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Meeting New Challenges: Agenda for the Future from a Scientific Perspective

The Hindu Kush-Himalayan Region: Common Goods or Common Concerns?

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Mountain Resources – Common Goods?

The interaction between human societies and environmental change in the very different climatic zones of our Earth has a long and complex history over thousands of years. But, in the second half of the 20th Century a period began of rapidly growing human impacts on all the different ecosystems of our planet, and especially on the Hindu Kush-Himalayan (HKH) region and its surrounding lowlands. Figure 1 gives an impression of this turbulent and dramatic process (McNeill 2005), which is unprecedented in the history of humanity in terms of magnitude, and which cannot continue with the same rate of population growth and resource use until the end of our century. The world population increased from about 3.85 billion people in 1972, to 6.1 billion in mid 2000.

Figure 1: **The 20th century – Modern global environmental history. A turbulent and dramatic scenario** (adapted from McNeill 2005)

Driving forces behind environmental change	
Human population	grew 4 fold
Urban population	grew 13 fold
Global economy	grew 14 fold
Industrial production	grew 40 fold
Energy use	grew 13 fold
CO_2 emissions	grew 17 fold

Scale of environmental change			
Freshwater use	grew 9 fold		
Marine fish consumption	grew 35 fold		
Cropland	grew 2 fold		
Irrigated land	grew 5 fold		
Cattle population	grew 4 fold		
Life expectancy at birth globally (years)			
1800: 30	1935: 35	1950: 45	2000: 67

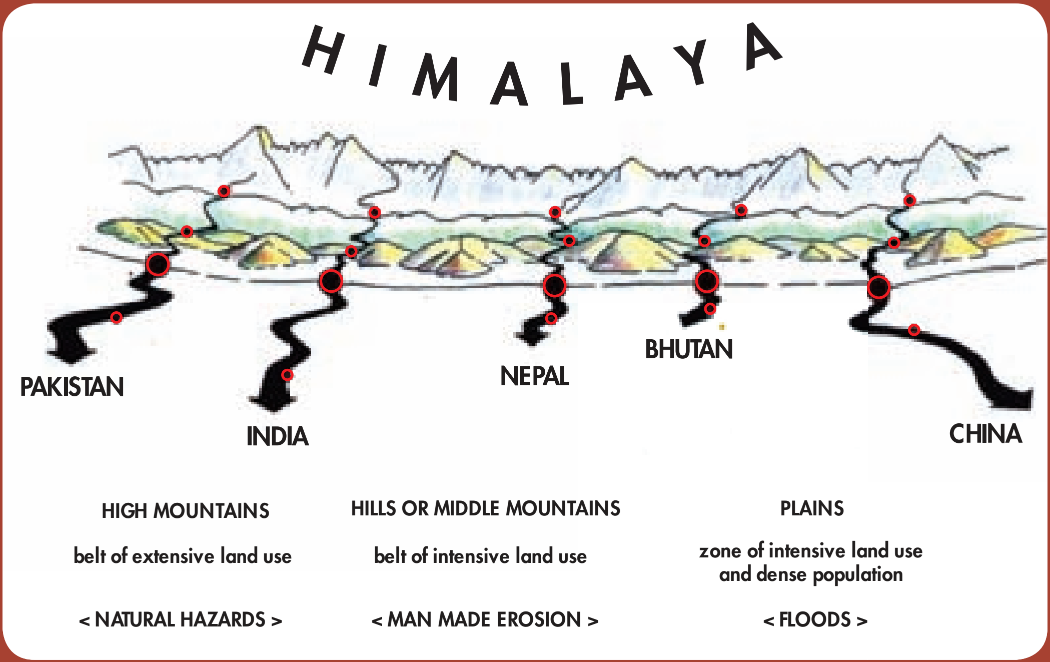
"Nothing like this had ever happened in human history. The mere fact of such growth, and its unevenness among societies, made for profound disruptions in both environment and society."

Six countries accounted for 50 per cent of the annual growth; four of them are regional member countries of ICIMOD – India, China, Pakistan, and Bangladesh (UNPD 2001). This change, from a nature-dominated to a human-dominated global environment, will probably result in a further acceleration in the rate of environmental change and resource use, and an increase in the vulnerability of societies and economies. It becomes more and more evident that major natural processes – from the local to the global scale – are influenced by human activity, creating a much higher degree of complexity through the interaction of human and natural, economic and political driving forces (Messerli et al. 2000, Steffen et al. 2004).

The rapidly changing relationship between the continuously increasing world population and the available natural resources has provoked a new thinking about territorial issues and so-called 'common goods'. This is especially true for the mountain regions of the world with their significant resource treasures like freshwater, biological and cultural diversity, recreation areas, and many others (Debarbieux and Price 2008). The World Heritage Convention was probably the first successful approach to declaring selected natural and cultural places as representative of a certain type of common goods. This Convention provoked no significant political opposition because the protection and management of sites were placed under national law and responsibility (UNESCO 1972). Problems emerged when the discussion turned to transnational or global common goods like the atmosphere and the oceans, ecosystems like tropical rainforests and wetlands, and geographical regions like Antarctica. Without going into the complex arguments, scientific controversies, or political disagreements to each of these, the question can still be raised as to whether or not some mountain areas and their resources should be given the status of common goods?

As an example, it may be interesting to discuss the hydrological significance of mountains and highlands. On a global scale, very few measurement series exist, the periods covered are very limited, and evaluations of the spatial and temporal heterogeneity of discharge conditions are not yet satisfactory in relation to most mountain regions of the world. A preliminary approach to an assessment of the hydrological significance of mountain areas was undertaken using discharge data provided by the Global Runoff Data Centre in Koblenz, Germany. River basins in various parts of the world were selected as case studies. The relationship between mountains and lowlands was examined, primarily using gauging stations above an altitude of 1000m and in the vicinity of the river mouth. In addition, upper gauging stations were chosen that were situated in real mountain terrain with mountain topography, ideally as close as possible to the border between the mountains and plains (see Figure 2). Regional precipitation and temperature conditions were also taken into account in order to evaluate the discharge regime in the climatic context of the region. In general, mountain areas are characterised by disproportionately high discharge, typically about twice the amount that could be expected from the proportion of the area of the mountain section. Mountains account for 30 to 60% of total discharge in humid areas, while in semiarid and arid areas, the contribution is 50 to 90% with extremes of over 90% in some areas like the Nile and Orange rivers in Africa, the Amu Darya in Central Asia, the Colorado in North America, and the Rio Negro in South America (Figure 3). These and other findings were quantified and used to elaborate an

Figure 2: **Highland-lowland interactions**

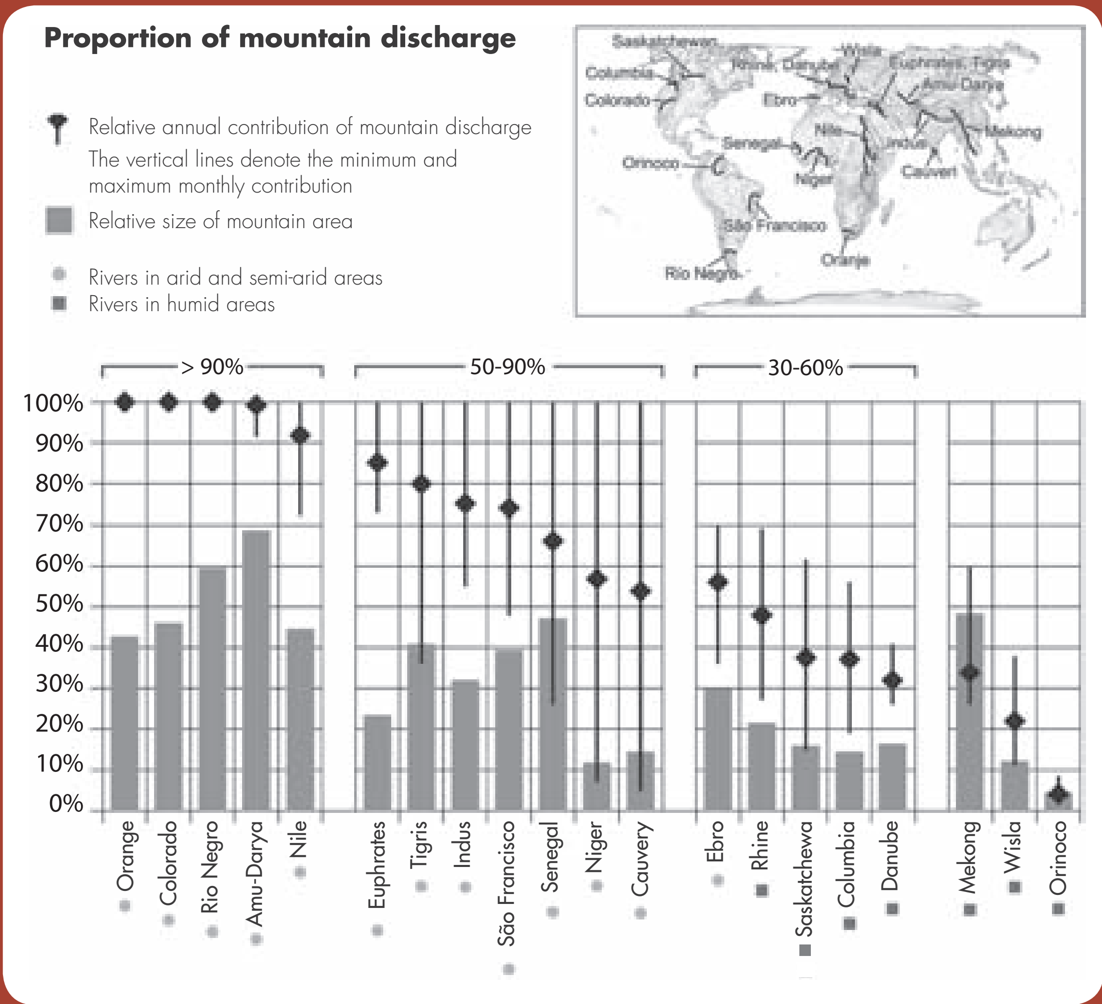


Research strategy for a better understanding of the water balance for every altitudinal ecosystem, from ice and snow down to the adjacent plains – precipitation, evaporation, runoff, erosion, sedimentation, and floods. Big circles represent the main stations in the transition between mountains and plains, small circles represent the mountain station network (Messerli, in Ives et al. 1987, p. 342).

overall assessment of the hydrological significance of mountain areas (Viviroli et al. 2003 and 2007). Without discussing this fascinating topic in more detail, this study reveals very clearly that the mountains of the world – differentiated for every climatic zone – play a very significant role in hydrology, and are particularly important in the most densely populated parts of the developing world. If we take into account that nearly all these rivers cross borders, then it becomes logical to speak or dream about mountain water flows as common goods.

From local to national levels, commons have been designated in mountain areas for many centuries. Collective management regimes have been common not only for pastures and forests, but also for water. The real breakthrough for mountains on a regional and global level was the Earth Summit in Rio de Janeiro in 1992, with its Agenda 21: Managing Fragile Ecosystems – Sustainable Mountain Development. The United Nations Food and Agriculture Organization (FAO) became the special, and most efficient, task manager for this mountain chapter. The International

Figure 3: **Mean annual mountain contribution to total discharge of freshwater and proportion of mountainous areas. Vertical lines denote the maximum and minimum of discharge.** For a further explanation see Viviroli et al. 2003.



Year of Mountains (2002) and the foundation of the Mountain Forum (1995) and the Mountain Partnership (2002) created the urgently needed awareness for the mountains at global level. The Food and Agriculture Organization (FAO), the United Nations Educational, Scientific and Cultural Organization (UNESCO), the United Nations Environment Programme (UNEP), the United Nations University (UNU), and various other international organisations became involved in mountain programmes. The last element in this too short global mountain history is the Mountain Resolution of the UN General Assembly on 12 December 2007, which consists of 42 paragraphs. The reasons for the strong international and intergovernmental support for mountains is well expressed in Paragraph 3 of this Resolution, which "recognizes the global importance of mountains as the source of most of the Earth's freshwater, as repositories of rich biological diversity and other natural resources, including timber and minerals, as popular destinations for recreation and tourism and as areas of important cultural diversity, knowledge and heritage, all of which generate substantial positive economic externalities" (UNGA 2007).

This very short summary on the growing significance of mountains and their resources, at local, national, regional, and global levels, combined with the overall idea of a certain type of common good is fascinating and stimulating – but not realistic! National sovereignty will never allow such a decision. However, is it not the case that the governments and people of the HKH region are all concerned about the changing climate, changing water resources, and changing ecosystem services in one of the most dynamically growing regions of the world? Is it not much more important to understand the common concerns instead of losing time discussing common goods? Are the main thrusts in ICIMOD's new strategic plan not precisely about defining common concerns? In order to reach an understanding about common concerns, it could be helpful to discuss the common constraints and common challenges.

Mountain Environmental Change – Common Constraints

Changes in climate and hydrology are major constraints for all the member states in the HKH region, regardless of political borders. Few model simulations have attempted to specifically address issues related directly to future impacts of climate change in mountain regions, primarily because the current resolution of the general circulation models, and even the regional models, is too crude to adequately represent the complexity of the mountain topography. In mountain areas temperature and precipitation can change over very short distances in both horizontal and vertical dimensions. Downscaling techniques have often been seen as a very valuable tool for generating climate change information for mountain regions. But projections of changes in precipitation patterns are often unreliable because the effect of topography on precipitation is not adequately represented. Snow and ice are a key component of the hydrological cycle for many mountain ranges. The seasonal character and the amount of runoff are closely linked to cryospheric processes (IPCC 2007a). All this means that the projections available today for climate and hydrological changes for the HKH region must be taken as a regional overview, with a high degree of uncertainty. It is most interesting that in the recent report of the IPCC, even in the chapters about South Asia, the name 'Hindu Kush-Himalayas' appears rarely and is almost non-existent, in contrast to 'Tibet', which often appears as a steering element in the regional circulation models. Perhaps we can interpret this omission with the difficulties in the database, divided among eight countries without any coordination, and with too short and too few reliable measurement series. It would be a great advantage for all the HKH regional countries to have common and comparable data about temperature, precipitation, snow and ice, aerosols, and land cover change. ICIMOD and the HKH countries should keep in mind the following diplomatically formulated sentence in the last IPCC report: "A lack of observational data in some areas limits model assessment" (IPCC 2007a, p.875). Thus today's knowledge as presented in Figure 4 should be seen as a highly generalised overview; we can interpret it in the following way.

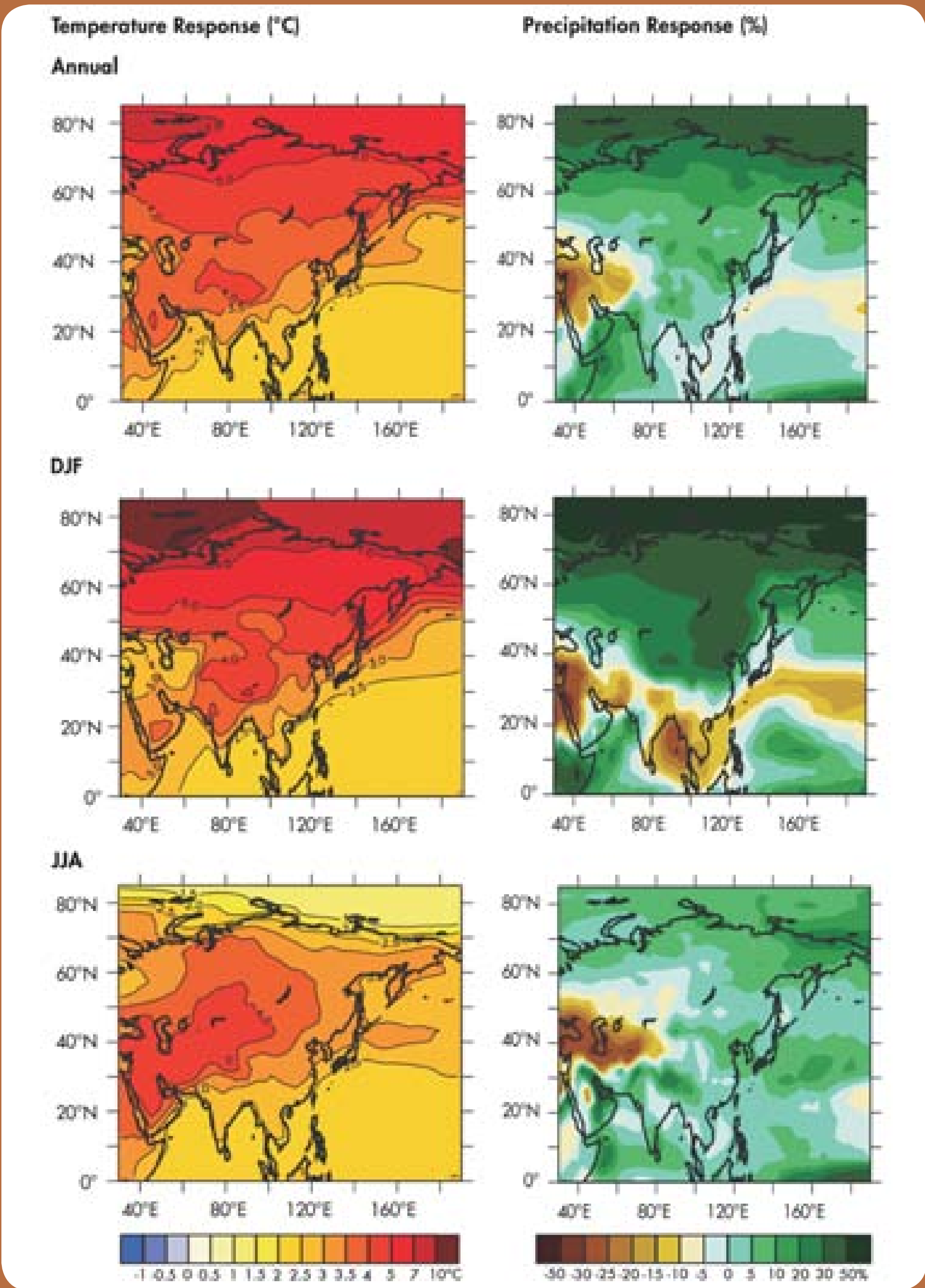
Temperature changes

A warming towards the end of the 21st Century of 3.3°C is projected for South and East Asia, greater than the global mean. Projections are much higher for the continental interior of Asia and the Tibetan plateau, with 3.7 to 3.8°C, and still higher for northern Asia, with 4.3°C. For most regions, the largest warming will occur in the winter months (Dec-Jan-Feb or DJF), but in central Asia the maximum warming will occur in the summer months (Jun-Jul-Aug or JJA). Downscaled projections indicate future increases in extreme daily maximum and minimum temperatures throughout South Asia due to increases in greenhouse gas concentrations. The greatest warming will be over the Tibetan plateau and at the highest altitudes (i.e., the greater Himalayas), which is interesting. This can be explained by the decrease in surface albedo associated with the melting of snow and ice (IPCC 2007a, p.883).

Precipitation changes

Boreal winter (DJF) precipitation is very likely to increase in Northern Asia and on the Tibetan plateau. Summer (JJA) precipitation associated with intense events is likely to increase in South Asia, even if the monsoonal flows and the tropical large-scale circulation are likely to weaken. There is an emerging consensus that the effect of enhanced moisture convergence in a warmer moisture atmosphere dominates over any such weakening of the circulation, resulting in increased monsoonal precipitation. Moreover, there seems to be a link between Eurasian snow and ice cover and the strength of the monsoon, with the monsoon strengthening if the snow cover retreats. Aerosols also have the same effect as greenhouse gases and can further modify monsoonal precipitation, as do modifications to the vegetation cover. Attention must be paid to the depressions and tropical cyclones generated over the Indian seas, which modulate the monsoon anomalies and can lead to damaging heavy rainfall events. This suggests that the spatial structure of warming in the Pacific will be relevant to these changes. Most important for the HKH region is the statement that most models indicate a general migration of seasonal tropical rain with maximum rainfall during the monsoon season to the North of the Bay of Bengal – even if it is poorly simulated by many models – and heavy rainfall over those regions with steep orography, with particularly large increases in Northern Pakistan and North-West India, as well as in North-East India, Bangladesh, and Myanmar. Interestingly, the annual number of rainy days may decrease by up to fifteen days over a large part of South Asia, but with an increase in extreme events and enhanced upward motion due to the northward shift of the monsoon circulation (IPCC 2007a, pp.879-887).

Figure 4: **Temperature (T) and precipitation (P) changes over Asia, averaged over 21 models. T and P change 1980-1999 and 2080-2099.**



First column T: Annual mean – December, January, February – June, July, August
Second column N: Annual mean – December, January, February – June, July, August
Source: Climate Change 2007: The Physical Science Basis. Working Group I Contribution to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Figure 11.9 Cambridge University Press. Reprinted by permission of the IPCC.

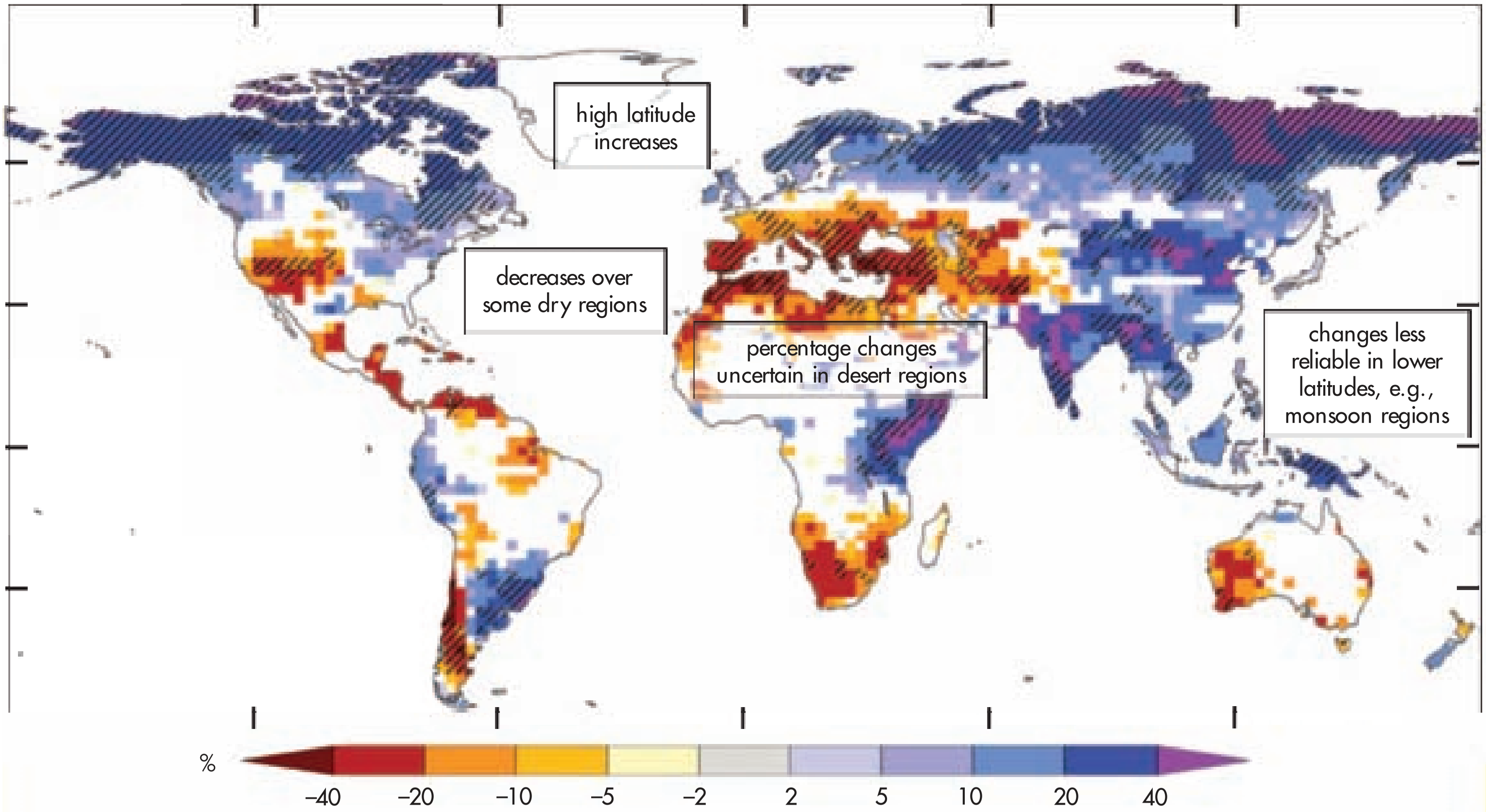
Runoff

Changes in precipitation and temperature lead to changes in runoff and water availability (Figure 5). Runoff is projected with high confidence to increase by 10 to 40% by mid-century at higher latitudes, and decrease by 10 to 30% in some wet tropical areas. The negative impacts of climate change on freshwater systems outweigh the benefits. Areas in which runoff is projected to decline face a reduction in the value of the services provided by water resources. The beneficial impacts of increased annual runoff in some areas are likely to be tempered by negative effects (precipitation variability, seasonal runoff shifts, and extreme events) on water supply, water quality, and flood risk. Twenty per cent of the world's population will live in areas where river flood potential could increase by 2080. Climate change is expected to exacerbate current stresses on water resources from population and economic growth, and land use changes including industrialisation and urbanisation. On a regional scale, mountain snow packs, glaciers, and small ice caps play a crucial role in freshwater availability. Widespread mass losses from glaciers and reduction in snow cover over recent decades are projected to accelerate throughout the 21st Century, reducing water availability and hydropower potential, and changing the seasonality of flows supplied by meltwater. In the IPCC report (2007b, p.49), it is stated that one billion people are dependent on mountain water resources, but from our knowledge of the HKH region, we believe that this figure must be much higher.

Constraints

Mountain regions react much more sensitively to climate change than the surrounding lowlands. Cross-border problems and processes or common constraints demand a stronger engagement of the scientific institutions of the HKH region, and this again could create a new understanding of the political authorities. In its new strategic plan, ICIMOD has formulated three main programmes: Integrated Water and Hazards Management; Environmental Change and Ecosystem Services; and Sustainable Livelihoods and Poverty Reduction, all of which will be seriously influenced by these ongoing and even accelerating changes, together with a fourth area as a basic tool, Integrated Knowledge Management and Capacity Development. If it is not realistic to declare mountain resources as common goods, we at least have to accept that the ongoing environmental changes are a common constraint which need solidarity and cooperation. If the HKH countries want more precise regional models to project potential changes, which form the basis of all mitigation and adaptation measures, then a coordinated network with comparable climatic and hydrological data is indispensable. Finally, we must keep in mind that natural resources such as water, forests, and ecosystems are already under considerable pressure from human activity. Climate change will add to that pressure, and it is the combined effect of global warming and these 'baseline' stress factors that matter when considering the impact of climate change on natural systems (OECD 2008).

Figure 5: **Large-scale relative changes in annual runoff (water availability in per cent) for the period 2090-2099, relative to 1980-1999.**



Values represent the median of 12 climate models. White areas indicate less than 66% of the 12 models agree on the sign of change and hatched areas that more than 90% of models agree on the sign of change. The global map of annual runoff illustrates a large scale and is not intended to refer to smaller temporal and spatial scales. In areas, where rainfall and runoff are low (e.g., desert areas), small changes in runoff can lead to large percentage changes. In some regions, the sign of projected changes in runoff differs from recently observed trends.

Source: Climate Change 2007: Synthesis Report. Contribution of Working Grouop I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Figure 3.5. IPCC, Geneva, Switzerland. Reprinted by permission of the IPCC.

Regional Mountain Development – Common Challenges

Population and economic growth will lead to an increased demand for natural resources. The lowlands in and around the HKH region and Tibetan plateau are some of the most dynamic regions with the highest growth rates in the world. These demographic-economic driving forces (also documented in Fig 1) must have serious consequences for the mountain regions. In other words, these processes present crucial common challenges, which need a higher level of attention from the scientific and political community and a special sense of responsibility towards highland and lowland populations. These challenges could include the following, for example.

Missing data for climate models and projections

The HKH region was, for the IPCC working groups, a so-called 'white spot', i.e., lacking a reliable database. If the countries concerned are not able to establish a well-coordinated network of climatic and hydrological stations with comparable data showing the impressive variety in these huge mountain systems from west to east and in some transects from north to south, including the instructive variety of ecosystems in the verticality, then we can never expect more precise regional models and projections as basic tools for mitigation and adaptation measures.

Observing the cryosphere and its significance for water resources

A careful and continuous evaluation of the changing ice and snow cover using fieldwork and remote sensing methods, is fundamental for estimating the potential change in the seasonality of water flows. It is astonishing to see in the Glacier Mass Balance Bulletin (WGMS 2007) that of the 127 glaciers regularly measured to provide a worldwide overview in this ICSU-UNEP-UNESCO-WMO supported programme, only two are in the HKH region – both in India (Chota Shigri in the Western Himalaya and Hamtah in Himachal Pradesh). The HKH countries need better and longer-term knowledge about the cryosphere, and need to be integrated in existing international networks, in order to gain a better understanding of ongoing environmental changes.

Water resources for sustainable development and food security

There are no runoff data available in the Global Runoff Data Centre in Germany for the most important HKH river basins (see Figure 3). In relation to food security, the Consultative Group on International Agricultural Research (CGIAR) started a 'Challenge Program on Water and Food' to grow more food with less water and to change the way we manage water for food, livelihoods, health, and the environment. This organisation estimates that 1.4 billion people live in water-stressed basins. By 2025, this number is expected to reach 3.5 billion (CGIAR 2006). Avoiding such a development will be a great challenge in the HKH region and in the water-dependent lowlands.

The FAO contributions to this topic, partly in cooperation with ICIMOD, are particularly important (ICIMOD and FAO 2006 and FAO 2005). FAO is currently preparing a publication of special significance titled 'Climate Change and Food Security'. Water and food could become a major challenge for the HKH water tower, especially considering the increasing population and rapidly growing economy of the region, with all its consequences for water supply in the adjacent lowlands. Hence, integrated studies about water and development in Himalayan watersheds are very important tools for calibrating climate change projections (Schreier et al. 2006). Finally, let's keep in mind that 2005-2015 is the UN International Decade for Action 'Water for Life'!

Climate change and disaster risk reduction

The IPCC report (2007b) shows a high probability that heavy rains and extreme events could increase in the monsoon region. This will have effects on runoff, erosion, sedimentation, and floods. Disaster risk reduction (DRR) will become a much more important challenge for the HKH region. Cross-border regional cooperation with early warning systems and transparent data exchange will be indispensable. Moreover, glacier retreat will produce an increasing number of lakes inside or just outside the rapidly changing permafrost zone and, therefore, special attention must be given to the potential for glacial lake outburst floods (GLOFs). Disaster risk reduction will depend on optimal teamwork between remote sensing experts and highly competent fieldwork specialists. Equally important is the rapidly growing amount of construction of small and large dams for hydropower and water retention. The last years and months have shown impressively the catastrophic effects of earthquakes and extreme rainfall on these man-made constructions in mountain areas (ICIMOD and UNEP 2007, Zimmermann 2008). Perhaps we should think about how the mountains of the world will look in the middle or at the end of our century. Perhaps in every mountain valley we will see a series of dams for energy, irrigation, urbanisation, and industrialisation?

Heavy rainfall and floods are normal processes of nature. They only become catastrophes because of human construction and habitation. If climate change is becoming a reality, do we have to correct the changing seasonal water flows with technical constructions? The conclusion is clear: reliable data about changing climate and hydrology all over the HKH region is vital to disaster risk reduction, especially in the coming decades.

It may be of interest to note that I proposed a research project more than 20 years ago, in a learning process during the first five years of ICIMOD, for a fully equipped training and experiment site in Nepal (Messerli in Ives et al. 1987), hoping that other countries in the region would follow suit (Figure 2). The donor agencies didn't see any priority need for such a project. It failed, but the idea survived and is perhaps even more important today with regard to environmental change. Information about the whole cycle, from precipitation and evaporation, to runoff and soil moisture, is fundamental for a better understanding of the connections between climate change and ecosystem services, biodiversity, land use, and livelihoods at different altitudes.

Preserving biodiversity, ecosystem services and protected areas

The UN General Assembly declared 2010 as the International Year of Biodiversity. What will be the contribution of the HKH region? ICIMOD and other institutions have published several most interesting reports in connection with biodiversity, forestry, land use, and protected areas, but an overview of the HKH region is still missing. We should keep in mind the fascinating variety of ecosystems and landscapes represented, with annual precipitation of less than 0.2m in the most western part, and more than 2m, and in some places exceeding 4m, in the eastern part. Moreover, the dominant precipitation in the south is caused by the summer monsoon circulation, and in the north and over Tibet, by the boreal winter circulation. All this means that biodiversity and ecosystem services are highly diversified, and a regional approach with selected test sites representing these highly different sub-regions is urgently needed. A planned conference in November 2008 will determine if such a comprehensive approach is realistic and feasible.

The Millennium Ecosystem Assessment (MEA) published a synthesis report for decision makers with some excellent tables to explain the complexity of ecosystem services (Figure 6). Changes in drivers that indirectly affect biodiversity, such as population, technology, and lifestyle (upper right corner of figure), can lead to changes in drivers that directly affect biodiversity, such as fishing or the application of fertilisers (lower right corner). These result in changes to ecosystems and the services they provide (lower left corner), thereby affecting human wellbeing. These interactions can take place on more than one scale and can cross scales. For example, an international demand for timber may lead to a regional loss of forest cover, which increases flood magnitude along a local stretch of a river. Similarly, the interactions can take place across different time scales. Different strategies and interventions can be applied at many points in this framework to enhance human wellbeing and conserve ecosystems (MEA 2005).

Figure 6 provides an excellent guideline for a common approach to the very different ecosystems from the warm lower to the cold higher belts, and from the extreme dry to the extreme humid parts of the HKH mountain system.

The changing environment and impacts on livelihoods

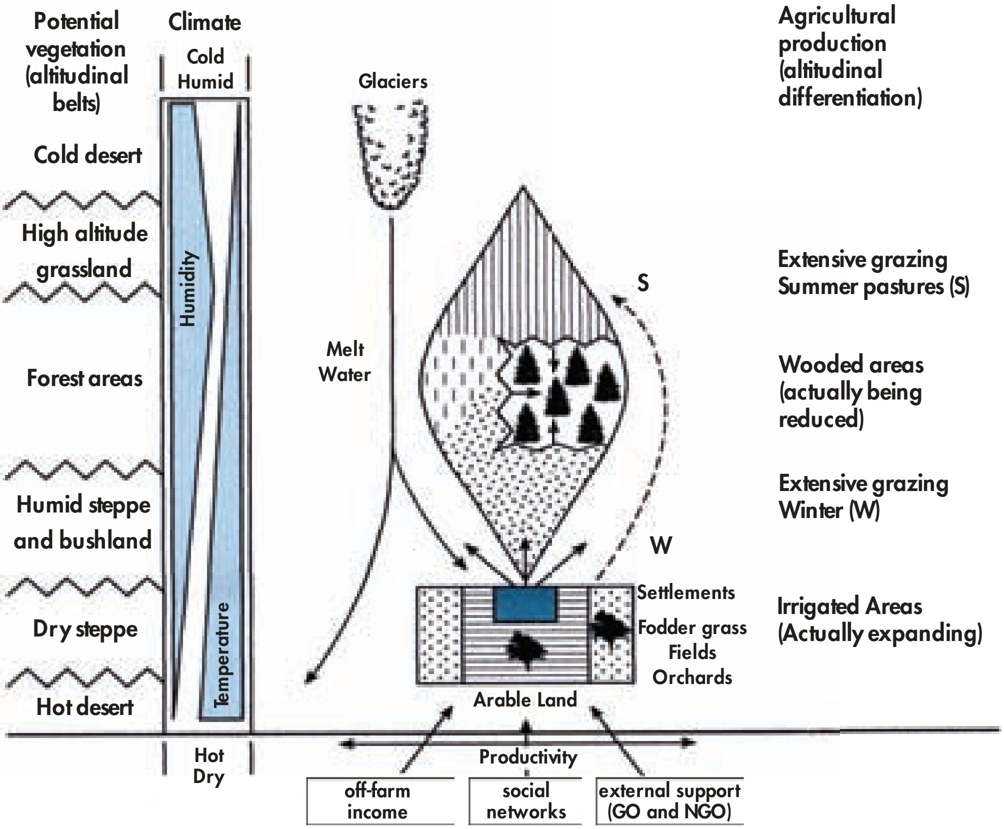
Global and regional climate change projections are highly generalised and we have discussed how difficult it is to downscale the results to the valley or village level. However, higher temperatures and more extreme precipitation and runoff events can be assumed. If we want to apply these changes to a certain place or village and its population, then we first have to understand the human-natural system. An instructive example has been developed for the village of Bagrot in the Karakorum as shown in Figure 7 (Winiger and Börst 2003).

Winiger and Börst analysed climate and hydrology, irrigated and non-irrigated land use systems, and summer and winter grazing land in different altitudinal belts. Based on this information, the

Figure 6: **Millennium Ecosystem Assessment: conceptual framework of interactions between biodiversity, ecosystem services, human well-being, and drivers of change.**

Taken from Millennium Ecosystem Assessment, Ecosystems and Human Well-being, Synthesis (MEA 2005), p.7. Reprinted by permission from the World Resources Institute, Washington

Figure 7: **Conceptual analysis of the village of Bagrot in the Karakorum, Pakistan – Vertical arangement of natural vegetation and agricultural productivity**



⊕ POTENTIALS

- Suitable Land for Irrigation (debris fans, glacial or fluvial terrasses)
- Meltwater from glaciers or snow fields (no temporal limitations)
- Access to grazing areas and forests (abundant)
- Short distance to Karakorum Highway (KKH) and to central places

⊖ LIMITATIONS

- **Hazards** (rock falls, floods, debris flows, avalanches)
- **Melt water** (temporally limited)
- **Grazing areas, forests** (scarce)
- **Long distance to KKH and to central places**

This basic knowledge is an important tool for observing and measuring future environmental changes (slow trends and extreme events) in order to understand and disentangle natural and human driving forces and to prepare the necessary adaptation measures in time. For further explanation see Winiger and Börst 2003.

potential and limitations could be evaluated, and changes in natural and human systems could be integrated and used for projections. The authors showed the changes in the land use structure with lower or higher temperatures: two harvests per year below 2000-2500m, less productivity with increasing altitude (also for irrigated land), and vegetation or desert in the valley bottoms depending on the amount of precipitation. The distance to the next road, in this case to the Karakorum Highway, determines cash crops (e.g., seed potatoes), and if there is a monetary market system or self-sufficient agriculture in isolated areas, with all the implications for livelihoods, and poverty. Such schemes, adapted to different climatic sub-regions, and also to different cultural sub-regions (World Bank and DFID 2006), could provide an excellent base to enable local communities to observe and understand any degree of human or naturally induced environmental change.

Migration can also have serious effects on the balance between potentials and limitations. Migration can lead to serious social problems and a missing labour force, which must be replaced by national and even international migration from neighbouring mountain areas. The World Bank (2008) has analysed the significance of migration and the amount of remittances in countries of the HKH region. For Nepal, the stock of emigrants is around 750,000, compared to a total population of 28 million. In 2007, remittances were US $1,600 million, or almost 20% of GDP. In Pakistan, the number of emigrants is 3,420,000 compared to a population of 159 million, with remittances of US$ 6,100 million. It is a pity that we do not have separated data for highland and lowland emigrants, hence, the figures for Nepal and Pakistan must be interpreted cautiously and the figures for China, India, and Bangladesh do not provide any mountain relevant interpretation. There is no or insufficient data for Bhutan, Afghanistan, and Myanmar.

The above-mentioned common challenges are by no means complete; they are more an answer to the main constraints of changing climate, water resources, and ecosystem services. Two points are of special interest. First, environmental change concerns natural resources and human wellbeing. Without bridging the gap between natural and social science studies, especially in a time of ongoing climate change, we shall never understand the livelihood conditions in a mountain environment (Messerli and Messerli 2008). Second, it is exciting to see in these different sections about common challenges the interaction between global, regional, national, and local scales. The constraints of climate change are presented on a global or continental scale, the challenges are shifting between regional and local levels, and the Millennium Ecosystem Assessment (Figure 6) tries to connect global, regional, and local levels in a short-term and long-term assessment.

Regional Mountain Cooperation – Common Concerns

An unpublished report by UNEP (2007) shows a fascinating, but politically difficult, process in and for the mountains of the world (Figure 8). Mountain systems are usually home to several independent countries. These countries usually begin to cooperate regionally because they experience common constraints and must overcome common challenges for sustainable

Figure 8: **Existing mountain conventions and planned new initiatives for new conventions** (UNEP 2007)

Strengthening mountain partnerships through legally binding agreements: Challenges and opportunities

(UNEP, FAO, Mountain Partnership, EU)

Alpine Convention (1991), 1995, 2002
Carpathian Convention (2001), 2006

Initiative for the Caucasus
Initiatives for south-east Europe
Initiative for the Central Asian mountains

Consortium for Sustainable Development of the Andean Region (CONDESAN)
International Centre for Integrated Mountain Development (ICIMOD) in the Himalayas, 1983

development, one example is the Alpine Convention, which led to the Carpathian Convention, both legally binding agreements. These conventions have a high significance for science and policy in mountain areas, and also for development and cooperation.

UNEP is supporting new initiatives in mountain regions where there are many ongoing conflicts like the Caucasus, the Balkans, and Central Asia (Figure 8). The road to a solution to these conflicts will be long and difficult, but no sustainable or long-term development will be possible without a certain degree of cooperation. The goodwill of the local population is very important, but this will grow with the engagement of the scientific community and the political authorities, and will depend on the improvement of the system supporting their lives.

The responsibility of the scientific community

The International Council for Science (ICSU 2006) published the following statement in its strategy plan 2006-2011: "Strengthening science for society means being aware of the emerging developments in science and the potential of science to address societal needs. Science is a cooperative exercise that thrives on open international interaction and exchange. It transcends national boundaries". ICSU Statute 5 is even more important for the future of the HKH region: "The Principle of the Universality of Science is fundamental to scientific progress. This principle embodies freedom of movement, association, expression and communication for scientists as well as equitable access to data, information and research materials. ICSU actively upholds this principle, and, in so doing, opposes any discrimination". China, India, Pakistan, Nepal, and Bangladesh are members of ICSU. This means that the scientific communities of these countries have a responsibility to intervene if certain data, for example concerning climate change and water resources, are classified and not accessible. Water resources in the HKH region are a common concern. The statements of ICSU and the universality of science are highly relevant to such common concerns, otherwise "it can have serious consequences for science and for society" (ICSU 2006: p.39).

The responsibility of political authorities

Adopted in 1991, the Alpine Convention brought together all the Alpine countries and the European Community to collaborate on mountain development and protection, and has provided much inspiration in this regard, particularly in Europe, Asia, Latin America, and Africa. Following this, the International Year of Mountains 2002, also had a very positive effect on new initiatives.

The Carpathian Convention entered into force in 2006, only five years after the first initiative by the government of the Ukraine. Collaborative arrangements such as the Alpine and the Carpathian Conventions have proven themselves to be useful approaches and powerful incentives for mountain-related action and support (UNEP 2007). In relation to successful political cooperation, focusing on a river basin could be of great interest in the HKH region. As an example, I quote the headlines of the International Commission for the Protection of the Rhine (ICPR 2008): "Nine states – one river basin. For the benefit of the Rhine and of all its tributaries, the members of the IPCR Switzerland, France, Germany, Luxemburg, Netherlands and the European Commission successfully cooperate with Liechtenstein, Austria, Belgium and Italy". Focal points of this cooperation are the sustainable development of the Rhine, its floodplains, and the good state of all waters in its watershed. In 2003, a new convention for the Rhine entered into force. Currently, activity is focused on the following objectives and tasks: the chemical and ecological state of the river; holistic flood prevention and flood protection; and the implementation of European regulations and directives. Progress since 2003 is impressive: water quality and the biological state of the river have improved; animal and plant species have increased; flood retention areas have been created; and, since 2006, salmon and other fish are again migrating upstream from the North Sea.

Another example is the 1995 Agreement on Cooperation for the Sustainable Development of the Mekong River Basin. Water sharing is discussed between the four lower riparian states, Thailand, Vietnam, Laos PDR, and Cambodia; however, China and Myanmar are not yet fully participating (UNU 2008). After two decades of work by the international law commission, an international convention has not yet entered into force.

Mountain conventions or river conventions not only point the way to the future, but also show the political difficulties in reaching the goal. Climate change and scarce water resources will increase the pressure to avoid conflict and find peaceful solutions. We should keep in mind the following quotation: "If there is a political will for peace, water will not be a hindrance. If you want reasons to fight, water will give you ample opportunities" (Lonergan 2005).

Figure 8 should remind us that ICIMOD was founded long before the Alpine Convention and, I may add, that the Hindu Kush-Himalayas are probably more vulnerable than the Alps, as the common constraints and concerns discussed above show. As we have seen, the concept of common goods may not be realistic, but common concerns are a reality, and our common future is also a reality. Solidarity and cooperation between large and small nation states are crucial to manage these common concerns, and for this great task ICIMOD could be the meeting point. But ICIMOD can only fulfil this role if there is a will for solidarity and dialogue, and for economic growth in harmony with the natural environment. At the beginning of the new millennium, Kofi A. Annan, UN Secretary-General said on 5 June 2000: "We celebrate the World Environment Day in the knowledge that environmental issues are inextricably linked to those of peaceful coexistence, international cooperation and economic development".

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Towards a Better Common Present

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The term 'sustainable development' came into widespread use following the submission of the report titled 'Our Common Future' in 1982 by the UN Commission on Environment and Development, chaired by Ms Gro Harlem Brundtland. The thrust of the report was a plea to adopt lifestyles and development strategies that would help to harmonise the needs of today and tomorrow, so that short-term goals do not jeopardise long-term development opportunities. In other words, equity in ecological terms should cover both intra-generational and inter-generational time dimensions. By choosing the title 'Our Common Future', the Brundtland Commission wanted to emphasise that whatever our political frontiers may be, ecologically, our fate is intertwined. This is clear from the potential impact of anthropogenically induced changes in climate, leading to adverse changes in temperature and precipitation, with the resultant droughts and floods as well as a rise in sea level.

Swaminathan (1988) emphasised that there can be no better common future without a better common present. This calls for mainstreaming the social dimension in development strategies. The social sustainability of development pathways is as important as environmental and economic sustainability. This is because it is the poor nations, and the poor in all nations, particularly children and women, who suffer the most from the adverse impacts of unsustainable development. The goal of sustainability science is, therefore, the mainstreaming of the principles of ecology, economics, social and gender equity, and ethics in all technology development and dissemination strategies. At the operational level, this will involve adopting a pro-nature, pro-poor, pro-woman, and pro-livelihood approach to designing research and development programmes. The biovillage model of human-centred development fostered by the MS Swaminathan Research Foundation (MSSRF) is based on this concept.

The three major components of sustainability science are awareness, analysis, and action. Education is the key to awareness generation. Alienation from nature has resulted in children developing what Richard Louv (2005) has termed 'nature deficit disorder'. Nature deficit disorder among children leads to attention deficit disorder, depression, and obesity. The following two steps can help to prevent the onset of the nature deficit disorder:

1 First, students in every school and college can be trained to prepare a 'Charter for Nature' for their respective village, town, or city. Such a Charter will help youth to understand the state of the life support systems like land, water, biodiversity, forests, and common property resources in the place where they live and study. Another aspect of the

Charter for Nature is an understanding of the population supporting capacity of the ecosystem. This will help to underline the need to stabilise human and animal populations to the level that the ecosystem can support in a sustainable manner.

2 The tools of information communication technology (ICT) like the internet, cable TV, FM radio, and mobile phones provide uncommon opportunities for spreading information on the science and art of sustainable development. The internet-mobile phone synergy helps to achieve last mile and last person connectivity and provides an excellent opportunity for spreading ecological literacy.

The UN Millennium Development Goals (MDGs) represent a global common minimum programme for sustainable human security and wellbeing. The eight MDGs to be achieved by 2015 provide a pathway towards sustainable human security. Among them, the first relating to the elimination of hunger and poverty is the most important for creating the substrate conditions of peace and security vital to sustainable development. The Roman philosopher Seneca said over 2000 years ago "A hungry person listens neither to reason nor religion, nor is bent by any prayer". The green revolution in wheat and rice of the 1960s provided a breathing space for achieving a balance between population growth and food production. Even before the term 'green revolution' was coined by Dr William Gaud of the US Department of Agriculture in late 1968, I cautioned against adopting agronomic practices that will undermine the green revolution and convert it into a greed revolution. Addressing the Indian Science Congress on 4 January 1968, at Varanasi, I said,

> "Intensive cultivation of land without conservation of soil fertility and soil structure would lead ultimately to the springing up of deserts. Irrigation without arrangements for drainage would result in soils becoming alkaline or saline. Indiscriminate use of pesticides, fungicides and herbicides could cause adverse changes in biological balance as well as lead to an increase in the incidence of cancer and other diseases, through the toxic residues present in the grains or other edible parts. Unscientific tapping of underground water would lead to the rapid exhaustion of this wonderful capital resource left to us through ages of natural farming. The rapid replacement of numerous locally adapted varieties with one or two high yielding strains in large contiguous areas would result in the spread of serious diseases capable of wiping out entire crops, as happened in the Irish potato famine of 1845 and the Bengal rice famine of 1942. Therefore, the initiation of exploitative agriculture without a proper understanding of the various consequences of every one of the changes introduced into traditional agriculture and without first building up a proper scientific and training base to sustain it, may only lead us into an era of agricultural disaster in the long run, rather than to an era of agricultural prosperity."

I later introduced the concept of an 'ever-green revolution', to enhance productivity in perpetuity without associated ecological harm. There are two major ways of achieving an ever-green revolution – organic farming and green agriculture. Organic farming precludes the use of mineral fertilisers, chemical pesticides, and genetically modified crops. Green agriculture, in contrast, permits the use of integrated pest management, integrated nutrient supply, and other agronomic methodologies that involve the use of the minimum essential chemical fertilisers and pesticides. For farmers with cattle and other forms of livestock, organic farming is easier.

The conservation of natural resources like soil, water, flora, fauna, and forests will ultimately decide the future of agriculture. In this context, the conservation of the Himalayan ecosystem is extremely important, as demonstrated by the wide range of studies carried out by the scientists of ICIMOD. ICIMOD has shown how the ecological, geological, and hydrological security of the Himalayas can be protected and enhanced. The integrity of the Himalayan ecosystem will also decide the fate of Indo-Gangetic agriculture, which is the breadbasket of India. There is a growing apprehension that damage to Himalayan soil and water resources, as well as its priceless biodiversity, is increasing due to anthropogenic pressures. Floods are increasing on the Indo-Gangetic plains, both in severity and frequency. The early ice melt in the Himalayas and the receding of glaciers will cause more frequent floods resulting in enormous damage to life and livelihoods. Because of the profound influence of the Himalayas on the wellbeing of the people in the plains, the Government of India has included a Mission for Sustaining the Himalayan Ecosystem under its National Action Plan on Climate Change.

The effective implementation of the Mission for Protecting the Himalayan Ecosystem will depend greatly on the vast amount of knowledge gathered by ICIMOD. The Himalayas hold great spiritual significance in the minds of millions of people on the Indian subcontinent; they are the priceless heritage of humankind. ICIMOD, as the custodian of this invaluable blessing of nature, will have an even greater role to play in protecting not only the agriculture of the Indo-Gangetic plains but, more importantly, the life support systems that make it possible for nearly a billion people to sustain their livelihoods.

To conclude, if farm ecology and farm economics go wrong, nothing else will go right in agriculture. The ever-green revolution technologies show the way to sustainable agriculture. This again will be possible only if harmony with nature becomes a non-negotiable human ethic.

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Preparing the Himalayas to Meet the Challenges of Climate Change: An Area for ICIMOD to Take the Lead

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Challenges

The world has changed profoundly since ICIMOD was established 25 years ago. The principal global environmental problems of the present day, such as climate change and the spread of invasive alien species, were barely public issues in the 1980s. Changes have also occurred in many other ways. The world today is much more globalised and inter-connected. Migration is now a widespread global phenomenon with new places affected by the movement of people. The effects of migration on mountains may include prosperity, as well as depopulation and the degradation of hill slopes. Among the countries with Himalayan connections, China and India are slated to become the future economic powers of the world. Nepal, where ICIMOD's office is located, now has a democratically elected government and is on the way to shedding the last vestiges of monarchy. However, life in the Himalayas is hardly any better. Inaccessibility, marginality, isolation, and poverty, which are generally associated with mountains, still affect the people of the Himalayas. Although some 'trickle-down effect' from the growing global economy is evident, Himalayan people remain poor with only a limited amelioration of physical hardships, in spite of the development of road networks and information technology. In many areas, the supply of ecological services has actually decreased. Firewood continues to be the main source of cooking energy. Literacy has increased substantially; however, water supply per person and its quality are on the decline. Dependence on lowland areas for food has increased (Table 1). Social conflicts continue to trouble the Himalayas, and wars, insurgencies, and forced human migration are integral components of the mountain societies.

In brief, while deforestation and resultant hazards such as erosion and floods were major concerns in the 1980s when ICIMOD came into existence, climate change and its consequences are the major threats now. It is ironic that people who barely have access to fossil fuel are the most vulnerable to the global warming caused by its combustion. In this article I attempt to (i) briefly analyse the strategy employed by ICIMOD all these years to tackle the various problems and challenges that humans encounter in mountains; (ii) discuss the importance of the Himalayas in relation to climate change; and (iii) give an outline of what more could be done to achieve the desired level of impact on the development processes of the Himalayan region.

Table 1: Changes in the Himalayas during the last 25 years (primarily based on experiences in India and Nepal)

Parameter	Change (+increase, - decrease)
Environmental background	
• Deforestation	Not as alarming as predicted in the 1980s
• Forest degradation (e.g., due to lopping of branches and forest litter collection)	Continues to be a matter of concern
• Loss of springs	Continues to be a concern
• Water pollution	+
• Damming of rivers	+ a matter of much debate
• Erosion	High, but poorly documented
• Biodiversity	Poaching a serious problem; lichens and native bamboos also badly affected
• Fire frequency	+
• Forest composition	Spread of pines (*Pinus roxburghii*)
• Spread of exotic invasive alien species	+
Forest management and conservation	Still very much state governed, but more particip-atory than in the past with the strengthening of village level institutions, particularly in Nepal. The importance of biodiversity, carbon, and other ecosystem services is now being realised.
Climate change	
• Temperature rising	Reported to be more than global mean
• Glaciers retreating	Faster than elsewhere
Social Factors	
• Poverty	Marginal reduction
• Sex ratio	-
• Out migration	+
• Literacy	+
• Participation of women and socially weaker sections	+
• Forest dependence	Still very high
• Dependence on lowland areas for food	Still high (nearly 50% of the total food requirement in many areas)
• Fruit production	
• Use of modern energy	+
– for lighting	+
– for cooking	Negligible
• Road network and transport	+
• Social Conflicts	+, insurgency, violence, discontent in many areas
Research	Still poor, perhaps on decline in most countries, except China.

ICIMOD's Strategy to Address Problems

Over the past 25 years, ICIMOD's primary strategy to address the problems of the Himalayan region has been (i) identification of the problems; (ii) development of projects in collaboration with one or two partners and applying for grants; and (iii) implementation of projects either alone or in collaboration with partners. Clearly, in this 'do alone or in partnership approach' the number of projects that can be carried out is limited by the number of staff working at ICIMOD, which was always small. I argue in this article that, apart from this strategy, ICIMOD should play the role of a facilitating agency for a number of institutions working in the Himalayan region. Given the vastness and heterogeneity of the Himalayan region, not much can be achieved through one or two institutions. ICIMOD can play the role of a facilitator by developing a consortium of institutions and individuals working in the Himalayan region, and by contributing to the development of a scientific base for the Himalayan countries. With this approach, ICIMOD would be able to function on a much larger scale bringing about changes in developmental processes. However, the task of networking could be enormous.

Significance of the Himalayas in Global Climate Change

Consisting mainly of an east-to-west arc of mountain chains more than 2500 km in length, the Himalayas are viewed with great, often divine, respect throughout much of Asia. The respect originates from their extraordinary dimensions, and the presence of a great variety of plants, which has led to the development of a famous oriental medicine system. The Himalayas determine the climate for much of South and East Asia, where more than half of the global population will live in the future. The economy of this region owes a lot to the rivers (ten river basins are connected with the Himalayas) that flow from the Himalayas-Karakoram-Pamir-Tibet high mountain region. The Gangetic system alone supports about 500 million people. These mountains of extraordinary height (the region contains 9 of the 14 tallest peaks in the world, including Everest at 8,848m) keep the adjacent plains in the south warm and moist by intercepting cold winds from the north and trapping the moist winds rising from the oceans in the south. The establishment of the monsoon pattern of rainfall in Asia is attributed to the rise of the Himalayas. The immature topography of these young and still rising mountains (established 30-40 million years ago) is highly vulnerable to erosion and landslips. The extraordinary altitudinal range has led to the establishment of a variety of forest types (more even than in the Amazon), ranging from tropical dipterocarp forests along the foothills to alpine forests of fir, birch, rhododendron, and juniper (Singh and Singh 1992). The region has some 9000 plant species, of which about 3000 are endemic.

The Himalayas have more snow and ice (about 35,000 km^2) than any other part of the world outside the polar caps. The Himalayan glaciers have not only produced perennial rivers, they also play a significant role in influencing climate through their albedo effect. There is evidence to suggest that the Himalayas are warming at a faster rate than the global average, and many of the Himalayan glaciers are receding at faster rates than glaciers in other regions (Xu Jianchu et al.

2007). The impact of the disruption of this hydrological linkage on the Himalayas and the Gangetic system is not known. A significant upward shift in the optimum elevation of species is reported to have already occurred during the last century in different parts of the world (Lenoir et al. 2008), and species migration is likely to be much more rapid in the future with more warming. Being one of the largest wilderness areas in the world, the Himalayas provide shelter to species migrating under the influence of temperature increases. Thus, the region is of great importance in any adaptation strategy dealing with climate change. It may be pointed out that much of the success in the green revolution in India and Pakistan was based on the plains, which are served ecologically by the Himalayan rivers.

Socially too, the Himalayas are going to draw public attention in the warming world, as many changes in human migration and economic activities are likely to occur in the future. Controversies over the construction of dams and the relationship between deforestation in the Himalayas and floods in Bangladesh have never completely subsided.

Lack of Data on Climate Change and the Role of Himalayan Forests

Except for some fragmentary data on glaciers, almost nothing is known about the Himalayan region with regard to climate change. The IPCC, in its recent report, refers to the Himalayas as a 'white spot' (region of scarce data). The region doesn't even have an adequate number of meteorological stations, let alone a carbon tower for measuring carbon fluxes. We have not yet collected data on the phenological responses of trees and birds to climate change, even though Himalayan forests are known for their rich biodiversity, ecosystem services (particularly carbon sequestration), and biophysical impact on climate change. Recent modelling exercises indicate that, depending upon several factors including the type of the forest, snow cover, and other environmental conditions, forests can have a cooling, as well as a warming effect on climate (Bonan 2008). There is a need to investigate the role of Himalayan forests from the standpoint of their biophysical impact on climate. The high forest cover (up to 3000-4000m in altitude) is a big source of vapours that are released through evapotranspiration. To what extent can their cooling effect moderate global warming?

Possible ICIMOD Initiatives

Climate change is the overarching environmental shift that can affect our future in many ways. Being the most important institute in the mountains, ICIMOD has a major responsibility to address the issues related to climate change and the sustainable development of mountains and the adjacent plains. The following objectives may help ICIMOD to set its long-term climate agenda:

1. To train students in conducting research and writing articles in research journals

2 To develop a network of institutions and individuals to educate and conduct research on climate change in relation to the Himalayas
3 To create climate-based courses for the Himalayan region and incorporate these in university curricula
4 To promote understanding of the geo-ecological and anthropogenic connections between the mountains and plains

Dr Schild, the present Director General of ICIMOD, has already taken some steps towards developing a consortium of Himalayan universities, with the support of several outside institutions interested in the Himalayas. The Himalayan University Consortium (HUC) at its first meeting decided to initiate several mountain specific courses in Himalayan universities. Attended by the vice chancellors of universities from all the major Himalayan countries (India, China, Pakistan, Nepal, Afghanistan, and others), the Consortium decided to begin with a graduate course on climate change in the Himalayas. The purpose of the Consortium is to run courses, as well as to develop centres of excellence in research on issues like mitigation and adaptation to climate change, greenhouse gas profiling of energy production, and ecosystem responses to climate change.

The relative position of Himalayan countries in science is still low. With the exception of China, which is making great progress in science, the ranks of the Himalayan countries, measured in terms of research published in cited journals, is on the decline. In some countries, research processes have yet to be established.

In India, for example, fresh talent is attracted to industry and service sectors, not many are interested in research and academia. The few that remain in academia go to biotechnology, pharmaceuticals, and the like, where there are more jobs. Ecology and other disciplines that involve people and field studies are not favoured. The Indian universities themselves are not in the best health as far as research is concerned. Isolation and lack of access to journals and outside contacts over several decades has made the Indian university system moribund. Although some of these obstacles have been partly removed, and more money is now available in universities, there has been little progress in recent years, and India's position among the countries of the world is declining continuously (8th in 1980, 13th in 1990, 21st in 2005). The problem is not only that the number of research publications per person is low, the number of scientists is also inadequate. India has 157 research and development scientists/engineers per million, which is 1/50th of that in South Korea and 1/30th of USA or Japan (Prathap 2004). In addition, the scientific knowledge base is weakest in mountain states. The result is that, with a few exceptions, all excellent research papers on the Himalayas are being contributed by outsiders, despite the creation of a number of research institutes and universities in the Himalayan region, at least in India. There is a need to overhaul the system. Immediate solutions need to be found, as waiting for science in Himalayan countries to come into its own will take too long. There are a few steps that can easily be taken by ICIMOD in collaboration with other institutions. Research students in the Himalayan region need training in (i) how to do ecology and other field studies, and (ii) how to write research papers for quality journals. Unfortunately, universities and institutes in the Himalayan region do not have properly organised systems to address these issues. The problem is so acute that reviewers of research journals often return research manuscripts, as they need to be re-written. ICIMOD could train 200-300 researchers in these two areas in a period of three years or so with the help of the human resources available in Himalayan universities and research institutes and outside organisations interested in the Himalayas.

A good linkage between Himalayan institutions as well as linkages with institutions outside the region will go a long way in improving the research capacity of local people on Himalayan issues. Good training and mentoring to 200-300 students over a period of time may prove to be a good beginning.

Research and Education on Climate Change through Networking

It is strongly felt that, at least in some places, courses on Himalayan-specific issues need to be conducted. A certain level of education and training is necessary to carry out such activities. ICIMOD needs to develop a network of experts on the Himalayas to achieve the goal of combining teaching and research on the region. The programme could be started with climate change, the overarching environmental shift on a global scale which is going to affect all spheres of our planet and life.

ICIMOD can develop several mechanisms to create a network for climate change in the Himalayas: (i) create chairs for top-notch experts so that the continuity of the academic groups that they represent is maintained; (ii) contract the services of these experts for a few days or weeks to run a course or assist in developing research programmes; and (iii) continue to develop the Himalayan University Consortium, for which preliminary steps have already been taken.

Taking Up the Cause of Mountains in International Forums

ICIMOD needs to create a mountain group and take up its cause at various forums – regional, continental, and global. Whatever data we have on climate change, they clearly suggest that mountains are among the most vulnerable regions on the planet; perhaps elevated surfaces are warming faster than lowland areas. Interestingly, mountains are not identified as a separate group in international meetings on climate change (COPs). In order to have effective representation of mountains at various meetings dealing with climate change, ICIMOD should have a backing of reliable data published in proper research journals. This may be costly, but there is no other way to participate effectively in debates involving several parties. The success of negotiations largely depends on (i) scientific evidence, (ii) educating people, and (iii) the commitment of the concerned governments.

To represent the Himalayan case in international forums, we need data, for example on the role of Himalayan forests in carbon storage and the scale of forest degradation and deforestation, and their impact on CO_2 emissions, the mass balance of glaciers, river flows, and so forth.

Long-term ecological research (LTER)

LTER was initiated in the USA about 30 years ago by the National Science Foundation (NSF). Subsequently, the National Ecological Observatory Network (NEON), the Global Lake Ecological Observatory Network (GEON), the Water and Environmental Systems Network (WATERS), Oceans Observatory Initiative (OOI), and National Phenology Network (NPN) were established. Their synergies may lead to many new research areas.

"All these networks recognise the importance of coordinated sampling that allows information for multiple sites in disparate environments to address the basic ecological question: How to meet the needs of a sustainable future in an increasingly connected world?" (Robertson 2008)

Network of Long-Term Ecological Research Stations

ICIMOD can contribute to establishing a network of research stations along the lines of the National Ecological Observatory Network (NEON) and the long term ecological research (LTER) stations, representing the various ecoregions of the Himalayas (see box). Apart from gathering meteorological data, these stations need to be equipped to monitor the carbon fluxes of ecosystems, the phenological responses of key species, the direct impact of forests on climate (through evapotranspiration and albedo effects), and changes in agricultural systems and people's perception and possible adaptation measures. Although the Himalayas are not known for their extensive agricultural fields, mountains can be used to develop effective adaptation strategies. For example, rising temperatures can severely affect wheat production in the Indo-Gangetic plains, which has played a major role in overcoming food shortages in the previous century. If wheat can no longer be produced in sufficient quantities in the plains, the foothills could be used to grow wheat in certain areas. The natural vegetation lost in the process could be developed in areas rendered unsuitable for the cultivation of crops due to global warming.

Conclusions

No single organisation alone can address the issues of sustainable development. Being one of the largest and most complex wilderness areas of the world, the Himalayas present difficult problems to those interested in environmentally sustainable development. ICIMOD, or for that matter any organisation, is too small to have a perceptible impact on the Himalayas. However, it can play the role of an effective facilitator, given the name and prestige that have come to be associated with it. Much of its success in addressing the needs of a sustainable future will depend on its capacity to establish linkages with and between various Himalayan institutes, universities, and individuals. However, this alone will not be enough. ICIMOD must take a few immediate steps to create a healthy research culture in the Himalayan countries, employing the services of experts who continue to be active. Adequate 'research literacy' is necessary to collaborate effectively at the international level. Until now, ICIMOD has not taken any serious initiative in this direction. What ICIMOD usually does is collaborate directly with other institutions. The scale of its collaborations remains small, as the number of persons working at ICIMOD is limited. Such collaborations could be expanded several-fold by promoting networks involving all those who work in the Himalayas, or are interested in the region and are capable of making a contribution. In that case, the role of ICIMOD has to be primarily one of a facilitator. To achieve this, the organisation would require a different kind of strategy and competence. In Dr Schild, ICIMOD has a determined and passionate leader; the chances of success have never been so bright as today.

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The Environment of the Tibetan Plateau and its Sustainable Development

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Long-term studies of the formation, evolution, and zonal differentiation of the environment of the Tibetan Plateau have provided a significant scientific foundation for its resources utilisation, environmental protection, and sustainable development.

Introduction

The Tibetan Plateau covers a quarter of the land area of China and is the region with the highest elevation on Earth. It has unique environments and ecosystems and is a critical region for response to climate change.

Over 35 years ago, in 1973, the Chinese Academy of Sciences (CAS) organised a series of integrative expeditions on the formation, evolution, environment, and development of the Tibetan Plateau with multi-disciplinary scientists from institutions and universities from all over China. This was followed by a scientific expedition in Xizang Autonomous Region (Municipality) in the 1970s. Some other scientific surveys were carried out in the Hengduan Mountains, Namjagborwa area, and Karakorum-Kunlun and Hon Xil area in the 1980s. In the 1990s, a project on the formation and evolution, environmental changes and ecosystems on the Tibetan Plateau was initiated by the Ministry of Science and Technology in conjunction with CAS. The project 'Formation and Evolution of the Tibetan Plateau and its Resources and Environmental Effects' was funded by the National Basic Research Program of China from 1998 to 2003. Following this, a further project on the 'Environmental Evolution of the Tibetan Plateau and its Response and Adaptation to Global Changes' was again funded by the National Basic Research Program of China from 2005 to 2010.

The Chinese Academy of Sciences, as a representative of China, has energetically joined in the activities of ICIMOD since its inception 25 years ago. ICIMOD, as a regional intergovernmental knowledge, learning, and enabling centre has successfully played the role of providing regional knowledge synthesis, training and capacity building, and advisory services for sustainable livelihoods and poverty alleviation. The results of CAS's studies of the environment and regional sustainable development on the Tibetan Plateau have made, and will continue to make, a good contribution to ICIMOD's mission.

Natural Environments of the Tibetan Plateau

The uplift and tectonics of the Tibetan Plateau have formed a wide variety of high mountains and deep valley patterns, on which the Himalayan mountain range, the Tanggula mountains, and the Kunlun mountains make an imposing landform framework. The elevation of the Tibetan Plateau averages about 4000m above sea level and reaches heights of 7000-8000m in the mountain areas. With high topography and a cold climate, the Tibetan Plateau has a vertical differentiation arranged in a clear pattern from the low-mountain tropical zone, to the mountain sub-tropical zone, plateau temperate zone, and alpine frigid zone.

The topographic configuration and atmospheric circulation determine the horizontal differentiation between natural vegetation zones. From the southeast to the northwest of the Plateau, vegetation changes successively from montane forest, through shrub and alpine meadow and alpine steppe, to arid desert.

This vast mountainous territory has a largely ethnic population. In this region, the natural resource that we consider to be most important, and which will probably receive most of our attention in the coming years, is water, which is fast becoming a very scarce resource. Six of the largest rivers in the world originate on the Plateau and hundreds of millions of people in China, South East Asia, and South Asia depend for their livelihoods on the water that these rivers carry to the plains. Therefore, the Tibetan Plateau is not only an important support system for social and economic activities, but also an ecological umbrella for east and south Asia.

Ecological Umbrella for East and South Asia

We would like to propose the term 'ecological umbrella' to describe the Tibetan Plateau, because it plays a very important role in protecting the environment and providing livelihoods for a large part of Asia, and even the rest of the world.

The Tibetan Plateau has been called the 'Roof of the World' and contains the greatest concentration of glaciers and permafrost soils outside the poles. According to reports, there are 34,465 glaciers on the Plateau, with a total area of 46,300 square kilometres. The Tibetan Plateau contains 77.4% of the total number of glaciers in China, and 82.6% of the total area of glaciers. These glaciers are the origins of rivers and provide freshwater for the millions of people living on the plateau, and also for the billion people living beyond.

The Tibetan Plateau has the greatest density of lakes in China. These numerous blue lakes and ponds form the highest plateau lake system in the world, present some of China's most superb landscapes. The total area of lakes on the Tibetan Plateau is approximately 38,000 square kilometres, about 38% of the total area of lakes in China.

Under the influence of their monsoon climate, the deep mountain valleys and secluded ravines are a sanctuary for a number of ancient forest trees. They can be classified into more than 100 families and 300 genera. Virgin forests cover about 113,000 square kilometres, with a volume of some 2.3 billion cubic metres. The forests growing in the deep mountain valleys and upper reaches of big rivers are of significance in the control of soil erosion, for water conservation, and as carbon sinks.

Grasslands cover about 50% of the total land area of the Tibetan Plateau and are important sources of food for animal husbandry and as carbon sinks. Livestock breeding also plays a large role in the socio-economic structure of the Plateau.

Farmlands cover about 0.5% of the total land area of the Plateau, mostly distributed in the basins, ravines, and valleys. Over the last decades, agricultural scientists and farmers have improved crop structures and increased crop production by introducing new breeds and varieties and by improving management techniques. The Plateau agriculture, with its enriched crop species, is unique among high-altitude farming systems in the world.

Sustainable Development of the Tibetan Plateau

Over the last 30 years, long-term studies of the formation, evolution, and zonal differentiation of the environment on the Tibetan Plateau have provided a significant scientific foundation for its resources utilisation, environmental protection, and sustainable development. China's central government and local governments are highly concerned about environmental protection and regional sustainable development of the Tibetan Plateau. A series of countermeasures have been efficiently implemented in the Plateau; examples include the following:

- In the south-eastern part, in the Hengduan Mountains, efforts have been made to convert farmlands on the steep slopes to forests and to rebuild farmlands on the gentle slopes into terraces to optimise project coordination and areal combination to strengthen the integrated control of soil and water loss and carbon sinks.
- In the rangelands, efforts have been made to implement the rangeland contract system of responsibility and to license the use of grasslands, and to develop artificial grasslands to overcome forage deficiencies in winter and spring.
- A network of field observations has been established in typical ecosystems to monitor the results of countermeasures and to collect long-term data for the study of environmental changes on the Tibetan Plateau.
- All engineering and industrial construction projects must conduct an assessment of their impact on the environment before implementation to ensure the balance between resource exploration and environmental protection.

We are very happy to see that the issues of environment and sustainable development have been included in ICIMOD's strategy. We anticipate that Chinese scientists will cooperate with ICIMOD on climate change, water and hazard management, and ecosystem services in the Hindu Kush-Himalayan region, and will make a new contribution to sustainable development in the region.

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