIAHS IN THE CONTEXT OF GLOBAL CHANGE

Biodiversity contributes to ecosystem functioning in a variety of ways, such as production, decomposition and nutrient-cycling dynamics, and thus aids the stability and resilience of the system. Figure 17.1 (page 134) illustrates the possible inter-relationships between biodiversity and agroecosystem types and the intensity of management, from the casually managed to the intensely managed modern mono-crop systems.

Most ecologists concerned with biodiversity in natural systems have tacitly assumed that the pattern in Curve I is most likely to occur, hypothesizing a substantial loss in biodiversity with increasing levels human intervention and management. Curve II, representing the other extreme, assumes that management has little effect until high intensity is reached; this too seems unlikely. Curve III depicts a smoother transition and suggests that, following a dramatic initial loss in biodiversity, further losses are slight until the extreme, namely modern agricultural management, is attained. Curve IV is

Box 3. *Biodiversity linked traditional ecological knowledge for soil fertility management*

- Traditional tribal societies in northeastern India organize nutrient-use efficient crop species on the upper slopes and less efficient species along the lower slopes, corresponding to the soil fertility gradient of a steep slope.
- By shortening the shifting agricultural cycle the farmer tends to place emphasis on tuber and vegetable crops rather than cereals with longer cycles.
- Operating a mixed cropping system, where species are sown simultaneously following the first rain during the monsoon, the farmer harvests crops one after the other as they mature over a period of a few months. After the harvest, the biomass is recycled into the agricultural plot.
- Weed biomass taken from the plots are put back into the system; about 20 per cent of weed biomass serves an important nutrient conservation role on the hill slope, which would otherwise be lost through erosive/leaching processes.
- Earthworms form an important component of many traditional agricultural systems. Under the 'tropical soil biology and fertility' (TSBF) programme, some of our collaborators have designed an eco-technology for *in situ* management of earthworms for the sustainable management of soil fertility, reducing the input of inorganic fertilizers in tea plantations in southern India; this technology is now patented by the researchers.
- Socially selected and/or valued species of traditional agricultural systems and those from natural systems often have an ecologically significant keystone value; these keystone species often play a major role in the nutrient enrichment of soil.
- Traditional eco-technologies, such as systems for water harvesting during the period of the monsoon, have been shown to be of value in altering biological processes in soil and thus improving soil fertility.

(Ramakrishnan, 1992)

Box 4. *Building upon the traditional ecological knowledge (TEK) associated with shifting agriculture and other related land uses in Nagaland, northeast India*

The NEPED project on traditional agroecosystem redevelopment is a unique experiment launched for the first time in northeastern India. Its main objective is to find a meaningful solution to the problem of shifting agriculture, which for the last century and more has defied any solution in spite of repeated attempts by governmental agencies to build on the rich TEK of the local tribal communities.

All the villages of the State of Nagaland – about 1,200 villages, 200 experimental plots in farmers' fields for agroforestry technology redevelopment, a coverage of about 5,500 ha of replicated test plots – were involved in the effort.

- Farmers have adopted tree-based strengthened shifting agricultural systems based on agro-foresty principles, for local testing in 870 villages, covering a total area of about 33,000 ha (38 ha per village × 870 villages).
- Locally identified edible legume crops are cultivated as part of the cropping phase, of about three to four years, followed by a period of fallow.
- Nepalese Alder (*Alnus nepalensis*) is the basis of a tree-based TEK; it is incorporated during both the cropping and fallow phases of shifting agriculture, which is widespread throughout the northeastern region. It is particularly extensive among the Angami tribe of Khonoma village near Kohima, where up to 120 kg of nitrogen per hectare is produced each year.
- Ten selected tree species planted for house construction and fuelwood could be harvested five to ten years after planting, and twenty tree species of value as timber have been identified and introduced into shifting agricultural plots in order to strengthen the agroecosystem in consultation with local communities.
- Traditional rainwater harvesting systems and erosion control measures are incorporated into redeveloped agricultural practices, wherever appropriate.
- The thatch grass, known in the south-east Asian region as 'Alang Alang' (*Imperata cylindrica*), which is extensive in northeast India, was shown to be controlled by dense cassava cropping.
- Mixed tree plantations in the jhum plots were shown to be better than monocultures and are being recommended and accepted by local communities.
- Agroforestry-related cultivation of non-traditional crops such as tea and oyster mushrooms are being promoted as alternative possibilities.
- Improving the yield of home garden systems by value-added vegetable cultivation is identified as an option for cash income; similarly multipurpose bamboo cultivation, including bamboo shoots as a food item, is being integrated into land use redevelopment.
- Biodiversity conservation (both natural and managed) is a consideration in redeveloped agroecosystem management.
- Land use redevelopment is initiated through participatory processes and dissemination; gender issues are adequately taken on board.
- Village development boards reflect the local value system based on a large number of cultural and linguistic traditional societies living in the State of Nagaland.

(Ramakrishnan, 1992)

more probable and noteworthy from the point of view of managing agroecosystem complexity for stability and resilience. This curve suggests that biodiversity is little affected by the initial management phases and that the loss is gradual until some critical stage in management intensity is reached, followed by a subsequent rapid decline at very high-intensity management levels.

It is reasonable to conclude that planning research activities, to develop agroecosystem models with a view to systems resilience combined with increasing agricultural productivity, should be focused on critical middle-intensity management. It is thus crucial to practice a level of management that is close to this critical area.

If we consider high-input modern agriculture as only one of the possible pathways for agricultural development, there could be at least two additional pathways for sustainable agriculture in the context of GIAHS: first, evolution by incremental change, and second, restoration through the contour pathway. These two additional pathways differ from modern agriculture.

The 'contour pathway', aims to ensure overall landscape integrity and thus, unlike modern agriculture, seeks to acknowledge and operate within the ecological forces that provide the basis on which the system must be constructed. It acknowledges that a well-integrated landscape unit must take into account the social, economic and cultural requirements of the farming communities. Many agroforestry system types of low and middle-intensity management fall into this category.

The 'incremental pathway' approach adopts a process of gradual change. Many traditional agricultural systems need to be redeveloped through TEK-based incremental steps rather than abrupt change, which is unacceptable to local communities. Short-term compromises might need to be considered in response to the restraints of ecological, economic, social and/or cultural factors, while not losing sight of a more ideal long-term strategy. A good example of the 'incremental pathway' is portrayed by the Nagaland initiative (see Box 4), whereby models are built in order to strengthen the forestry component of shifting agriculture (Ramakrishnan, 1992). Nepalese alder (*Alnus nepalensis*) found in northeast India, is one example of an ecologically significant and socially valued keystone species which contributes to overall soil fertility through nitrogen fixation up to about 125 kg per ha per yr (Ramakrishnan, 1992). Building upon TEK in local communities, where community participation was solicited, the conclusions arising from this analysis are now being implemented in over 1,200 villages in Nagaland (NEPED and IRR, 1999) and indeed have wider applications as this land-use system is prevalent throughout Asia, Africa and Latin America (see Box 4).

Efforts should be made to strengthen the working of the GIAHS rather than replacing them with drastically changed land-use systems. Examples of this can be seen within the context of UNESCO's world network of biosphere reserves and natural world heritage sites from south and central Asia (Ramakrishnan et al., 2002), which can provide added value to the proposed GIAHS initiative.

GIAHS: CULTURAL LANDSCAPES AND SUSTAINABLE DEVELOPMENT IN MOUNTAIN REGIONS

Many of the potential GIAHS sites are often part of mountain systems. Mountain systems, and their associated cultural landscapes, are often in remote areas and are thus cut off to a greater or lesser extent from external pressures (see Box 2; Messerli and Ives, 1997). GIAHS are often embedded within the notion of 'cultural landscapes': they are recognized by traditional societies as an important representation of human–nature interconnection, with locally evolved TEK important for landscape maintenance. The guiding principles that regulate the use of natural resources are embedded in the codified – and often uncodified – institutions that have evolved (Ramakrishnan et al., 1998). These sacred institutions were initially intended to enhance social solidarity rather than promote environmental consciousness *per se*, but conservation values also benefit.

Temperate mountain regions in developed countries remain to a large extent heterogeneous in a biophysical sense, due to their uneven topographical features; but the societies have to a large extent become homogenized through industrialization and urbanization, unlike the developing tropics where sociocultural heterogeneity is still upheld. However, communities in the tropical regions in developing countries are struggling to sustain sociocultural heterogeneity while aiming to improve the quality of life for mountain peoples (Ramakrishnan, 2001). By contrast, local communities in the developed world are struggling to rediscover their 'cultural landscape' and revitalize 'organically connected agriculture' with attempts to reclaim the ancient linkages between nature and natural resources.

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18. *Globalization in the Mountain Context*

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WHAT IS GLOBALIZATION?

- Globalization is a market-friendly, market-driven process directed towards the integration of world economies through (supposedly) the unrestricted flow of resources, products and services between different countries.
- It differs from conventional market-related processes in terms of:
  - unprecedented primacy given to market forces in local to global economic and related affairs
  - pro-market formal trading norms enforced by the WTO.
- It marginalizes state and communities in guiding and supporting economic decisions/actions.
- It carries environmental/economic risks for mountain areas and communities.
- It represents highly magnified forms of human intervention with adverse ecological/environmental impacts on mountains.
- Major paradigm shifts favour policies and priorities rooted in external (non-mountain) contexts.

GLOBALIZATION AND FRAGILE MOUNTAINS

- Visible mismatch between:
  - the driving forces, operational mechanisms and provisions of globalization, and
  - the imperatives of mountain specificities such as fragility, marginality, diversity and similar aspects, indicating potential risks for mountain areas and communities (see Table 18.1).
- Direct impact:
  - External demand pressure
  - profit-driven selectivity
  - intensification
  - over-extraction of mountain resources (products, services).
- Indirect impact:
  - Erosion of protection/conservation practices and well-adapted resource use systems conducive to ecological and economic resilience (due to their incompatibility with profitability and external demand driven focus of economic transactions).
- Likely accentuation of unequal highland–lowland economic links adversely affecting mountain areas and communities.

GLOBALIZATION AND MOUNTAINS: EMERGING IMPACT PROCESSES

Direct inducements to shifts in resource use/management

- Profitability and demand-driven changes in land use (disregarding resource limitations, imperatives of diversities and so on).
- Indiscriminate resource use intensification dictated by largely external demands/inducements.
- Narrow specialization discarding organic links between diverse resource-based activities.
- Replacement of better-adapted technological and institutional practices by the ones promoted by market forces.
- Macro–micro disconnections and widening gaps between resource users and resource use decision makers.
- Selective acceptance and exploitation of mountain resources/products by global market.

Major consequence: primacy to narrow market-profitability over other multiple considerations guiding resource use/management in mountain areas.

Indirect poverty-driven pressures for shifts in resource use systems (negative changes promoted by poverty)

- Declining range and quality of resource-use options due to their mismatch with market-determined decisions/actions.
- Disregard of traditional and well-adapted crops/technology choices that favour production with conservation.
- Decline of practices, collective activities and institutions as source of resilience due to erosion of community authority/concerns.
- Decline of natural niche-based opportunities (for instance, due to trade liberalization, changed investment priorities, resource access and ownership rights).
- Decline of 'social transfers' to help mountain communities due to fiscal reforms and marginalization of public sector.
- Gradual transfer of community and private lands to market agencies that have been permitted and encouraged by pro-market policy reforms.
- Rising control of mountain niche resources by external market agencies.
- Poverty induced intensification and over-extraction of mountain resources causing further degradation and enhanced poverty.

Major consequence: enhanced process of social and ecological vulnerabilities accentuating each other.

POTENTIAL POSITIVE OPPORTUNITIES

- *Potential gains of honest application of market principles*: that is, appropriate valuation/costing of mountain contributions to global economy and ecology; and fair compensation for the same including investment and support for resource conservation.

- *Socially and environmentally responsible market processes* and state policies (that is, mountain-interventions with a mountain perspective).
- Biophysical and socioeconomic *'constraint-relieving' investment and infrastructure* in mountain regions by global users of mountain ecology and other services/resources.
- *Special treatment given to mountain regions* while designing and implementing WTO provisions; for instance, 'environmental', 'cultural' and 'sustainable livelihood' windows.
- *Local capacity building* and local participation in decision making and actions involving usage of mountain resource, products and services under globalization.
- Strategies to *protect, upgrade and carefully harness 'niche' resources*, and services of mountain areas with full recognition of intellectual property rights of mountain communities.
- Identify and *act upon poverty–environment nexus* in mountain areas.
- Strong *global/regional lobbies* to support the above possibilities based on shared experiences and disaggregated research evidence from different mountain areas including MAB Reserves.

Table 18.1
Potential sources of adverse repercussions of globalization for mountain areas and communities and approaches to adapt to them

(continued next page)

a) Visible incompatibilities between: (i) driving forces of globalization and (ii) imperatives of specific features of mountain areas (fragility, diversity, etc.)

(i) Market driven selectivity, resource use intensification and over-exploitation induced by uncontrolled external demand versus
(ii) fragility-marginality induced balancing of intensive and extensive resource uses; diversification of production systems, niche harnessing in response to diversity of resources.

Consequence:
Environmental resource degradation; loss of local resource centred, diversified livelihood security options; increased external dependence.

b) Globalization promoting erosion of provisions and practices imparting protection and resilience to marginal areas/people (including disinvestments in welfare activities)

(i) Traditional adaptation strategies based on diversification, local resource regeneration, collective sharing, recycling and so on likely to be discarded by new market-driven incentives and approaches to production, resource management activities.
(ii) Shrinkage of public sector and welfare activities (including subsidies against environmental handicaps, etc.) depriving areas/people of investment and support facilities (except where externally exploitable niche opportunities exist).

Consequence:
Likely further marginalization of the bulk of the mountain areas and people.

c) Loss of local resource access and niche-opportunities through the emerging 'exclusion process'

Niche resources/products/services with their comparative advantage (e.g. timber, hydropower, herbs, off-season vegetables, horticulture, minerals, tourism etc.) and their likely loss under globalization through:

Table 18.1
Continued

i) Market-driven over-extraction/depletion due to uncontrolled external demand.
ii) Focus on selective niches, discarding diversity of niches, their traditional usage systems, regenerative practices; indigenous knowledge.
iii) Transfer of 'niche' to mainstream prime areas through market-driven incentives, green-house technologies, infrastructure and facilities (e.g., honey, mushrooms, flowers produced cheaper and more in green house complexes in the Punjab plains compared with naturally better-suited Himachal Pradesh).
iv) Acquisition and control of access to physical resources: forest, waterflows, biodiversity parks, tourist attractions by private firms through sale or auction by government, depriving locals of access, destroying customary rights and damaging livelihood security systems.

Consequence:
Loss of comparative advantages to fragile areas or access to such gains for local communities.

d) Adapting to globalization process: possible approaches to loss minimization

i) Sharing gains of globalization through partnership in primary and value-adding activities promoted through market; building of technical and organizational capacities using NGOs and other agencies including market agencies to promote the above.
ii) Promotion of local ancillary units (run by locals) to feed into final transactions promoted by globalization; this needs institutional and technical infrastructure and capacity building.
iii) Provision for proper valuation of mountain areas resources and compensation for their protection; management by local people for use by external agencies.
iv) Enhanced sensitivity of market-driven initiatives to environment and local concern to be enforced by international community and national governments.
v) All the above steps need local social mobilization, knowledge generation and advocacy movements; and policy framework and support.

Consequence:
If above steps are followed, there are chances of influencing the globalization process and reducing its negative repercussions for mountain areas/people.

19. *The Mountain Initiative Taskforce of IUCN: The World Conservation Union*

Martin F. Price, Centre for Mountain Studies, Perth College,
UHI Millennium Institute

The World Conservation Union (IUCN) has diverse interests and competencies in mountain environments. The maintenance of mountain ecosystem integrity is completely congruent with its mission 'to influence, encourage and assist societies throughout the world to conserve the integrity and diversity of nature and to ensure that any use of natural resources is equitable and ecologically sustainable'. Given the combination of technical expertise, experience in policy development, and a constituency and membership involved in advocacy for mountain peoples, the conservation and sustainable development of mountains can be greatly enhanced through IUCN's unique attributes. Among these are its diverse global membership, including governments and non-governmental organisations (NGOs), as well as its representation around the world through both its offices (that is, its Secretariat) and its members.

IUCN's work on mountains has largely been undertaken through components of global thematic programmes such as the Forest Conservation and Protected Areas Programmes, or through regionally supported projects/programmes in Asia, Central and South America, Central Asia, and East and West Africa. As of January 2003, about a third of the activities of global and regional offices of IUCN's secretariat were in mountain ecosystems. The Commission on Ecosystem Management (CEM) and the World Commission on Protected Areas (WCPA) both have strong commitments to addressing mountain issues. Four of the five priority activity areas of the CEM relate to mountain areas. The WCPA has had a mountain programme with a vice-chair since 1993.

Up to, and during, the International Year of Mountains in 2002, IUCN did not have a coordinated approach to conservation and sustainable development in mountain ecosystems. At the Second World Conservation Congress (October 2000, Amman, Jordan), IUCN members recognized the need for a more coordinated approach through their adoption of Resolution 2.45, requesting the Director General to undertake measures for conservation and sustainable development of mountain ecosystems and to consider establishing a longer-term institutional capacity to guide and coordinate IUCN's work on mountain ecosystems. In this context, the chairs of the CEM and the WCPA established the Mountains Initiative Taskforce in January 2003.

OBJECTIVES

The objectives of the Taskforce are:

- To coordinate, promote and facilitate communications among and between components of IUCN's programme and other institutions so as to provide integrated policy guidance on mountain ecosystems.
- To conserve mountain ecosystems at the regional scale and enhance the livelihoods of the people who depend on them.
- To contribute effectively to international partnerships on mountain conservation and sustainable development in mountain regions.

TASKFORCE STRUCTURE

The Chair of the Taskforce is co-appointed by the Chairs of the CEM and WCPA. The Taskforce is limited to fifteen people, chosen for their expertise in and understanding of mountain ecosystem issues. The membership currently includes WCPA's Vice-Chair for Mountains, the CEM Special Advisor on Mountain Cloud Forest Ecosystems, and representatives of mountain research initiatives (GLORIA, GMBA, MRI) and key UN organizations with mountain interests (FAO, UNEP, UNESCO). The Taskforce meets annually. Funding is limited, and members are expected to cover their own travel costs or rely on support provided by the sponsoring commissions.

COLLABORATION

Key issues addressed at the first meeting of the Taskforce were:

- How can the collaborating institutions be more effective at communicating and coordinating their activities within and among themselves?
- Where do the different collaborating institutions fit in the landscape of mountain actors?
- What strengths or added value does each, and particularly IUCN, have the potential of delivering?

In this context, the terms of reference were defined as:

- providing high-level advice and guidance to IUCN and other institutions regarding priority actions/needs related to mountains
- advising the IUCN Secretariat and Commissions on how to achieve greater coherence in IUCN's mountain-related activities
- providing a forum to review and recommend priority activities both within institutions represented by members of the Taskforce and among prospective donors
- monitoring mountain-related work undertaken on the advice of the Taskforce

- ensuring that the meetings of the Taskforce include a time for members to exchange information on their mountain work
- ensuring that perspectives and knowledge gained from IUCN field activities are made available to advise and guide the global mountain agenda.

ACTIVITIES

Since its first meeting in January 2003, the Taskforce has undertaken the following:

- Coordinating contributions on mountains at the March 2003 meeting of the CBD SBSTTA. A policy brief on mountains was prepared, and a sidebar event was organised in collaboration with Mountain Forum.
- Fostering partnerships within the framework of the International Partnership on Sustainable Development in Mountain Regions, or 'Mountain Partnership'. A key theme is 'Linking Research to Action'. Another partnership might be tied to IUCN's protected areas work.
- Contributing to the World Parks Congress, September 2003. A folder with outlines of partners' mountain activities and four projects was prepared. These were presented and discussed at a 'donor's lunch'.

The Taskforce met again in January 2004, and agreed principally to focus its efforts during the year towards the World Conservation Congress, taking place in Bangkok in November 2004.

LINKAGES TO THE MRI/BIOSPHERE RESERVE INITIATIVE

There are a number of potential synergies between the MRI/UNESCO 'Global Change Research in Mountain Biosphere Reserves' initiative and interests and activities of IUCN and the Taskforce. The fact that every biosphere reserve includes one or more protected areas – always encompassing the core zone, often in the buffer zone(s) and occasionally in the transition area(s) – represents a clear connection with the interests of the WCPA. From the viewpoint of the CEM, the initiative links to three of its priority areas:

- promoting implementation of the principles of the ecosystem approach (as endorsed by the parties to the CBD)
- identifying and testing indicators of ecosystem status
- developing and communicating tools and knowledge of ecosystem management.

The initiative could also link to the interests of other IUCN commissions, notably the Species Survival Commission and the Commission on Education and Communication. Equally, given that many of mountain biosphere reserves are in countries with IUCN members – whether at the level of states, government agencies or non-governmental organizations – further synergies might be sought with these members.

20. The Consortium for Integrated Climate-Related Research in Western North American Mountains (CIRMOUNT)

Constance I. Millar, Sierra Nevada Research Center, USDA Forest Service, Pacific Southwest Research Station, Albany, California, USA

INTRODUCING CIRMOUNT

I represent a nascent effort in western North America that is committed to improving integration of climate-related research and its societal implications. We go under the name of CIRMOUNT, that is, Consortium for Integrated Climate-Related Research in Western North American Mountains. In a sense, CIRMOUNT is a North American answer (in the affirmative) to Thomas Schaaf's (UNESCO/MAB) question of whether the global mountain change community represented at Entlebuch wants to continue the Mountain Research Initiative, MRI-UNESCO Mountain Biosphere Reserve (MBR) commitment. The answer is a resounding 'Yes', given that CIRMOUNT is one feasible response from developed countries, which – unlike other network nations here – cannot easily fold into the GEF (Global Environment Facility) proposal.

While I came to Entlebuch assuming that CIRMOUNT was philosophically aligned with MRI's mission, I am now convinced that CIRMOUNT's goals and intents are entirely consistent with MRI, and that CIRMOUNT could be a pilot project of MRI at the regional scale. Recognizing this, Dan Fagre (USGS, another of the CIRMOUNT coordinating group) and I decided that I should ask Harald Bugmann, as Chair of the MRI Executive Steering Committee, if MRI would consider formally endorsing CIRMOUNT as a fledgling project within MRI.

WHO ARE WE?

CIRMOUNT is a small but growing interdisciplinary group of scientists from physical (climate, hydrology, meteorology) to ecological (forests, fire, ecosystems) sciences, and hailing from universities and public research and land-managing agencies. Together we share a common interest in climate – both directly and for its role as an ecosystem driver.

In the last two years, we have come together at the grass-roots level to launch an initiative whose goal, parallel to MRI's, is to improve integration among climate- and climate-related disciplines and across mountain regions of western North America, and also to improve application of this knowledge in natural-resource management and policy. As of yet, we have no institutional umbrella, nor dedicated funding. We do, however, have both conceptual and fiscal support for specific activities from our individual universities and agencies.

WHY ARE WE COMING TOGETHER?

CIRMOUNT responds to four situations in western North American mountain regions:

- A significant amount of research information on climate- and climate-related sciences has accumulated, but it is poorly integrated.
- Although lowland sites are well represented by weather monitoring stations, mountain areas are vastly under-instrumented.
- Escalating demands on western North American mountain ecosystems increasingly stress both natural resources and rural community capacities.
- Scientific knowledge about climate change as well as the need to monitor changes in climate have been virtually ignored in mountain land-use planning and natural resource policy.

We are proposing a consortium that focuses on a scale that is greater than individual sites or single mountain ranges as is typical for an individual MBR, but less than the global network engaged by MRI. Rather, we aim at an intermediate scale for integration, that is, a regional network of geographically and politically coherent mountain ranges, as is the case for western North America.

Note that in western North America, unlike most situations discussed elsewhere in the world, our mountain lands, above a certain elevation, are mostly publicly owned and administered. We have systems of National Parks and other state, provincial and federal reserves as well as lands administered by federal agencies such as the US Forest Service and the Bureau of Land Management, which manage lands for multi-use as well as preservation.

WHAT HAVE WE DONE?

So far we have taken steps to rally ourselves among a small set of colleagues, to better understand the interdisciplinary state-of-research at present, and to prepare an agenda for the future. Activities we have achieved or have in-progress include:

- Consortium for Integrated Climate Research in Mountain Regions (White Paper, February. 2003). This unpublished document is a preliminary effort to outline the scope and rationale for CIRMOUNT, and has been used mostly as an internal organizing framework.
- ‘Sierra Nevada Climate Change and Implications for Resource Management’ (special session of the Sierra Nevada Science Symposium, October 2002, Lake Tahoe, California). This session communicated current climate-related research information to an interdisciplinary science and resource-management audience at the scale of a single mountain range. Proceedings in press: http://danr.ucop.edu/wrc/snssweb/snss.html
- ‘Integrated Climate Research in Western North American Mountains’ (two-day special session at the 20th Annual PACLIM [Pacific Climate] Workshop, April 2003, Asilomar, Pacific Grove,

California). Topical presentations on current research, multi-mountain-range scale. Proceedings in press: http://meteora.ucsd.edu/paclim/agenda03.pdf (PACLIM homepage: http://meteora.ucsd.edu/paclim/).

- Installation of a remote-accessed high-elevation meteorological station at White Mountain/Barcroft Summit, California, October 2003. http://www.wrcc.dri.edu/weather/wmtn.html
- 'Mountain Climate Science Symposium' (MCSS). 25–27 May 2004, Lake Tahoe, California. CIRMOUNT's 'coming out' event, this three-day symposium is devoted to developing a framework and agenda that will guide the CIRMOUNT initiative in coming years. Not a traditional conference with research presentations, MCSS will feature a small number of plenary talks on state-of-science in priority topics, but will be, as at the MRI/UNESCO Entlebuch event, primarily a working meeting. The symposium is limited to 100 invited participants, who will contribute ideas during facilitated discussion groups. http://www.fs.fed.us/psw/mcss/

Goals of the MCSS are:

- Summarize states-of-knowledge in four priority topics of climate and climate-response research for mountain regions of western North America.
- Develop support for long-term, interdisciplinary, and integrated climate and climate-related research and monitoring in western mountains.
- Facilitate communication and understanding of climate sciences and their implications to local and regional resource managers and decision-makers.
- Promote data integration, quality assurance, management, and archival capacities for climate-related databases.
- Establish a roadmap for long-term regional integration of climate sciences, assessment, natural resource policy and management.

The set of plenary speakers and discussion leaders from MCSS will join CIRMOUNT's coordinating group following the symposium to produce a framework publication that describes priority topics, questions, and problems, and outlines opportunities for improving coordination, collaboration, and communication among western North American climate- and climate-related scientists, resource managers, and policy specialists. With this written framework, we will then seek funding and further endorsements within appropriate institutional contexts. As well we hope the framework will encourage voluntary buy-in from individual researchers who would see benefit both to their own work and to the regional science community by aligning their research with the CIRMOUNT programme.

WHAT ACTIONS DO WE FORESEE FOR THE NEAR FUTURE?

Specific target activities that we propose could develop from the MCSS include:

- Institute 'MACLIM (Mountain Climate) Biennial Workshops'. Research meetings based on the PACLIM (Pacific Climate) Workshop model would alternate every other year with PACLIM to focus specifically on current research findings relevant to CIRMOUNT topics and goals. These would follow the PACLIM approach, although unlike PACLIM, which are regularly held at Asilomar, California, they would preferably rotate around mountain-region host sites.

- Add GLORIA Multi-Summit and Master Station Sites. One site exists now at Glacier National Park, MT. Opportunities/priorities for additional sites include:
  - Sierra Nevada (Multi-summit)
  - White Mtns (Multi-Summit and Master Station: Univ. Calif. White Mountain Research Station)
  - Cascades/Olympic Mtns (Multi-Summit)
  - Central Rocky Mtns (Multi-Site and Master Station: Niwot LTER – Long-Term Ecological Reserve)
- Add High-Elevation Meteorological Stations. Ray Bradley (Univ. MA, Amherst) has made (at Entlebuch) a formal proposal that MRI/UNESCO sponsor and administer an extended GCOS (Global Climate Observation System) network of monitoring stations globally at high elevations in MBRs. He described the recently installed station on White Mtn/Barcroft Summit, CA (Dan Cayan, SCRIPPS, WMRS) as a defining model. Priorities for additional stations in our region include: Sierra Nevada, Cascades/Olympic Mtns, Central Rocky Mtns, Colorado Plateau.
- Initiate and expand projects that effectively communicate climate-change science into conservation and resource management contexts. Specifically:
  - expand the 'Climate-Friendly Parks Initiative' to additional National Parks. Priorities: Olympic-N Cascades National Parks (NP), Yosemite NP, Sequoia/Kings NP, Rocky Mtn NP
  - collaborate and promote the 'Sierra Nevada Climate Change Assessment Project' (SNCCAP), a USFS-collaborative proposal to assess regional climates and effects on natural resources and local communities, and to develop scenarios and tools for managers.
- Seek allocated funds for CIRMOUNT, for example, direct Congressional solicitation, NCEAS (National Centers for Ecological Analysis and Synthesis), other grant opportunities.

These are examples of immediate priorities for CIRMOUNT. We eagerly anticipate working within the MRI/UNESCO-MAB network as an example of regional mountain-climate science integration.

CIRMOUNT COORDINATING GROUP

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21 *Comparing Himalayan – Andean Watersheds: A Framework for Building a Global Network of Mountain Biosphere Reserves*

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ABSTRACT

Conservation of mountain watersheds is key to supplying water resources and energy to the lowland inhabitants and many projects around the world have focused on this topic. Unfortunately there is little collaboration between watershed groups working in different mountain regions, but information technology tools can effectively improve this situation. The Himalayan–Andean watershed project was initiated to facilitate collaboration between the eight different teams working in two mountain regions with the objective of sharing common interests, comparing approaches and highlighting successes that can be examined, tested and adapted to other watersheds around the world. The eight teams agreed to use a common framework, select comparative indicators and produce a multimedia CD-ROM for each watershed. The watersheds are located in Bolivia, Peru, Ecuador, China, Bhutan and Nepal, and are representative of typical mountain watersheds where poverty is widespread, subsistence farming is the main activity, pressure on the natural resources is high, and hazard risks are widespread. Each of the participating teams was taught how to produce a multimedia CD-ROM of their watershed that contained basic resource information, rates of resource degradation, successes in improving the resources and resource conservation efforts. The knowledge gained and the conditions in each watershed were then compared between the watersheds and between the two regions.

The approach and framework used in the Himalayan–Andean watershed project could be expanded and applied to mountain biosphere reserves around the world, and this would foster better collaboration and sharing of innovative ideas on how to conserve resources, rehabilitate degraded areas and promote economic activities that follow sustainable resource use concepts. The paper illustrates the approach used for comparing projects, and highlights the advantages and obstacles that were faced in building this collaborative network and in using multimedia information technology tools.

HIMALAYAN – ANDEAN WATERSHEDS: A COMPARATIVE PROJECT USING INFORMATION TECHNOLOGIES

Mountain watersheds are rapidly emerging as a barometer for how well we manage our water resources in the world (Messerli and Ives, 1997). Mountains are the key freshwater resources for the lowland population; they provide a large portion of the energy we use, and they are a highly sensitive system, responding rapidly to climate and land use changes (Liniger et al., 1998). Our knowledge base on mountain watersheds is poor and there are large data gaps. Most of the global climate models do not apply to mountains because of their great spatial and temporal variability, in addition to the complexity associated with elevation, aspect, geology and land use.

The Himalayan–Andean Watershed Project was initiated to improve our knowledge base on water and natural resources management in mountains, and to bridge the communication gap between researchers in different mountain regions. The main idea was to experiment with information technology tools to determine if we could collaborate over the Internet, to teach each participating team how to integrate information, produce a multimedia CD-ROM, share information and learn from each other in a global context.

The aims of the project were to examine the biophysical and human resources in eight mountain watersheds with a focus on land use, land-water interactions, rate of resource degradation, options for rehabilitation, and the conservation measures to prevent degradation of land and water resources. The specific aims were to:

- identify and compare key issues, problems, and priorities within and between watersheds
- highlight successful techniques that focus on the linkages between water, people, land use, and resources
- identify common and unique indicators to be used to characterize and compare watersheds
- document what approaches were successful in improving the livelihood of the people in each watershed
- create a multimedia CD-ROM for each watershed that uses an integrative framework and facilitates information access and distribution
- share successes in resource management that can be tested and applied to other watersheds.
- produce a comparative CD-ROM that highlights the similarities and differences between the watersheds and regions, and that features the most successful lessons learned from the comparison.

Scaling out from a watershed to the region and comparing watersheds between regions can be greatly facilitated due to the advances in information technology. Techniques and tools such as geographic information systems (GIS), remote sensing, remote data logging, Internet and multimedia tools can be used to quantify and visualize information in a much more interesting and efficient manner than has been done using conventional communication tools (Schreier et al., 2002; Schreier and Brown, 2002). The content can be organized in a hypermedia manner so as to be of interest to multiple audiences.

WHY THE HIMALAYAS AND THE ANDES?

The two mountain regions are home to more than 100 million people, most of whom rely on subsistence agriculture; they are the headwaters of major streams that impact more than 50 per cent of humanity. The indigenous people in these watersheds are among the poorest in the world and have some of the highest workloads, striving to earn a living under some of the harshest conditions on earth. Although the mountain regions extend in different directions (east–west vs. north–south), the environmental conditions and resource constraints are similar. In contrast the cultural, historic and political systems are quite different. It is postulated that by learning what is common and unique in each watershed and by exploring experiences that are transferable from watershed to watershed and between the regions, we can not only increase our understanding of the problems but we can contribute to more effective development and management of the resources.

METHODS AND APPROACHES

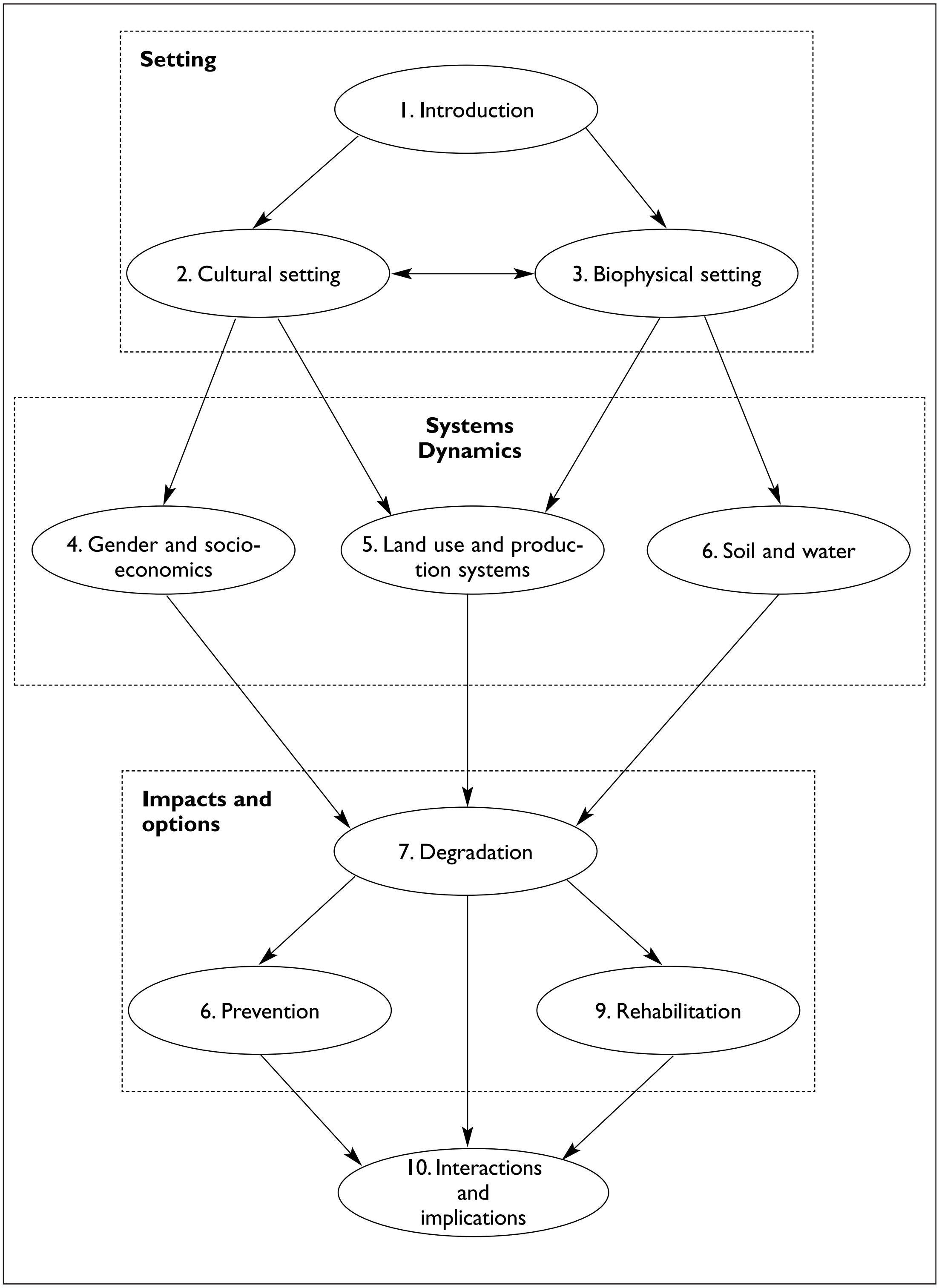
The project relied heavily on the Internet and multimedia techniques as tools to organize, evaluate and integrate the resource information. Eight research teams from six different countries participated in this project (Table 21.1). In each watershed the natural resources, the socio-economic conditions, and the forestry and agricultural land uses were evaluated, and resource degradation rates were quantified. At the same time methods to prevent degradation were highlighted and successful rehabilitation projects were identified. Each watershed had a rich database available for the evaluation. The key natural resource management issues were identified, and training was provided to each research team on how to produce a website, and how to incorporate the data into a multimedia CD-ROM format. An Internet bulletin board was used to assist each team in the development of the multimedia material and in sharing information. Two workshops were held, one in each region, to develop the framework and to identify quantitative watershed indicators that were then used for the comparison. The integrative framework is provided in Figure 21.1, and details of the approach used can be found at website www.ires.ubc.ca/projects/himal/index.htm

The CD-ROMs contain all resource information for each watershed and can be used as wide-ranging information systems in an easily accessible digital format. The value of the CD-ROMs is

Country	Watershed	Key Collaborators	Collaborating Institution
Nepal 1	Jhikhu Khola	P.B. Shah, J. Merz, H. Schreier	ICIMOD, Kathmandu
Nepal 2	Yarsha Khola	P.B. Shah, J. Merz, S. Brown	ICIMOD, Kathmandu
Bhutan	Lingmutey Chhu	S. Duba, G. Chettry, Y. Yeshey	RNRRC, Min. Agric. Bajo
China	Xizhuang	Xu Jianchu, J. Wang	Kunming Inst. Botany, CAS
Ecuador	El Angel	S. Poats, W. Bowen, C. Chrissman	Manrecur II, CIP. Group Paramo.
Peru 1	La Encanada	R. Quiroz	CIP, Lima
Peru 2	Ilave-Huenque	R. Quiroz, R. Valdivia	CIP, Lima, CIRNMA, Puno
Bolivia	Desaguadero	R. Quiroz	CIP and IGM, La Paz
Canada	Coordination	H. Schreier, S. Brown, R. Bestbier	IRE, UBC, Vancouver

Table 21.1
General information on the eight watersheds used in the comparative study

Figure 21.1
Integrative framework used by each team to organize each CD-ROM



threefold. First, they provide comprehensive information on the status of the watersheds and ways to improve the livelihood of the people. Second, they provide educational material to create awareness of water issues and factors that affect water resources. Third, they promote comparative learning and global information sharing.

The comparison of the watersheds is likely to be the most important part of the research because common priorities were identified, successful techniques or actions were highlighted, and unique techniques were identified that serve as examples to be applied to other watersheds not included in this study. Comparing watersheds is a scaling out effort and avoids the complication of scaling up from a watershed to the region (Swallow et al., 2002; Schreier and Brown, 2002).

Identifying Common Priorities that Apply to All Watersheds

All teams were asked to rank resource management issues according to priorities in their watershed. As shown in Table 21.2, irrigation and drinking water issues were dominant in most watersheds, followed by concerns over food security, maintaining soil fertility, market problems, health concerns and the workload of women.

Poverty is widespread, food shortages are present in most areas, and high population growth and mobility were common problems to all. The water problems are of obvious concern because they largely determine the food production potential and the health of the people. The extent of the problems and the rate of resource degradation varied significantly between the watersheds, as did the techniques used to assess the problem and the action taken to improve the livelihood of the residents. This proved to be the most valuable component of the study because it allowed us to determine how these problems were identified and quantified, and what actions were taken to overcome the problems in each watershed.

Table 21.2
Ranking of priority issues in the eight mountain watersheds (1 = most important 10 = least important)

Priority issues	Jhikhu Nepal	Yarsha Nepal	Bhutan	China	Bolivia	Ilave Peru	Enca. Peru	Carchi Ecuador
Irrigation water	1	3	1	1	3	5	1	1
Drinking water	2	4	8	2	3	4	8	2
Adverse climate					2	1	3	
Food production	4	2	2	5	4	8	9	9
Animal fodder	3	6	7	10	1	3		
Health/pesticides	5			3	6		6	3
Land tenure/access		9	10			6		4
Market access	8	1	4	6	7	7	4	7
Education/extension	10	5	9	7	10		5	6
Soil fertility/erosion	7	8	3	8	5	2	2	5
Workload for women	6	7	6		8	10		
Forest degradation (fuel)	9	10				10	7	10
Rehabitating degraded land			5					
Migration	10			9	9	9	10	8
Community involvment				4				

Determining which Successful Technique or Action in One Watershed Provides the Greatest Potential to be Tested and Used in Other Watersheds

While many of the resource conditions were similar, there were also some major biophysical and socio-economic differences between the two mountain regions. As shown in Table 21.3, volcanic rocks dominate the Andean watersheds while sedimentary and metamorphic rocks form the dominant geology in the Himalayas. Climatically there are also some significant differences, in that the chosen Andean watersheds are somewhat drier and have more adverse climatic conditions, mainly because the watersheds were located at a slightly higher elevation zone than the Himalayan ones.

In the Himalayan watersheds the population pressure is much higher, resulting in much more intensive land use activities (more annual crop rotations, more irrigation). Differences in grazing land, milk production and forest cover are more a reflection of the elevation differences of the watersheds in the two regions. Himalayan forest cover is significantly greater and the use of forests for a variety of purposes (fuelwood, fodder, litter collection, timber) is also much higher.

These differences can be used to great advantage by other watershed researchers; those watersheds with the greatest population pressure and land use intensity can be used as an example of what can happen in other cases if similar population expansions and land use intensification occur. The

Table 21.3
Differences between the Andean and the Himalayan watersheds

Indicators	Himalayan Watersheds	Andean Watersheds
Population Indicators		
Population density	1.2–4.4 people/ha	0.1–0.7 people/ha
Infant mortality	10–20 per 1 000	60–70 per 1 000
Land Use Indicators		
Land owned	<1 ha	1–26 ha
Amount of irrigated land in watershed	3–9 %	0–3 %
Amount of forest land in watershed	32–89 %	28–55 %
Amount of grazing land in watershed	1–30 %	28–55 %
Average number of crop rotations	1.5–2.7 per year	1–1.7 per year
Average manure input in agriculture	2–12 t /ha	1–5 t/ha
Average fertilizer input in agriculture	20–200 kg N/ha	4–10 kg N/ha
Income from milk production	$0–70/year	$55–720/year
Agrobiodiversity: Potato varieties used	3	13–40
Climate, Water and Geological Indicators		
Average annual precipitation	713–1700 mm	400–807 mm
Frost-free days	270–365 days	105–350 days
Max. no. of days without rain	40–150 days	45–120 days
Drinking water shortages	3–4 months/year	0.3–1 month/year
Irrigation water shortages	1–4 months/year	0–3 months/year
Farmers owning irrigated land	30–85 %	0–57 %
Geology and rock formation	Dominantly sedimentary	Dominantly volcanic

Jhikhu Khola watershed in Nepal is the most densely populated and intensively used of the cases in the comparative study. The environmental stress and degradation processes experienced there can be used as examples of what to anticipate if, for instance, similar pressures occur in the Bhutanese, Chinese or Ecuadorian watersheds. At the same time innovative techniques used to improve food production or rehabilitate forests in one watershed can be used to advantage in others that are not yet facing the same stresses. Anticipating problems and addressing the issues in a proactive preventative manner is the main advantage of comparing watersheds.

The most effective way to transfer information is by using those cases where the same problems were identified in most watersheds and where one or two watershed teams were able to highlight the successful application of an innovative technique or successful action to mitigate the problem. Table 21.4 summarizes the approaches that were identified as the most promising to be tested and applied in other watersheds. These include assessment methods to quantify the resource problems, action research to improve the resource, conservation approaches to minimize future problems, and rehabilitation efforts to reduce impacts.

Five examples are provided below to highlight specific accomplishments. They include: a) agrobiodiversity and pesticide use; b) soil nutrient dynamics and sustainability: c) water scarcity and quality problems; d) gender and workload problems; and e) forest rehabilitation in community forests.

AGROBIODIVERSTIY AND PESTICIDE USE

The knowledge of agrobiodiversity is better developed in the Andes, mainly due to the fact that many crops have their origin in the region; also, the green revolution has not spread as widely and rapidly in the Andean mountains as in Asia. Potatoes are grown in all watersheds (except China) although the cultivation of this crop has only become popular in the Himalayas over the past fifteen years. Typical farmers in the Peruvian watersheds have access to more than forty different potato varieties (Tapia, 2000) and they plant up to twenty different varieties in a single field for food security. In contrast only three varieties are planted in Himalayan watersheds, and although their production is slightly higher than in the Andes due to higher inputs and more favourable climatic conditions, the farmers are at a much higher annual risk of crop failure due to climatic variability and disease problems. Late blight is one of the greatest problems facing potato growers, and as a result pesticide use has increased rapidly in all watersheds. Excessive application of pesticides is a common problem in most of the watersheds. This not only affects water quality but poses a significant long-term health hazard, because of both the high rate of application and the fact that few preventative measures are taken when applying the products. Many of the pesticides available in the watersheds have long been banned or restricted in North America. Biodiversity and integrated pest management have the potential to reduce the use of these chemicals and thus can reduce the health risk.

The use of agrobiodiversity in potato production was best documented in the Peruvian watershed. The problem of excess pesticide use was identified and quantified in the Nepalese watershed, and the testing of the health effects was best illustrated in the Ecuadorian watershed. In each case innovative methods were developed to quantify some aspects of the problem. The most comprehensive evaluation of the pesticide problem was conducted in the Ecuadorian case, where medical tests were developed to diagnose the short and long-term health impacts. The

Table 21.4
Successful approaches and actions highlighted in the comparison

Source of successful examples	Key topic addressed
Ecuadorian watershed	Health evaluation of pesticide use impacts on potato production
Nepalese watersheds	Developing water budgets and balances for the watershed
Nepalese watersheds	Determining nutrient budgets at the farm and watershed scale and address nutrient sustainability issues in agriculture and forestry
Nepalese watersheds	How to determine gender workload and how to reduce it
Peruvian and Bhutanese watersheds	Improving pasture and forest by the introduction of nitrogen fixing fodder trees and grasses
Ecuadorian watersheds	Addressing water equity issues/multi-stakeholder processes
Bolivian and Peruvian watersheds	Crop production in rustic greenhouses
Nepalese and Bhutanese watersheds	Community based forest resources management
Nepalese watersheds	Constraints and opportunities in milk production
Nepalese watersheds	Water harvesting and drinking water protection
Nepalese Watershed	Low-cost drip irrigation for off-season cash-crop production
Bhutanese and Nepalese watersheds	Rehabilitation of degraded land to improve biomass production and minimize soil erosion and sedimentation
Bhutanese and Peruvian watersheds	Different approaches to soil conservation and erosion control

entire diagnostic process and the safety precautions to be followed were illustrated in this interesting case study, recorded on the CD-ROM. The techniques used and the lessons learned can now be readily applied to other watersheds to document the extent of the problem, to improve safety measures, and to use improved management options to reduce pesticide use.

SOIL FERTILITY DYNAMICS AND NUTRIENT SUSTAINABILITY

Maintaining a balanced nutrient pool is a problem identified in all watersheds, and is particularly critical because productivity is generally lower in mountains due to adverse climatic conditions. A lack of sufficient nutrients has serious long-term consequences for crop yields, affects nutrient content in food, and can lead to serious soil degradation. Soil acidification, organic matter losses and phosphorus deficiencies are problems in all watersheds (except Ecuador and Bolivia). Simple soil testing is proving insufficient to diagnose the problem and nutrient budget calculations are essential to determine long-term deficiencies in nutrient inputs in agriculture and forestry. This becomes particularly important when trying to improve food production through increasing the annual number of crop rotations.

In the Jhikhu Khola watershed in Nepal it was found (Brown et al., 1999, 2000) that, in order to meet the growing food demands, average annual crop rotations increased from 1.8 to 2.6 crops per year between 1985 and 2000. High nutrient demanding crops such as potatoes and tomatoes were introduced because of their potential to create cash income. Nutrient budgets determined for individual farms have shown that in 1995 phosphorus and nitrogen inputs were too small to meet the crop demand, leading to large P and N deficits. Concerns were expressed regarding long-term production declines and increased erosion rates. In the late 1990s more concentrated fertilizers became available and the inputs of phosphorus and nitrogen for potato and tomato production increased significantly. By 2000, the phosphorus budget calculation showed that P inputs were well in excess of the crop needs, resulting in widespread eutrophication and contamination of stream and drinking water. Over the same time period, potassium budgets have gone from a surplus to a significant deficit raising renewed concern about nutrient imbalances (von Westarp, 2002).

The technique of conducting a soil and socio-economic survey, calculating nutrient budgets for farms and then scaling them up to the watershed level was well illustrated in the Jhikhu Khola watershed study. Many of the other watersheds are facing similar problems of increasing production through multiple cropping. The lessons learned and the analytical techniques used from the Nepalese study can now be shared and tested so as to improve the soil nutrient pool management, to sustain long-term productivity and minimize impacts on freshwater resources. This is not only critical to food security but excess nutrients cause water pollution problems, and insufficient nutrient inputs will lead to yield declines, soil erosion problems, and increased sedimentation.

WATER SCARCITY AND WATER QUALITY

Irrigation and drinking water shortages and water pollution were identified as key issues in almost all watersheds. The problem appears to be most acute in the Nepalese and Ecuadorian watersheds. In the Jhikhu Khola watershed, innovative techniques were developed to quantify all water sources, to determine an overall water balance, to conduct a user survey, and to determine what issues are of greatest concern to the inhabitants. Table 21.5 shows the important water resource issues. The techniques used in this study can readily be tested and applied in other watersheds to determine the extent of water problems and to determine priority actions.

Water conflict between upland and lowland users is a common problem in most watersheds and resolving this issue is one of the most challenging problems facing watershed managers. The Ecuadorian team has addressed this by presenting a case study of a multi-stakeholder process that has the potential to resolve the key issue through negotiation. They showed that good scientific data is needed, the stakeholders need to be educated and exposed to other people's concerns, and negotiations have to be conducted in a patient and skilful manner.

Identifying the issues, documenting the extent of the water problem, and negotiating solutions to the conflicts are only the first steps. Other equally challenging issues are: how to reallocate water uses, how to mitigate and prevent deterioration, and how to conserve the resource. Studies in the Jhikhu Khola watershed have shown that action research focusing on water harvesting (Nakarmi and Neupane, 2002), source protection, and efficiency in use are equally challenging (Merz, 2003). In these case studies it was shown how run-off water during the rainy season could be collected and stored for use during the dry season. In addition, experiments were carried out to test the technical and economic viability of using low-cost drip irrigation to produce a cash crop and at the same time conserve water during the critical season. The results showed that under conditions of water stress a low-cost drip system produced higher cauliflower yields than hand watering (von Westarp et al.,

Table 21.5 *Dominant water resource issues and drinking water concerns*

Overall water concerns	% of respondents	Water quality concerns	% of respondents
Irrigation water quantity	33	Sediments	61
Drinking water quantity	29	Bad taste	12
Drinking water quality	27	Unhealthy/bad quality	10
Erosion and instability	12	Bad quality	9
Irrigation quality	7	Animal waste	9
Others	3	Others	1

2003). The system, designed for use by poor farmers, could be paid off over a one-year period through the added cash income from producing off-season crops. The results from these three case studies can now be replicated in other watersheds in order to determine their applicability to improve the livelihood and reduce the workload of the people.

GENDER AND WORKLOAD PROBLEMS

There are many reasons why the workload of women in mountain watersheds is increasing (Gurung, 1999; Brown, 2003). The different watersheds vary greatly in patterns of work allocation and decision making, but agricultural intensification, milk production and temporary and permanent migration for off-farm work (mostly by men) have contributed to the increase in the workload of women in the Nepalese watersheds.

The case study in the Yarsha Khola watershed in Nepal provides an excellent example of how to document workloads, how to determine time allocations for different tasks and how to quantify and display the results in a GIS format. Eighty households were interviewed using a participatory survey and the results provided in Figure 21.2 show that on average women in this watershed work 3.8 hours longer per day than their male counterparts. This is largely because women are mainly responsible for household care, water collection, animal care and compost management. Due to the increase in agricultural intensification, water scarcity is increasing and women therefore spend more time collecting safe drinking water and watering animals. This problem is further aggravated because milk production is seen as a new way of entering the market economy, and having more animals means more demand for water and fodder. It is traditionally the responsibility of the women to look after both of these resources, and as the resources degrade, the distance to alternative sources – and hence the workload – increases.

Documenting how and where the workload has increased in the watershed was a first step in this study. It was followed by a second research initiative on how to improve water supplies and local fodder production so that the daily walking distances to collect water and fodder could be reduced. This action research focused on the use of grasses and fodder trees to improve feed sources, the introduction of water-harvesting techniques, and the protection of local water supplies. Successful examples of how to improve fodder production were also documented in the Ilave-Huenque watershed in Peru, through the introduction of alfalfa and the enhancement of 'bofedales'. Again these techniques and approaches can readily be tested and applied to other watersheds.

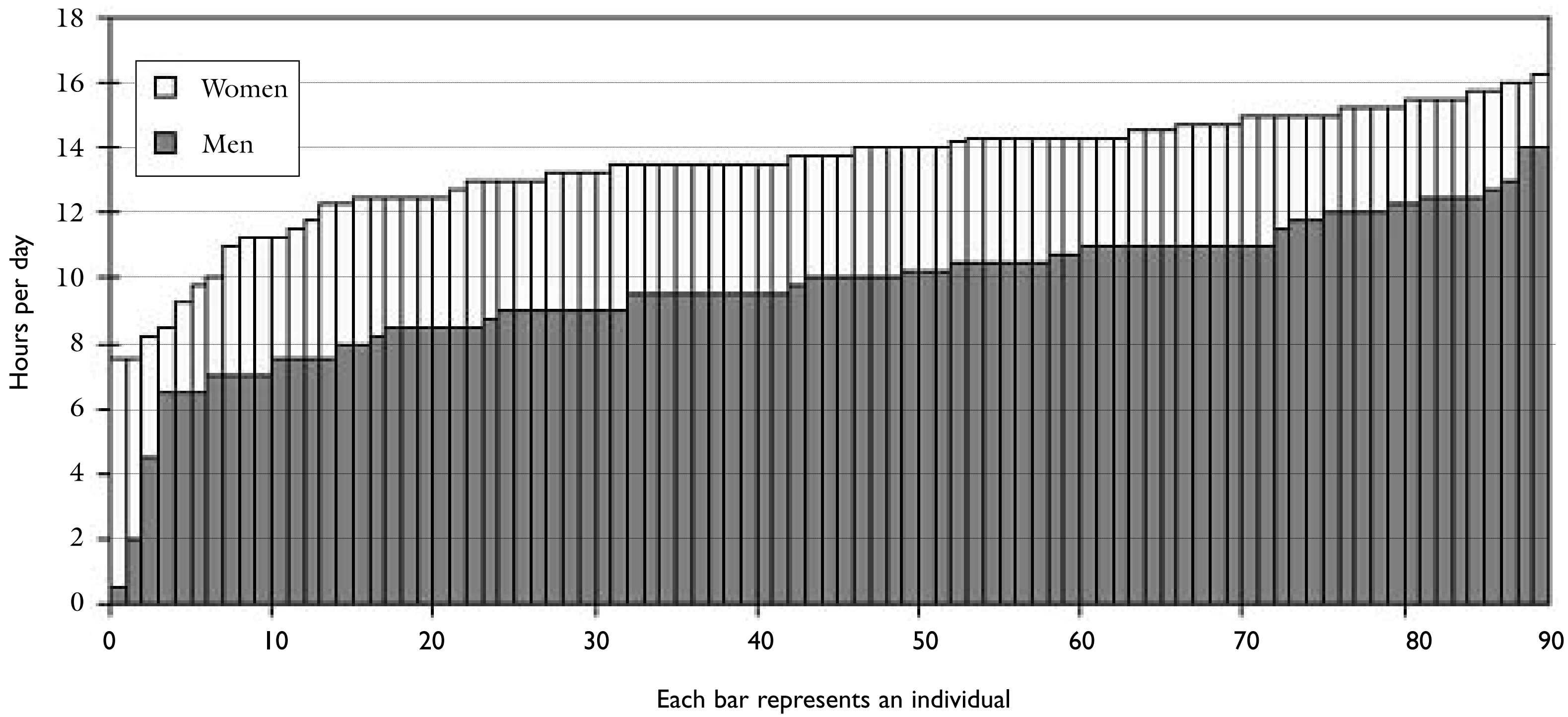


Figure 21.2
Difference in workload between males and females in the Nepalese watersheds

FOREST REHABILITATION IN COMMUNITY FORESTS

Forests play a key role in watershed management and the use of forests for timber, fuelwood, animal bedding and fodder have been well documented in mountain watersheds. The forest resources in all eight watersheds are under great pressure, and since many forests are common resource properties their management has always been controversial. The establishment of community forests has been pioneered in India and Nepal in an effort to give more local control to the resource. It is hoped that these initiatives will lead to a more sustainable way of managing forests. Examples were provided in the two Nepalese watersheds to show the variety of management practices that are being initiated by the different community user groups. This was done using a GIS database so that the practices and the forest conditions could be displayed spatially.

In many cases soil erosion due to over-use of forest resources has resulted in higher erosion rates and degradation of forested land. These areas produce little biomass and make a very large contribution to the annual sediment load, which in turn affects irrigation. To reduce sedimentation and increase fodder production, rehabilitation experiments were carried out in several degraded sites with a focus on planting nitrogen fixing fodder trees and grasses (Shah et al., 2000). These efforts have been very successful in both the Nepalese and the Bhutanese watersheds, particularly as they involved community groups. Not only was it possible to stabilize the soils over a three to five year period, but also the biomass produced is proving to be a highly valuable source of animal feed. At the same time the workload of women is being reduced, the biodiversity in the rehabilitated forest has increased, and the community has been given the legal rights to manage these new forests in a shared community manner. Successful efforts in the Bhutanese watershed have resulted in the establishment of the first community-managed forest in the country to be endorsed by the national government. Again these efforts are well documented in the CD-ROMs and can serve as good training sets to be applied in other watersheds.

Identifying Unique Problems and Techniques that Serve as Examples to be Applied to Other Watersheds Not Included in this Study

The watershed comparison identified how communities in the different watersheds address specific issues, how widespread each problem is, and what successful techniques and approaches have been used to address them. There are of course some unique issues that occur in individual watersheds and are not applicable to others (e.g. salinity problems in Bolivia, high-elevation wetland protection in Ecuador, tea production in China). However, with the development of a global watershed network even these unique issues can become useful for comparative purposes in other watersheds that experience similar problems.

HOW CAN THIS CONCEPT AND APPROACH BE USED FOR UNESCO'S BIOSPHERE RESERVES?

The chief purpose of many biosphere reserves is to protect unique resources, and to develop buffer zones between the protected conservation areas and the more intensely used surrounding lands. Land use activities take place in these buffer zones, but attempts are made to reduce the associated environmental impacts and to develop activities that emphasize good stewardship and sustainability while enabling residents to improve their living conditions. A range of innovative land management ideas have come out of those biosphere reserves that were established some time ago. Many of the newer reserves could benefit significantly for the knowledge and experiences of these more established reserves.

Information technology tools are clearly useful and very cost effective in facilitating communication and knowledge sharing, since most of the activities and comparisons can be made by remote means. At the same time, the material to be shared can be presented in a much more integrated, understandable, and better-illustrated manner than is possible using conventional approaches. In addition, globally accessible web-based courses have been developed that allow researchers to learn how to deal with most aspects of integrated watershed management by remote means (Schreier et al., 2002).

CONCLUSIONS AND LESSONS LEARNED

The participating watershed teams learned how to integrate resource information from their watersheds and convert it into a comprehensive information system that is readily available to a wide audience. The multimedia CD-ROMs not only contain all the background information on the biophysical and socio-economic conditions in each watershed but also include data about rates of changes in resources, and innovations in management and rehabilitation of these resources. The focus was placed on:

- the use of techniques or evaluation methodologies that proved successful
- action research that improved the livelihood of the people
- approaches that improved resource conservation or rehabilitated degraded sites.

These successes form the basis for learning together and sharing experiences. There were gaps in the data and knowledge base in each watershed, and by conducting this collaborative project it was possible to show what essential watershed resource information is needed to arrive at an integrated assessment. The results show that the social and biophysical components need to be well balanced and integrated if we hope to improve watershed management and the livelihood of the people on which it depends. Another important finding was that in none of the watershed studies were all aspects of resource management assessed in a balanced manner. The majority of the efforts focused on documenting and quantifying the extent of the resource problems. Less effort was devoted to action research for improving the resources, and even less emphasis was placed on preventing resource degradation and rehabilitation. All watershed projects should strive towards an equal effort in all three areas.

The Himalayan–Andean watershed project explored how information technology tools could be used more effectively to improve communication among watershed researchers. The production of the CD-ROMs and the use of the Internet for comparing and sharing information were relatively easy. Each team mastered the technology in a relatively efficient manner, considering that the CDs were developed by local researchers in their respective countries. The main advantages of using a multimedia approach are:

- The material is presented in an interesting manner because it combines text, images, GIS maps, graphics and animations in an interactive manner.
- The CD-ROM-based framework and hypermedia format serve as an excellent platform to integrate all resource information.
- The cost of producing and distributing the CD-ROMs is modest and thus allows for a much wider distribution of the information.
- The CD-ROM can be updated relatively easily and thus becomes a permanent and dynamic record of the watershed and its resources.
- The CD-ROM and the Internet are ideal platforms for sharing information and learning from each other.
- Using common indicators for comparison and sharing success stories facilitates extrapolation globally.

It is suggested that a similar approach could be used in building a global network that links biosphere reserves managers and allows them to foster positive interactions of mutual benefit to all.

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22. *Ecosystems and Glaciological Studies in the Aktru Glacier Basin (Associated Aktru Cluster)*

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INTRODUCTION

The long-term glaciological studies in the Altai generalized by Professor M. Tronov (Tronov, 1949; Tronov et al., 1965), a classic of Russian glaciology, demonstrate that the Severo-Chuisky Range, including the Aktru glacier basin, is comparable with other Altai glacier centres in the total volume of glaciation and is first in terms of the diversity of glaciation forms. Tronov suggested that the basin is glaciologically and climatologically representative of high altitudinal Altai ice areas. This basin was selected by UNESCO as a representative area for the study of glaciological and hydrometeorological processes during the International Geophysical Year and the International Hydrological Decade.

The associated Aktru cluster is located in the glacier basin of the Aktru river on the northern slope of the Severo-Chuisky Range in Central Altai. Its elevation ranges from 1,800 m to 4,073 m above sea level.

Long-term glaciological and climatic observations (since 1911 and 1957 respectively) and the high species and ecosystem diversity in the 40 km² basin make it a natural testing area.

The flora situated in the basin are rich and unique, with 380 species of vascular plants including fifty-six rare and endangered, endemic and relic species. The rate of endemism in the area is equal to 15 per cent. Six plant species are included in the *Red Book of Russia* (*Mesostemma martjanovii, Cypripedium macranthon, Dendranthema sinuatum, Aconitum decipiens, Rheum altaicum, Allium altaicum*), fourteen in the *Red Book of the Altai Republic* (*Allium altaicum, Asplenium altajense, Rosa oxyocantha, Rhodiola algida, Rhodiola rosea, Rhaponticum carthamoides, Astragalus pseudoastralis, Saussurea glacialis* and so on) and twenty-five in the book *Rare and Endangered Plants in Siberia*.

A diversity of terrestrial ecosystems can be found in the mountain tundras of the Aktru glacier basin, forming plant communities on the moraine complexes of the Kupol and Vodopadny glaciers (3,000 to 3,100 m above sea level), the forest-tundra ecotones near the climatic and edaphic forest lines (2,300–2,500 m), the open Siberian stone pine forest on the moraine of the Bolshoy Aktru glacier (2,400 m) as well as two fragments of remaining Siberian stone pine forests

(2,200–2,350 m) near the moraine of the Maly Aktru glacier, forming plant communities on the moraine complexes of the Maly Aktru, Levy Aktru, Pravy Aktru, Bolshoy Aktru (2,200–2,800 m above sea level) glaciers (Timoshok, 2000; Vorobjev et al., 2001)

MATERIALS AND METHODS

Measurements of glaciation and climate dynamics were collected and phytosociological (geobotanical) descriptions of the terrestrial ecosystems (young moraine complexes, relic forests, etc.) were made employing classical methods used in glaciology, climatology, phytosociology (geobotany) and soil science studies as well as Russian population-ontogenetic methods. This enables us to assess the significance of the sustainability and self-maintenance of populations over a long period of time by analysis of the physiological age of plants among different biomorphs.

The Maly Aktru glacier has provided the most detailed glaciological data. Its boundaries were demarcated by Professor V. Sapozhnikov (Tomsk University) in 1911 and Professor M. Tronov in 1936, and observations of glacier retreat have been noted over a ninety-year period. Since 1952 the distance of retreat has been determined annually by specialists at the Glacioclimatological Laboratory, Tomsk State University (Narozhniy and Yu, 1999; Revyakin and Mukhametov, 1981). In addition, data is available from the forty-year meteorological observations of the region (relatively rare for high altitudinal areas of the Altai).

Between 1999 and 2003, studies were made of the revegetation of the glacier moraine complexes in the Aktru glacier basin on the moraine complexes of the Maly Aktru, Levy Aktru, Pravy Aktru, Bolshoy Aktru and Vodopadny glaciers. Another example of a data-collection study is the moraine complex of the Little Ice Age – from the frontal moraine of the nineteenth century to the present day edge of the Maly Aktru glacier, which was divided into nineteen sections according to the instrumental glaciological data. These sections became free from ice at different times:

(1) 2000–1999	(2) 1998–1993	(3) 1993–1988
(4) 1988–1983	(5) 1983–1978	(6) 1978–1973
(7) 1973–1968	(8) 1968–1963	(9) 1963–1958
(10) 1958–1952	(11) 1952–1946	(12) 1946–1941
(13) 1941–1936	(14) 1936–1931	(15) 1931–1926
(16) 1926–1921	(17) 1921–1916	(18) 1916–1911
	(19) 1911–1850	

To clearly distinguish the first stages of plant recolonization of ice-free areas, the recent seven-year period (2000–1993) was studied on an annual basis. However, there are gaps in the overall record because of the lack of glaciological data during the period from 1911 to 1850.

Botanical studies were performed by conventional phytosociological (geobotanical) methods. We took into account the important methodological features for studying plant successions in general and primary successions in particular cited by V. Aleksandrova (1964). The species of flowering plants and trees at different stages of development (generative and pre-generative physiological age: juvenile, immature, and virginal (Revyakin and Mukhametov, 1981; Uranov, 1975; Plant Cenopopulations, 1988) and mosses were carefully revealed in transects that crossed every section of the moraine complex in different directions. On the whole, we made nineteen phytosociological (geobotanical) descriptions indicating the abundance of each species according to the Braun–Blanquet scale, and approximately fifty descriptions of different variants of primary plant microgroups at different succession stages.

THE DYNAMICS OF GLACIERS IN THE LITTLE ICE AGE

Three large trough glaciers descend to the Aktru river valley: Maly Aktru, Pravy Aktru and Levy Aktru. These glaciers repeatedly intruded into the forest belt during the Little Ice Age and disrupted the continuous Siberian stone pine (*Pinus sibirica*) forest area at the time of their maximal development (mid-nineteenth century). In this period (from the fourteenth century onward) three advances of approximately equal magnitude occurred during the lowest ambient temperatures: the first took place in the first half of the sixteenth century; the second from the second half of the seventeenth century up to the first two decades of the eighteenth century, and the third from the late 1780s until the mid-nineteenth century when the glaciers reached their maximum size during the last millennium (Adamenko, 1986; Okishev et al., 2000). The regression of the glaciers occurred during periods of the highest ambient temperatures (1740–1760, 1900–1950), and the retreat still continues today. The beginning of the regression phase of the Little Ice Age in the Altai dates from the mid-nineteenth century (Narozhniy and Yu, 1997, 2001; Narozhniy et al., 1999, 2003; Revyakin and Mukhametov, 1981).

In the mid-nineteenth century, the Maly Aktru glacier, situated in the trough valley and running in a NNW direction, reached an elevation of 2,190 m above sea level and was 4.8 km long. By 2000, it had retreated from its earlier position on the frontal moraine by 660 m and its elevation was 2,230 m. Its length has decreased to 4.1 km, and its recent size corresponds to that of the warmest period of the fourteenth century. Over the last 150 years, the size of the glacier has changed inconsistently; its regression occurred at different rates and even alternated with temporary advances. Four distinct stages of glacier activity over the period 1850–2000 can be distinguished: the period of ingression (1909–1914) and three stationary periods (1889–1893, 1927–1931 and 1992–1993) when small oscillation moraines, well defined in the relief of the moraine complex, were deposited.

Continental, sea and Mongolian steppe air masses affect the Altai and determine climatic features in the area. These masses are characterized by temperature and precipitation contrasts. In the Aktru basin the winter weather (from October to April) is determined by the large but stable Asian anti-cyclone. Spring brings about an active polar front chill. Cyclones move to the north. In summer, anti-cyclone weather with convective cloud cover is often repeated during daytime. South and southwesterly winds are prevalent in winter and west and northwesterly ones in summer. In the mountains there is local air circulation (for example, slope, valley and glacier winds).

Analysis of meteorological data from the Aktru weather station (2,150 m above sea level) over the past forty-five years demonstrates that the development of vegetation cover and revegetation on the moraine complexes of the Little Ice Age in the Maly Aktru and Bolshoy Aktru glaciers and on the slopes of the Aktru river valley are characterized by the following climatic parameters: high solar radiation (975 to 1,045 Wt/m^2), low temperature (annual average 5.2 °C), and high relative air humidity, which averaged 67 per cent and varied from 54 to 71 per cent in summer. Annual precipitation over the observation period varied widely: from 380 mm in 1974, the driest year, to 770 mm in 1958, with an average of 563 mm. Almost 75 per cent of this amount fell in summer: from 138 mm in dry years to 400 mm in wetter years, averaging approximately 240 mm. The average summer temperature differed in various years from 7.7 °C to 10.2 °C, with monthly average temperatures ranging from 5 °C to 10.2 °C in June, from 7.5 °C to 10.8 °C in July, and from 5.6 °C to 9.4 °C in August.

The development of vegetation communities, plant species and trees occurs during an extremely short growing period. The snow cover in the valley melts in the first ten days of June. The average daily temperature hovers around zero degrees in the middle of May and in early September. The numbers of days with average temperatures above 5 °C and 10 °C vary significantly from year to year, averaging between fifty-two and thirty-four days, respectively. In some years, the temperature never rises above 15 °C. The range of daily variations is significant. In the observation period, frosts occurred throughout summer and were most frequent in June and August. Winds blow constantly, including those from the glacier, which cool the adjacent areas of the moraine complex. For example, the Maly Aktru glacier contrasts sharply with the underlying valley and changes the temperature regime in its immediate vicinity; the temperature decreases by 3 °C at a distance of 100 m from the glacier (Podrezov, 1962). Hence, the establishment of plants at new ice-free sites; flowering and fruiting, germination of seeds produced by first colonizers, seed and vegetative self-maintenance of developing cenopopulations, and the first stage of postglacial succession in the 100 m band adjoining the glacier, occur at significantly lower temperatures. The annual average temperature is 2–3 °C, and the average summer temperature is 5–7 °C.

MODERN VEGETATION COVER

In the Aktru glacier basin, the distribution of the vegetation cover is determined by the relief forms (a combination of mountain tops up to 4,000 m above sea level, high mountain plateaus up to 3,000 m, abrupt slopes of the Aktru valley with deep circuses, moraine complexes and so on).

The modern vegetation cover in the basin includes natural landscapes that are significant in the study of the responses of high-altitude ecosystems to global warming. The elements include: slopes of the valley of the Aktru, moraine complexes (the Little Ice Age) with all the stages of post-glacial succession from the mid-nineteenth century to the present day, and sections of relic Siberian stone pine forests preserved since the fourteenth century (the period of the maximum warming).

The current forest line in the Aktru basin is formed by Siberian stone pine, Siberian larch (*Larix sibirica*) at an elevation of 2,400 m above sea level. There are two types of forest line, climatic and edaphic. The former is positioned on the southern slopes; the formation and development of Siberian stone pine and Siberian larch trees is limited by temperature. The latter is found on the lower northern slopes (elevation 2,200 m) due to the great moving screes.

In the basin there are tree lines, the forest line (with a tree overstorey that includes 300–500 year old cone-bearing Siberian stone pine and Siberian larch trees; they survived the cold periods of the seventeenth and eighteenth centuries), the tree group line and the tree line (individual Siberian stone pine and Siberian larch trees are found higher up the southern and northern slopes as well as on young moraines).

At the forest line, climax forest communities have survived on areas that were not covered by glaciers during the last millennium. In the Aktru headwater there are five sections of relic Siberian stone pine and Siberian stone pine/Siberian larch forests which have remained after the cold periods in the seventeenth and nineteenth centuries, and the great fires in early and middle nineteenth century. These forests represent unique climatic types of communities in the Altai. Their study provides opportunities to reconstruct the climate of 400–500 years ago. Examples of these forests are outlined below.

Shrub Siberian stone pine forest (2,350 m above sea level) is located on a horizontal site between the moraine of the Bolshoy Aktru glacier and the moraine complex of the Maly Aktru glacier at the stone ground swell of about 15–20 m height. Currently, this forest is a narrow line composed of old, middle-aged and young trees. The overstorey consists of two Siberian stone pine generations (their average ages are 275 and 420 years; the life expectancy of the principal generation is from 373 to 450 years) (Timoshok et al., 2003b). On the ground, there are many trees that are either very old and semi-decayed or relatively young. The soil is rich in very big stones. The shrub storey is heterogeneous, mainly sparsely distributed and consists of *Betula rotundifolia*, *Lonicera altaica* and *Salix reticulata*. Three exceptional groups are found among the understoreys in the forest. The first contains almost no herbs, while rare individuals of *Aegopodium alpestre* and *Bergenia crassifolia* can be found under the tree crowns; the second comprises *Bergenia crassifolia*, *Empetrum nigrum* and green mosses found on moss-covered stones of a metre in height; and the third is mainly *Gastrolychnis tristis, Cerastium pauciflorum, Swertia marginata, Carex macroura subsp. Kirilovii, Festuca altaica* and *Poa sibirica* among the stones. The soil type (Vorobjev et al., 2001) is typically cryosoil. The soil profile consists of an organogeneous peaty horizon AT of 15–25 cm in thickness and a developed horizon A up to 20 cm thick. The permafrost is 40 cm deep. The soil profile is gley because of excessive moisture, especially in close proximity to the permafrost.

Siberian larch/Siberian stone pine forests with *Betula rotundifolia*, herbs, lichens and green mosses (2,200 m above sea level) are found under the end moraine of the Maly Aktru glacier after its maximum advance in the mid-nineteenth century. The overstorey is made up of three Siberian stone pine generations (average ages 127, 277 and 455 years) and two Siberian larch generations (average ages 324 and 490 years). The life expectancy of the principal generation of Siberian stone pine is from 420 to 550 years and of Siberian larch, 420 to 565 years (Vorobjev et al., 2001). The shrub storey is quite developed. *Betula rotundifolia prevails* while *Salix glauca* and *Lonicera altaica* are less abundant. The herbaceous storey is not dense and there is moss and lichen cover. The main species (*Calamagrostis pavlovii, Poa sibirica, Anthoxanthum alpinum, Festuca altaica*, *Bistorta vivipara, Castillea pallida*, etc.) grow mainly in gaps. Soil is mountain brown permafrost (metamorphic cryosoil) (Vorobjev et al., 2001) and the soil profile displays quite divided horizons. Living mosses and moss remains are positioned in the horizon A_d, which is 10–15 cm in thickness. The next horizon A is dark brown raw humus of 5–15 cm thickness. Its structure is coprolite with many roots. The next light brown (unstructured) horizon A_2 of 7–10 cm thickness transforms into the brown packed horizon B of up to 30–40 cm thickness (with a nutty structure). The permafrost is found deep in the soil profile.

The great age of the trees enables us to construct tree-ring chronologies of the Siberian stone pine and Siberian larch, as well as seed-cone production chronologies of Siberian stone pine. These chronologies cover two major tree processes (growth and seed productivity) and are the basis for dendroclimatological and dendroecological analyses, forecasts and predictions. Studies from previous scientists (Adamenko, 1986; Okishev et al., 2000) and our colleagues (Timoshok, 2000; Timoshok et al., 2003b; Vorobjev et al., 2001) were analysed; the multi-year variability of tree ring indexes indicated climatic factors limiting tree growth and cone production, and revealed cold and warm periods affected glacier dynamics.

During global warming in the twentieth century we observed a recolonization of Siberian stone pine and Siberian larch tree groups and individual trees upwards on the southern and northern slopes as well as on the moraine complexes of the Maly Aktru and Bolshoy Aktru glaciers, following their retreat since the mid-nineteenth century in the Aktru glacier basin. The tree group line is 100 m further upward on the slopes and moraines than the forest line.

Forest-tundra ecotone with Siberian stone pine and Siberian larch tree groups. Here these trees grow together (Siberian stone pine and Siberian larch) or separately (Siberian stone pine groups and Siberian larch groups), occupying a narrow line at 2,300–2,500 m above sea level. *Betula rotundifolia* and *Salix glauca* dominate in the shrub storey (the former makes up 20–40 per cent of the cover). The dwarf shrub storey is made up of *Vaccinium vitis-idaea* with *Vaccinium uliginosum subsp. alpinum* prevalent. Dominants of the herbaceous storey include *Festuca altaica, Festuca ovina, Poa alpina, Poa sibirica, Calamagrostis pavlovii, Anthoxanthum alpinum, Carex macroura subsp. Kirilovii, Bistorta vivipara, Viola altaica, Schulzia crinita* and *Gentiana grandiflora.*

Forest-tundra ecotone: Siberian stone pine with dwarf shrub, herbs and green mosses. This lies at 2,400 m above sea level and is located on the moraine of the Bolshoy Aktru glacier (above the present mountain forest zone). The overstorey is not dense. Siberian stone pine tree groups (with a mean age of about seventy years) grow here. Species of *Salix* dominate in the shrub storey; *Vaccinium uliginosum subsp. alpinum* and *Empetrum nigrum* in the dwarf shrub storey; and *Poa sibirica, Poa altaica, Poa alpina, Festuca altaica, Carex macroura subsp. Kirilovii* in the herbaceous storey, as well as green mosses but rarely lichens. The herbaceous storey becomes denser at lower levels. The soil is mountain-tundra permafrost cryosoil (Vorobjev et al., 2001) with a total thickness of 20–30 cm.

A forest community with Siberian stone pine and Siberian larch tree groups on the moraine complex of the Maly Aktru glacier (elevation 2,250 m) on the area plot that was ice-free between 1850–1911. The sparse overstorey is made up of young Siberian stone pine and Siberian larch trees as well as unique Siberian spruce (*Picea obovata*) trees. Cone-bearing pine and larch trees are the first to be found. The oldest trees are 100–110 years old. A dominant species in the shrub storey is *Betula rotundifolia* (from 30 per cent of area on steep slopes among blocks and big stones to 80 per cent in horizontal plots with crushed stones) as well as *Salix saposhnikovii, S. reticulata* and *S. glauca*.

The following species can be found in the herbaceous storey: *Astragalus alpinus, Hedysarum austrosibiricum, Aster alpinus, Poa alpina, Festuca lenense, Trisetum mongolicum* and *Carex macroura subsp. Kirilovii*. The moss cover develops under the dense shrub storey. The soil cover is fragmentary. It develops under the larch trees and *Betula* shrubs and is absent in rocky, stone and crushed stone slopes. Soil is 'podbur' (Davydov, personal communication). The horizon A_{01} (0–3 cm depth) contains undestroyed litter with fallen remainders of herbs, leaves, needles and mosses; the horizon A_{02} (3–8 cm) consists of destroyed brown litter; the horizon A (8–21 cm) is brown and moist, with many roots, stones and crushed stones; and the horizon B (21–40 cm depth) is light brown and moist but has fewer roots and more stones than horizon A.

Siberian stone pine and Siberian larch individual trees colonize stone screes and rock splits on the northern slope of the valley of the Aktru River up to 2,300 m above sea level, and on the southern slope up to 2,500 m.

On the moraine complex of the Maly Aktru glacier the line of Siberian stone pine is situated in the area that was ice-free between 1963 and 1968, and Siberian larch in the area free between 1936 and 1941. When the age of the moraine complex increases by 51–66 years, the organogeneous horizon of the litter A_0 and organomineral humus horizon A appear in the soil. The litter depth is 3 cm, weight is 803 g/m^2 with 34.9 per cent of carbon and 1.2 per cent of nitrogen. The humus horizon is brown; its depth is 7 cm, 388 g/m^2 of roots, 1.31 per cent of carbon and 0.20 per cent of nitrogen (Davydov, personal communication).

The tree line comprises individual Siberian stone pine and Siberian larch trees. They grow on the northern slopes of the Aktru river valley in stone screes and rocky cracks up to 2,300–2,400 m above sea level, and up to 2,500 m on the southern slopes. Separate trees on open stone sites with unformed vegetation and among subalpine shrubs with mossy-lichen cover can be observed. On the moraine complex of the Maly Aktru glacier the first Siberian stone pine trees were observed on stone sites (those that were ice-free about twenty years ago: the 1988–93 section) with unformed vegetation (the pioneer stage of revegetation) at a distance of 70–150 m from the glacier end as well as other sites (those that were ice-free thirty to thirty-five years ago: the 1968–73 section) with primary vegetation microgroups of *Salix saposhnikovii, Salix sajanensis* and *Salix glauca*. The Siberian stone pine and Siberian larch individuals are conspicuous in the herbaceous-mossy-willow stage of revegetation on the moraine complex (sites that were ice-free in 1911–1968). On the 1936–41 section, there are individual Siberian stone pine or Siberian larch young trees that are higher than the surrounding shrubs (*Salix saposhnikovii, Salix berberifolia, S. glauca, S. vestita*). The herbaceous and mossy storeys are quite remarkable under them. For the soil cover the organogeneous horizon of litter A_0 and organomineral humus-accumulative horizon A form here (Davydov, personal communication). The humus horizon is brown and 7 cm in thickness.

The studies of upper forest dynamics, tree group and individual tree lines in the ice areas are interesting because they provide new information about the forest ecosystems during the global cold and warm cycles near glaciers and their moraines, and about the recolonization of trees on ice-free areas. This information is necessary for investigations of the tree ecology and the environment for correct paleogeographical reconstructions. Currently, there is no human impact on the primary forests and communities on the moraine complexes in the Aktru river valley. They can be therefore used as a standard of natural ecosystems for biosphere monitoring and the development of scenarios and behavioural trends of plant individuals and communities, soils and ecosystems under conditions of global warming. Thus, the Aktru glacier basin (associated cluster Aktru) is a highly sensitive dynamic testing area where we can trace the responsea of chosen indicator species, communities, soils and ecosystems combined with the reconstructed change of climate over 400–500 years.

ACKNOWLEDGEMENT

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Final Workshop Report

INTRODUCTION AND WORKSHOP OBJECTIVES

Global change will have serious repercussions on fragile mountain ecosystems. The anticipated changes will not only affect the socio-economic conditions of mountain dwellers, but also downstream communities that are dependent upon the flow of goods and services from mountain regions. Mountains serve as the 'water towers of the world', with more than half of humanity depends on freshwater generated in mountains. Changing precipitation regimes, increased water run-off, reduced ice and snow storage capacities in mountains, changing frequency and magnitude of mass events (e.g. landslides and avalanches) will be some of the consequences of global change that may also increase natural disasters in mountains and – perhaps even more pronounced – in the associated lowland areas.

Moreover, rising temperatures will affect the current altitudinal location of the snowline, the vegetation line and the treeline in mountains, and will have an impact on ecosystem properties through the effects on habitats, population dynamics and distribution of species in high-altitude areas. Mountain regions provide a number of key indicators with which the impacts of global changes can be detected, such as changes in snowline, glacier mass balance, and shifts in ecological properties (e.g. changes in the elevation of the upper limit of vascular plants). Mountain regions are distributed nearly from pole to pole, and from highly maritime to highly continental areas; therefore, comparative analyses of the impacts of global change on mountain regions are particularly rewarding.

Mountain people, often living in marginalized societies, especially in developing countries, will have to cope with such drastic changes while make a living from already limited mountain resources. The severity of the anticipated changes will dictate their response strategies, which could range from adaptation in a changing environment to outright emigration to the lowlands.

These issues should be addressed in a new global network of scientists and protected area site managers using mountain biosphere reserves as study and monitoring sites within the UNESCO World Network of Biosphere Reserves. The network will operate at the interface of scientific research, protected area management and the promotion of sustainable development of mountain regions, using a comparative study approach. Mountain biosphere reserves have been selected as they contain protected areas in their core zones (with little direct human disturbance) as well as areas in use for economic activities (buffer and transition zones), so that the impact of global change can be analysed both in a natural or near-natural environment, and in an environment with similar environmental conditions that is used by humans.

A workshop was therefore organized as a joint endeavour of the Mountain Research Initiative

(MRI), comprising the International Geosphere-Biosphere Programme (IGBP), the International Human Dimensions Programme on Global Environmental Change (IHDP), and the Global Terrestrial Observing System (GTOS), as well as UNESCO's Man and the Biosphere (MAB) Programme and the International Hydrological Programme (IHP). The specific objectives of the workshop were:

- to review the state of global change research (natural, social, cultural, economic and political sciences) in a range of mountain biosphere reserves (MBRs) that could be used as pilot study areas for implementing the activities defined by the MRI (cf. Becker and Bugmann, 2001)
- to refine and prioritize MRI activities to an operational level for application in MBRs
- to identify gaps in coverage and methodological problems with respect to global change research in MBRs
- to provide guidelines for implementing integrated global change research in MBRs around the world, with a view towards general applicability in mountain regions.

In order for the meeting to be a success, it was essential that all participants became familiar with the global change research that is ongoing in the selected Biosphere Reserves. Therefore, a significant fraction of the workshop was devoted to presentations from MBR representatives.

WORKSHOP AGENDA

Monday, 10 November 2003

WORKSHOP OPENING. OVERVIEW OF WORKSHOP STRUCTURE AND OBJECTIVES

Chairperson: Harald Bugmann, President of Mountain Research Initiative (MRI)

- Opening of the workshop – Harald Bugmann
- The Mountain Research Initiative – Mel Reasoner
- UNESCO–MAB and the World Network of Biosphere Reserves – Thomas Schaaf
- UNESCO's International Hydrological Programme (IHP) – Lalji Mandalia
- Entlebuch Biosphere Reserve – Engelbert Ruoss

SESSION 1: PRESENTATION OF MOUNTAIN BIOSPHERE RESERVES IN LATIN AMERICA

Chairperson: Thomas Schaaf

- Cinturón Andino Biosphere Reserve – Marcela Canon (Colombia)
- Huascarán Biosphere Reserve – Marco Zapata/Jorge Recharte (Peru)

SESSION 2: PRESENTATION OF MOUNTAIN BIOSPHERE RESERVES AND GLORIA SITES IN EUROPE AND NORTHERN AMERICA

Chairperson: Bruno Messerli

- Lake Torne Biosphere Reserve – Christer Jonasson (Sweden)
- Swiss National Park Biosphere Reserve and GLORIA site Biosphere Reserve – Thomas Scheurer (Switzerland)
- Gossenköllensee Biosphere Reserve – Roland Psenner (Austria)

- Glacier National Park Biosphere Reserve and GLORIA site – Dan Fagre (USA)
- Mt. Arrowsmith Biosphere Reserve – Glen Jamieson (Canada)

SESSION 3: PRESENTATION OF MOUNTAIN BIOSPHERE RESERVES IN AFRICA
Chairperson: Daniel Maselli

- Mount Kenya Biosphere Reserve – Francis Ojany (Kenya)
- Oasis du Sud Biosphere Reserves – Driss Fassi (Morocco)

POSTER SESSION

- Berchtesgaden Alps Biosphere Reserve – Michael Vogel (Germany)

Tuesday, 11 November 2003

SESSION 4: PRESENTATION OF MOUNTAIN BIOSPHERE RESERVES IN THE ASIA-PACIFIC REGION
Chairperson: P. S. Ramakrishnan

- Changbaishan Biosphere Reserve – Li Yang (China)
- Issyk-Kul Biosphere Reserve – Erkinbek Kojekov (Kyrgyzstan)
- Uvs Nuur Basin Biosphere Reserve – Bayarsaikhan Bayarmagnai (Mongolia)
- Katunskiy Biosphere Reserve in the Altai – Z. A.Viktorovich/Yuri Badenkov (Russian Federation)
- Kosciuszko Biosphere Reserve – Ken Green (Australia)

FIELD TRIP TO ENTLEBUCH BIOSPHERE RESERVE, INCLUDING WORKSHOP DINNER

Wednesday, 12 November 2003

SESSION 5: PERSPECTIVES AND COMMENTS FROM THE POINT OF VIEW OF GLOBAL CHANGE-RELATED SCIENTIFIC PROGRAMMES
Chairperson: Mel Reasoner (Switzerland)

a) Long-Term Monitoring
- Alpine Vegetation (GLORIA) – Georg Grabherr (Austria)
- Cryosphere (WGMS) – Wilfried Haeberli (Switzerland)
- Land Use/Land Cover – George Malanson (USA)
- Climate – Ray Bradley and Douglas Hardy (USA)

b) Integrated Modeling
- Integrated ecosystem modeling – Harald Bugmann (Switzerland)
- Regional Atmospheric models – Marco Verdecchia (Italy)

c) Process Studies
- Biodiversity and Ecosystem Function (GMBA) – Christian Körner (Switzerland)
- Biogeochemistry (INSTAAR-MRS) – William Bowman (USA)

d) Sustainable Development
- Sustainable Water Use (NCCR North-South) – Daniel Maselli (Switzerland)
- Agriculture and Traditional Knowledge (GIAHS) – P. S. Ramakrishnan (India)
- Globalization in Mountain Contexts (ICIMOD) – N. S. Jodha (Nepal)

EXAMPLES OF INTEGRATED GLOBAL CHANGE PROGRAMMES

Chairperson: Thomas Schaaf

- Himalayan-Andean Watershed Project – Hans Schreier (Canada)
- The GLORIA Master Station concept – Georg Grabherr (Austria)

BREAKOUT GROUP DISCUSSIONS: SELECTION OF PROGRAMMES, DEFINITION OF PRIORITIES

- Long-term Monitoring – Chair: Georg Grabherr (Austria)
- Integrated Modeling – Chair: Dan Fagre (USA)
- Process Studies – Chair: Bill Bowman (USA)
- Sustainable Development – Chair: Jörg Stadelbauer (Germany)

Thursday, 13 November 2003

BREAKOUT GROUPS REPORT TO PLENARY

Chairperson: Mel Reasoner

- Long-term monitoring – Georg Grabherr
- Integrated Modeling – Dan Fagre
- Process Studies – Bill Bowman
- Sustainable Development – Jörg Stadelbauer

OPEN FORUM: DISCUSSION ON NEXT STEPS AND WORKPLANS FOR COLLABORATION

Chairperson: Bruno Messerli

CLOSE OF THE WORKSHOP (NOON)

BRIEF SUMMARIES OF THE SESSIONS

Presentations on Mountain Biosphere Reserves (Sessions 1–4)

The sixteen oral presentations from the selected mountain biosphere reserves (MBRs) around the world were essential for the success of the workshop. They were very informative in portraying the general situation of the MBRs in socio-economic and political terms as well as serving to inform of their research infrastructure while recognizing the opportunities that Biosphere reserves provide for global change research activities. Unfortunately however, five of the MBRs that had initially been selected by the Programme Committee for presentation at the workshop were unable to send a delegate. They were Araucarias and Torres del Paine Biosphere Reserves in Chile, Kruger to Canyons Biosphere Reserve in South Africa, Tassili N'Ajjer Biosphere Reserve in Algeria, and

Sierra Nevada Biosphere Reserve in Spain. Nanda Devi Biosphere Reserve in India has since been selected to become part of the study. It is hoped that a representative from these biosphere reserves will be able to attend the forthcoming thematic workshop. Despite the absences, MBRs from all continents were represented at the workshop.

Even though the extent of ongoing global change research activities varied widely among the biosphere reserves and also among continents, all the MBR representatives expressed their strong interest in participating in the new MRI/UNESCO–MAB 'Global Change Research in Mountain Biosphere Reserves' initiative or even in starting small national-to-continental networks of mountain researchers and reserve managers, along the lines suggested by the MRI at the global scale. Many of the MBR representatives, especially those from developing countries, expressed the need for financial assistance. Despite the fact that all the MBRs possess the necessary infrastructure to at least carry out the most basic measurements, indicators that can be measured at relatively low cost with basic technological infrastructure, many of the MBRs from developing countries lack advanced technology at the intermediate level of global change indicators. Ideally, assistance should be provided to these MBRs so that they can achieve this intermediate level.

The range of research activities presented at the workshop was impressive and covered all aspects outlined in the Implementation Plan of the Mountain Research Initiative, from monitoring activities (e.g. glacier dynamics, climate, hydrology) through to process studies and modeling (which are currently being undertaken in several MBRs), to research programmes geared towards defining sustainable land use practices.

A more extensive description of the state of global change research in individual MBRs is available from the Proceedings of the Entlebuch kick-off workshop, which is currently being compiled by UNESCO–MAB.

Commentaries from the Point of View of Global Change Programmes (Session 5)

A number of scientists involved in international global change programmes had the opportunity to present brief (ten-minute) perspectives for global change research in MBRs. A common thread throughout these presentations was that this new initiative is very welcome from both a research and a development perspective, but that we should be careful not to re-invent the wheel, particularly in the context of environmental monitoring. Notably, a large number of protocols are available and have been in use in some cases for many decades, and it would be advantageous to make use of them when implementing global change research activities in MBRs. Examples include the ongoing GLORIA (Global Observation Research initiative in Alpine Environments) initiative for monitoring climatic and vegetation changes on mountain summits, and the World Glacier Monitoring Service, which has been in operation for many decades. As regards the GLORIA approach, whose principal aim is to implement a long-term observation network to obtain standardized data in alpine environments, it was proposed that the actual European-wide network be extended worldwide and that the MRI/UNESCO initiative would provide the ideal platform to achieve this.

The contributions on land-use/land-cover change research, integrated ecosystem modeling and regional atmospheric modeling suggest that such activities, despite their importance, would be rather less straightforward to implement in MBRs and their environs for a number of reasons, largely linked to financial constraints. This is particularly true for MBRs in developing countries. Nevertheless, it is important to bear these activities in mind at least for the longer-term goals of the MRI/UNESCO initiative, and the inputs provided by the respective scientists were useful in providing a wider perspective.

Finally, the contributions on the relationship between biodiversity and ecosystem function and mountain biogeochemistry clearly showed the importance of the link between land-use practices and fundamental ecological research. Judicious land use cannot be achieved without a profound knowledge of its associated ecological processes, be it through traditional or formal knowledge systems, nor is it possible to conduct ecological research without taking into account land-use history and practices in the area under investigation. It has become clear that for purely methodological reasons we need a standard protocol for such research investigations, otherwise results from the different studies will remain difficult to compare.

In the context of climate monitoring, it was suggested that it would be appropriate to submit a GEF proposal for the establishment of a network of reference-quality, high-elevation climate observation systems, an integrated global set of monitoring stations that can relay data by satellite, so that the information can be accessed worldwide. The idea of a 'Global Mountain Environet' was welcomed by the workshop participants, and it was suggested that other aspects of Global Change Research in MBRs might be added to such a GEF effort.

RESULTS FROM THE BREAKOUT GROUPS

Breakout Group 'Monitoring Environmental Change in MBRs' (Rapporteur: G. Grabherr)

For each environmental parameter to be monitored, it will be necessary to define such details as the method of data collection as well as the temporal and spatial considerations of data collection. In order to address the minimum set of required data, the initiative must evaluate and balance the importance of the data, the ease with which it is obtained and the cost of obtaining it. Furthermore, the programme must take into consideration the capacity of the biosphere reserve's to carry out measurements and thus its ability to collect data.

The success of the initiative will largely depend on the data available as well as the collection of high-quality and comparable data. Although high-quality monitoring systems are expensive, they will be needed to ensure that data are consistent. Moreover, the the better the information collected, the more likely it is to be attractive to funding agencies.

Capacity building will be necessary to implement the monitoring programme effectively, and we should explore the development of training courses that are be specifically tailored to this programme. The training of personnel will make it easier to implement the initiative, and at the same time serve to increase the skills of local people involved in the project and train them in the initiative, thereby providing a sense of ownership in the process. The importance of the proceedings and other publications stemming from the thematic workshops, and of their diffusion among the biosphere reserve and science communities concerned with global change, should be highlighted. Other communication tools that could help in capacity building would include the creation of thematic websites and a discussion forum or bulletin board.

Monitoring activities in biosphere reserves are being carried out under the Biosphere Reserve Integrated Monitoring programme (BRIM), which places a strong emphasis on the social dimensions of monitoring. As a precondition, monitoring should only be established if it adds to already existing observation networks or those that are in status nascendi. This is particularly the case when establishing stations for climate observations at high elevations and glacier mass balance monitoring. The core zone may provide perfect sites for looking at climate change effects on vegetation, but other indicators such as birds should also be included. Most of these observation activities could make use of already existing standardized approaches in the different fields. Where possible, paleo studies should be taken into consideration. Exceptional events such as floods and fires should be protocolled in all BRs.

FURTHER COMMENTS:

- Existing hydrological stations should be used and new ones established in collaboration with FRIEND and HELP projects of the UNESCO International Hydrological Programme (IHP).
- Climate change (sophisticated set of indicators): High elevation stations; calibration; indicators measured as precisely as possible; comparable and standardized equipment should be used at all sites to ensure consistency in data collection.
- Wherever possible, historical records of events in each BR should be established (e.g. paleo data, floods or droughts).

Breakout Group 'Process Studies in MBRs' (Rapporteur: W. Bowman)

The discussions in this breakout group focused on environmental forcing factors and the study of their impacts on ecological and hydrological processes. It was accepted, however, that economic driving factors are probably of equal or even greater importance in mountain regions, at least in the short-to-medium term (i.e. over the coming few decades).

Process studies are important for better understanding of the consequences of global change on MBRs. Accurate prediction of future changes in pertinent resources (including ecosystem services and aesthetics) requires an understanding of how specific environmental forcing factors (such as climate change or land use) will change the component ecosystems. The goals of the process level studies are:

- to increase understanding of the mechanisms that lead to environmental change, including the exceeding of thresholds that can initiate undesirable environmental conditions
- to provide future scenarios for biosphere reserve managers and the people who live in and use the reserve
- to provide data for modeling studies in order to assist the MBR in its likely response to global change.

The products provided by the process studies should include feedback to and from the MBR managers with a view to adaptive resource management so as to mitigate undesirable effects of global environmental change.

The resources of interest and the relative importance of environmental forcing factors will vary considerably among the mountain biosphere reserves. Therefore, rather than propose a set of universal experiments among the MBRs (and we recognize that there are many potential experiments that could be done in all or many of the set of selected reserves), we suggest the following strategy. First, stakeholders within the MBRs, including people using and living in them as well as managers and scientists, should provide input on the factors that are of concern. Second, existing studies, and proxies of paleaoenvironmental change should be used where appropriate to help determine the possible range of variability for parameters of interest. This is particularly true where extreme events (e.g. floods, fires) are a concern. This cumulative information should be used to determine what variables should be measured at what frequency, and what factors are experimentally manipulated.

Examples of process studies that could be performed in MBRs include:

- the influence of land use (e.g. grazing) on water yield and water quality
- the role of plant and soil biodiversity on ecosystem processes, particularly production, water yield and quality, nitrogen sequestration, and resilience to disturbances
- the influence of nitrogen deposition on ecosystem services.

Process studies should include a replicated range of intensities or treatment levels along with appropriate control treatments, in order to evaluate system thresholds: that is, the level at which an ecosystem is impacted before detrimental effects occur. As water quantity and quality are viewed as critical response variables in nearly all of the MBRs, catchment level studies are encouraged. Some treatments may not be appropriate in some MBRs (e.g. where there is only one catchment, manipulative experiments are not permitted), and thus variation in pre-existing conditions (for example in grazing intensities or in geomorphic disturbance) may be used as a surrogate for experimental procedures. This approach however is less desirable for statistical and interpretive reasons. New or existing management activities should be viewed as experiments that provide information on the processes that influence MBR resources, and should be coupled closely with monitoring activities to evaluate their influences.

It is hoped that networks of MBRs will develop process-level experiments to address the comparative responses to global change. Such networks may be within a similar physiognomic region and constitute a 'virtual mountain biosphere reserve', emphasizing sites where long-term environmental records and experimental sites exist. These networks should utilize existing protocols where available. An example of such protocols includes the GCTE 'Network of Removal Experiments on the Role of Biodiversity in Ecosystem Functioning' (http://gcte.org/Diaz.pdf). Collaborations between developed and developing countries (e.g. US LTER and ILTER) to accomplish comparative process level studies are encouraged.

Breakout Group 'Integrated Modeling for MBRs' (Rapporteur: D. Fagre)

VALUES AND USES OF MODELING

Models are not magic. Models structure existing information in ways that allow us to develop new ideas and pose new questions. Models summarize how we think an ecosystem works and how it will respond to drivers, forcing functions or stressors but cannot be given much weight until validated by real world data. Models are simply hypotheses to be tested and improved. They can fill in gaps where measurements or experiments cannot be performed. They can provide common outputs for comparing mountain systems with mismatched datasets. They are tools, not end products.

We determined that modeling is a very useful tool for biosphere managers because it provides information not currently available from monitoring or process studies alone. Modeling can shape an MBR manager's views of potential future conditions, helping to make more informed decisions in the present. It can help managers better understand the underlying dynamics of ongoing change, possibly identifying thresholds of irreversible change or other unexpected consequences of land use and climatic change.

Models must be implemented or developed with inputs from, and linkages to, MBR managers to make sure that relevant questions are answered. Modeling provides explicit forecasting value but, like weather forecasts for the coming week, should be used cautiously.

EXAMPLES AND RANGE OF MODELS

Models can be conceptual, empirical or statistical, spatially or temporally extrapolative, scale independent, biogeographic (geospatial), deterministic, mechanistic, first principal-based, process-oriented, nested, integrative and simulation-based or combinations thereof, but they all seek to improve our understanding of system behaviour so that we can better anticipate the future.

SUGGESTED MODELING ACTIVITIES FOR MBRS

There is a need for a complete inventory of available data at each MBR. The data that modelers can access will determine which models can be used, the spatial and temporal scales that can be addressed, and the priority for acquiring new data. The goal is to have a minimum common dataset to support modeling and to standardize the model (and its application) being used to answer basic questions. This step will facilitate direct comparisons between MBRs (where possible).

We decided that it was important to model a series of ecosystem processes for management of MBRs in the face of global change and to clarify the value of MBRs to society (e.g. ecosystem services). These processes are:

- Hydrology: the change in quantity and timing of the MBR water output.
- Land cover: a proxy for productivity, structure and function.
- Carbon flux: impacts of changes in climate, grazing and logging on carbon stocks (balance), rates of fixation (growth, net primary productivity).
- Nitrogen: critical to ecosystem dynamics.
- Disturbance role: ecosystem sensitivity to perturbation, future range of variability.

Three different levels of intensity of the possible modeling activities were distinguished by this breakout group, with recommendations for each level.

Breakout Group 'Sustainable Development in MBRs' (Rapporteur: J. Stadelbauer)

DEFINING THE TASK, THE AIM AND THE CONDITIONS OF THE SEARCH

The task concerns the human system integrated into biosphere reserves:

- monitoring of social, cultural, economic and political variables in the context of ecological issues
- land-use, water, integrated aspects: landscapes and sustainable development.

More precisely:

- identification of indicators for a system of continuous monitoring
- indicators of sustainability
- evaluation of practicability of the indicators
- suggestions for the creation of a differentiated system for socio-economic monitoring of sustainable development.

Main problems:

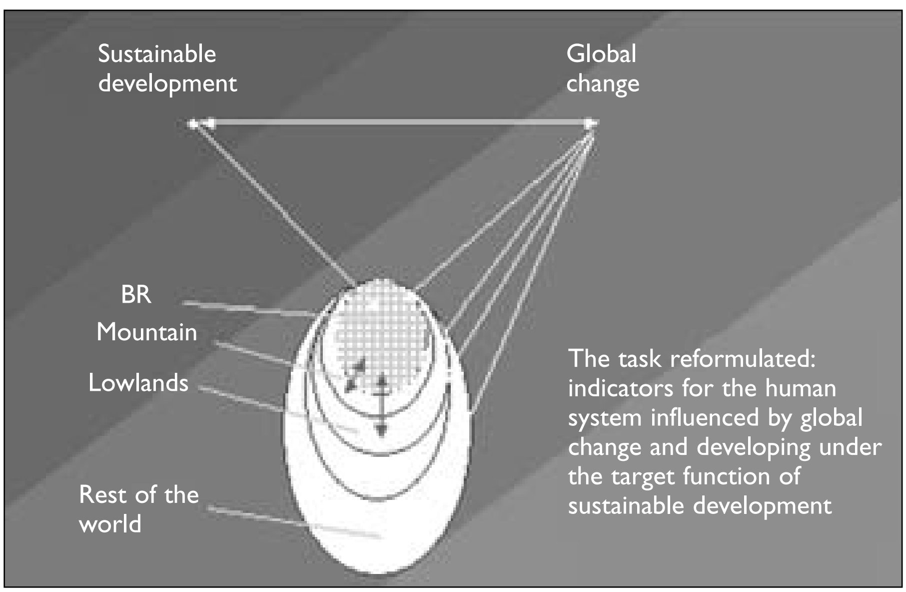
- awareness of the task: specific indicators of sustainability
- practicability of the indicators (availability of data)
- systemic interference of the indicators
- difference and lack of comparability of the MBRs.

Given all this, two leading questions can be formulated:

1. How many indicators or parameters are necessary in order to describe the effects of sustainability in a mountain biosphere reserve under the conditions of globalization? Do we need a large 'shopping list' of indicators or can we see a real reduction of parameters?
2. Is there an order of indicators? Which ones are the key/core indicators, which for advanced surveys, and which for more sophisticated research?

Furthermore, living conditions in MBRs have to be taken into account:

- It is necessary to take into account the vulnerability and the continuous coping of the population with uncertainties.
- We may not neglect the dependence of biosphere reserves on state subsidies.



IDENTIFYING THE INDICATORS

A list was developed during the discussion session that contains the indicators that were identified as relevant for describing the development of MBRs. The impact of globalization is a secondary one; its relation to the development of MBRs depends on hypotheses about the influence of globalization on economy and society. Thus, local population dynamics are regarded as being relevant if we assume that sustainability needs a continuous composition of all age groups and a balance of male and female population, that global change means a decreasing population in the post-industrial societies and a further increase of population in low-income countries. The balance of immigration and emigration is interconnected to local population dynamics because this indicator regards the out-migrating and immigrating groups (possibly through people of working age leaving the MBR region, or through retired people immigrating for recreation and permanent residence).

SUMMARY

A small number of (normally) easily available variables should be used as key indicators:

- local population dynamics
- immigration/emigration – reasons: economic, political reasons, disasters
- ethnic composition of the population
- institutions and rules
- seasonal water availability and quality
- energy supply and consumption
- earning opportunities
- food security
- investment and subsidies
- governance
- tensions and conflicts.

However, in reality it may often be quite difficult to achieve the aim of collecting a few relevant indicators:

- A large system of hypotheses and related indicators is necessary.
- The search for relevant indicators should be regarded as a chance for more sophisticated socio-economic research on a balance between ecological demands, conditions of global change, economic strategies and political realisation.

Results of the Final Session

During the Final Plenary Session, many participants expressed their interest in becoming involved in the future development of this new initiative. Global change processes are often judged to be of high relevance for the future sustainable use of land in MBRs (and elsewhere), and hence the MRI/UNESCO initiative we welcomed as being useful and timely. Also, it was generally felt that the workshop had been a good start for putting things into practice. It was emphasized by many participants that training aspects are important, so that research activities can be conducted locally without long-term dependence on scientists from abroad.

UNESCO–MAB informed the workshop participants about their plans to get endorsement for the MRI/UNESCO initiative from the International UNESCO–MAB Secretariat for those MBRs that expressed their desire to be involved in the initiative.

A number of participants informed the audience about their plans for regional workshops or similar events to carry the new initiative a step further. These include:

- a national Russian network to foster the implementation of the MRI activities at the national scale
- the western climate science initiative in North America, which has already produced a white paper, and will hold a larger workshop (100 participants) in May 2004
- an IHP workshop in 2004 to discuss the state of the Andean glaciers and the associated research efforts
- a regional meeting in South America in early 2004 that will discuss the implementation of MRI Activities in South American MBRs.

The participants agreed that one important next step would be to take a survey of the indicator variables that are being collected in the MBRs, so as to define the next practical steps. Also, the workshop participants were informed that the European Union has agreed to fund through its Sixth Framework Programme an initiative to define the implementation of global change research activities in MBRs at an operational level. To this end, a series of four workshops culminating in an Open Science Conference is foreseen, to take place within two years. These events will be coordinated through the MRI Office. The first workshop, entitled 'Global Environmental and Social Monitoring', has been scheduled to take place from 9–11 May 2004 in Vienna, under the guidance of Professor Georg Grabherr. Further workshops on Process Studies, Integrated Modeling and Sustainable Development will follow in August 2004, spring 2005 and summer 2005, respectively, culminating with the Open Science Conference, possibly in late 2005.

WORKSHOP PRODUCTS

The workshop participants agreed that two major products would be sought from this event, the first short term, and the second with a medium-term perspective, as follows:

1. A written compilation of the state of research in the MBRs that were selected for the workshop. It is anticipated that the compilations will be published in 'synthesis' form as a proceedings volume by UNESCO–MAB, using the discussion reports from the breakout groups. This will include, recommendations about which research activities should be implemented in MBRs, and how, including a review of possible conceptual, technical and technological limitations.
2. A handbook or manual (to be completed after the workshop, based on inputs from workshop participants plus additional efforts to be conducted in the future) describing the technical details of these measurements and activities. Notably, the series of workshops to be held during the coming two years will be instrumental for addressing these questions in detail.

WORKSHOP CONCLUSIONS

The UNESCO/MRI Workshop held 10–13 November 2003 in Entlebuch Biosphere Reserve had originally been planned as a small gathering of perhaps twenty or thirty people. The organizers were overwhelmed by the expressions of interest in participating that came from both biosphere reserve managers and from scientists involved in global change research activities. Hence, the size and the fruitful discussions of the Entlebuch workshop clearly demonstrate the strong interest in and the concern about global change impacts and the associated research activities from the point of view of the managers of mountain biosphere reserves, but also from the point of view of the scientific research community.

The participants welcomed this new UNESCO/MRI initiative and expressed their interest in staying involved in the future development of this endeavour. In particular, the following recommendations emerge from the deliberations in the plenary discussions as well as during the Breakout Group session at the Entlebuch workshop:

- The workshop was judged to be a success, both from the perspective of the MBRs and from a scientific point of view. It is clear that scientific research cannot and should not be restricted to the subset of questions that is of immediate relevance for MBR managers. However, it was agreed that there exists a considerable overlap in the interests of MBR managers and global change scientists, and the new initiative should aim to build upon these potential synergies.
- The present workshop can only be considered as the first in a series that will need to be held to define MRI activities to an operational level in the context of MBRs and their regional needs. It is appreciated that significant funding is available from the Sixth Framework Programme of the European Commission, and it was also welcome news that UNESCO is likely to be able to contribute some additional funding to this endeavour.
- The MRI Coordination Office should take the lead for carrying this initiative further, in close collaboration with the UNESCO–MAB Secretariat in Paris.

Overall, the workshop participants are convinced that this workshop has been the first step in an exciting new collaboration that has the potential to be of mutual benefit to both biosphere reserve managers and the global scientific community interested in the impacts and feedbacks of global change processes in fragile mountain environments.

Appendix
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List of Acronyms

ACIA	Arctic Climate Impact Assessment
ALPE	Acidification of mountain lakes: Palaeolimnology and Ecology (European Commission project)
ALS	autodidactic learning for sustainable development
ALTER-NET	A long-term biodiversity, ecosystem and awareness research network of the European Commission
ARGOS	Advanced Research and Global Observations Satellite
BALANCE	Global Change Vulnerabilities in the Barents Region: Linking Arctic Natural Resources, Climate Change and Economies (EU-funded project)
BR	biosphere reserve
BRIM	biosphere reserve integrated monitoring
CAM	Corporación Autónoma Regional del Alto Magdalena (autonomous regional corporation of the Alto Magdalena, Colombia)
CAMP	Central Asian Mountain Partnership Programme (SDC)
CBD	Convention on Biological Diversity
CBD SBSTTA	Subsidiary Body on Scientific, Technical and Technological Advice of the Convention on Biological Diversity
CDE	Centre for Development and Environment of Berne University, Switzerland
CDM	clean development mechanism
CEM	Commission on Ecosystem Management (IUCM)
CEON	Circum-Arctic Environmental Observatories Network
CETEMPS	Centre of Excellence: Integration of remote sensing techniques and modeling for the forecast of severe weather (University of L'Aquila)
CFCs	chloro-fluro-carbons
CHYM	Cetemps hydrological model
CIRMOUNT	Consortium for Integrated Climate-Related Research in Western North American Mountains
CMPACT	Community Management and Protected Areas Conservation
DEM	digital elevation model
EMERGE	European mountain lake ecosystems: regionalization, diagnostics and socio-economic evaluation
ESAPP	Eastern and Southern African Partnership Programme

ETH	Zürich Swiss Federal Institute of Technology, Zürich
EUROLIMPACS	EU-funded integrated project to evaluate impacts of global change on European freshwater ecosystems
FORMAS	The Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning
GAW	Global Atmosphere Watch
GCM	general circulation model
GCOS	Global Climate Observation System
GCTE	Global Change and Terrestrial Ecosystem
GEF	Global Environment Facility
GHCN	Global Historical Climatology Network (WMO)
GIAHS	globally important ingenious agricultural heritage system(s)
GIS	geographic information system
GLOCHAMORE	Global Change in Mountain Regions
GLORIA	Global Observation Research Initiative in Alpine Environments
GMBA	global mountain biodiversity assessment
GOES	Geostationary Operational Environmental Satellite
GTOS	Global Terrestrial Observing System
GTS	global telecommunications system
GTZ	German technical assistance programme
IAvH	Instituto Alexander von Humboldt
ICIMOD	International Centre for Integrated Mountain Development
ICSU	International Council of Scientific Unions
IGBP	International Geosphere-Biosphere Programme
IGFA	International Group of Funding Agencies for Global Change Research
IHDP	International Human Dimensions Programme on Global Environmental Change
IHP	International Hydrological Programme (UNESCO)
ILTER	international long-term ecological research
IM	impact monitoring
INGEOMINAS	Colombian Institute of Geology and Mining
INRENA	National Institute of Natural Resources - Instituto Nacional de Recursos Naturales (Peru)
IPSDMR	International Partnership for Sustainable Development in Mountain Regions (SDC)
IUCN	World Conservation Union
KWS	Kenya Wildlife Service
LIMCOs	Lake Ice Microbial Communities
LTER	long-term ecological research
MAB	Man and the Biosphere programme (UNESCO)

MACNE	Mongolian Association for Conservation of Nature and Environment
MAP-21	Mongolian National Programme for the Twenty-first Century
MAVDT	Ministry of Environment, Housing and Territorial Development (Colombia) – Ministerio de Ambiente, Vivienda y Desarollo Territorial
MBR	mountain biosphere reserve
MMA	Ministerio del Medio Ambiente (Colombian Ministry of the Environment)
MOLAR	Mountains Lakes Research (European Commission Project)
MoU	memorandum of understanding
MPAS	Massif Protected Area System (Colombia)
MRD	*Mountian Research and Development* (Quarterly journal)
MRI	Mountain Research Initiative
NCCR	National Centre of Competence in Research (Switzerland)
NERC	Natural Environment Research Council (UK)
NNPSSAU	National Natural Park System Special Administrative Unit (Colombia)
NOAA	National Oceanic and Atmospheric Association (USA)
NP	National Park
ONERN	National Office of Natural Resources Evaluation (Peru)
PACLIM	Pacific Climate workshops
PINE	Predicting Impacts on Natural Ecotones
PNC	Parque Nacional Huascarán (Peru)
RCM	regional climate models
RSA	rolling stones algorithm
SCANNET	Scandinavian/North European Network of Terrestrial Field Bases
SDA	sustainable development appraisal
SDC	Swiss Agency for Development and Cooperation
SIRAP	National System of Protected areas (Colombia)
SNCCAP	Sierra Nevada Climate Change Assessment Project
SNNP	National Natural Parks System (Colombia)
SNP	Swiss National Park
START	System for Analysis, Research and Training on global change (IGBP–IHDP–WCRP)
STEPPS	Snow in Tundra Environments: Patterns, Processes and Scaling Issues (NERC-funded project)
TEK	traditional ecological knowledge
TEMS	Terrestrial Ecosystem Monitoring Site (FAO–GTOS)
TSBF	tropical soil biology and fertility
UAESPNN	National Parks Administrative Unit (Colombia)
UNCED	United Nations Conference on Environment and Development (Rio de Janiero, 1992)
UNESCO	United Nations Educational, Scientific and Cultural Organization
US LTER	US International Long-Term Ecological Research

VDBs	village development boards
WCPA	World Commission on Protected Areas (IUCN)
WCRP	World Climate Research Programme
WGMS	World Glacier Monitoring Service
WMO	World Meteorological Organization
WNBR	World Network of Biosphere Reserve
WOCAT	World Overview of Conservation Approaches and Technologies