payment for environmental services by those using them to those adopting resource uses that secure biodiversity; equal, albeit differentiated, responsibilities on the part of developed countries for the Kyoto Protocol; and development of alternative technologies.

Public awareness and engagement – These include full disclosure and prior information to grass-root societies about the impacts of climate change. It is also important to engage the media and academic sector and facilitate policy dialogue and international cooperation.

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Glacier surges in the Karakoram Mountain range

Glacier-capped Mt. Kawagebo ('White Snow Mountain'), part of the Hengduan Mountain Range, is one of the most sacred landscapes for Tibetan people


He Bin

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The Melting Himalayas

Regional Challenges and Local Impacts of Climate Change on Mountain Ecosystems and Livelihoods[1]

This policy summary looks at reported and possible, future consequences of climate change in the greater Himalayan region. The main emphasis is on responses in high mountain phenomena like glaciers, permafrost, and avalanches; the implications for water resources, ecosystems, and hazards; and how these threaten regional populations. The assessment points to a serious need to improve relevant knowledge in the region concerning key policy areas and strategies to improve the adaptive capacities of communities at risk.

The Greater Himalayan Region

The greater Himalayan region is taken to include the inner and south Asian mountains and high plateaux – the 'roof of the world'. It contains the most extensive and rugged high altitude areas on Earth, and the largest areas covered by glaciers and permafrost outside the polar regions. The ecosystems and human cultures are exceptionally diverse.

The region plays an important role in global atmospheric circulation, biodiversity, water resources, and the hydrological cycle, apart from the beauty of its landscape and provision of other ecosystem amenities. It is the source of the nine largest rivers in Asia, whose basins are home to over 1.3 billion people. It is one of the world's poorest regions and the plains below are densely populated.

Glaciers and ice cover some 17% of the high Himalayan and inner Asian ranges, a total area of nearly 113,000 sq. km, although distribution is uneven. The Himalayan range alone has some 35,000 sq.km of glaciers, and a total ice reserve of 3700 cubic km. The contribution of snow and glacial melt to the major rivers in the region ranges from less than five per cent to nearly half of the average flow.


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Glaciers in the Tien Shan Mountain range, Central Asia

Principal rivers of the Himalayan region – basic statistics

	River		River basin			
	Mean discharge (m^3/s)	Percentage of glacial melt in flow	Area (sq.km)	Population x1000	Population density	Water per person (m^3/year)
Indus	3,850	44.8	1,263,000	178,483	165	830
Ganges	15,000	9.1	1,075,000	407,466	401	~2500
Brahmaputra	19,824	12.3	940,000	118,543	182	~2500
Irrawaddy	13,565	Unknown	413,710	33,097	80	18,614
Salween	1,494	8.8	271,914	5,982	22	23,796
Mekong	15,948	6.6	805,604	57,198	71	8934
Yangtze	35,000	18.5	1,970,000	368,549	214	2265
Yellow	1,365	1.3	944,970	147,415	156	361
Tarim	146	40.2	1,152,448	8,067	7	754
Total				**1,324,800**		

[1] Extracted from a longer paper with the same title by Xu Jianchu, Arun Shrestha, Ramesh Vaidya, Mats Eriksson, and Kenneth Hewitt being published by ICIMOD

Glacier melting and glacial-lake in the Himalayas

In the mountains, climatic conditions vary more sharply with elevation than with latitude. Mean temperatures, for example, decline about 1ºC per 160m of elevation, compared with 1ºC per 150 km by latitude. Hence, the effects of climate change are expected to intensify in mountain areas, and these areas are expected to be unique areas for detection of climate change and related impacts (Beniston 2003).

The Melting Himalayas

The areas of ice and snow in the mountains (the cryosphere) are particularly sensitive to sustained changes in temperature. However, broad predictions of global climate change, especially the emphasis on shifts in mean temperature, do not take into account the complexity in mountain areas resulting from the effects of slope and elevation. Relatively small changes in average temperature can have marked effects if they mean changes between 'frozen' and 'not frozen' and the altitude at which this change takes place, for example. The effects of climate change will be modified by the ruggedness, elevation, and orientation of mountain areas. The highest mountains, or those facing or funnelling the prevailing winds, may retain a substantial, if diminished, glacial cover, whereas lower or more south facing watersheds may lose theirs.

In general, local impacts of climate do not follow single or simple paths. In the mountains, the situation is made more complex by the interactions among different cold climate elements – processes related to freeze-thaw and glaciers, snowfall, valley wind systems, avalanches, and seasonal or spatial balance between snow and rainfall. All of these are likely to change with general climate shifts; at the same time the interactions among them can buffer, exaggerate, or redirect the changes. Already many Himalayan glaciers are shrinking, some extremely rapidly compared with the global average, and areas under permafrost are decreasing. At the same time in the Karakoram, for example, more than thirty glaciers have expanded (Hewitt 2005) – not because of lower temperatures, but because higher temperatures have caused the existing ice to move faster downslope. A large increase has also been noted in the incidence of glacial surges compared to long-term records (Hewitt 2007).

The most rapid and varied interactions occur through the 'vertical cascade' between different climates at different altitudes and on different slopes, which lead to transport of water and sediment and can lead to major hazards, such as avalanches, debris flows, landslides, and flash floods. Whereas snow avalanches and glacial lake outburst floods (GLOFs) predominate at very high elevations (>3500m), landslides, debris flows, and landslide dam outburst floods (LDOFs or 'bishyari') are more common in the middle mountains (500-3500m). Riverine floods are the principal hazards in the lower valleys and plains. The causes of these floods are related to climatic conditions (Chalise and Khanal 2001; Dixit 2003; Xu and Rana 2005).

Various studies suggest that warming in the Himalayas has been greater than the global average. Warming in Nepal and Tibet increased progressively within a range of 0.2-0.6°C per decade between 1951 and 2001, particularly during autumn and winter. The length of the growing season (daily temperature >10°C) has increased by almost 15 days over the last thirty years. Changes have been observed in the timing of natural events: the leaves and fruit of wild plants are unfolding, blossoming, and ripening earlier; hibernation, migration, and breeding of wildlife is also affected. Throughout China, the average timing of natural events is two to four days earlier than in the 1980s. All these changes will have an impact on water resources, forest ecosystems, biodiversity, agriculture and food production, infrastructure, and human health. As temperatures rise and glaciers retreat, species, too, will shift their ranges. However, the abilities of species to respond to a changing climate vary. Shifts in species' ranges during past major global climate changes indicate that all species have climatic limitations beyond which they cannot survive.

As yet, the relationship between climate change and the Himalayan cryosphere is not understood sufficiently well to enable detailed policy recommendations to be formulated. While in-depth studies of glaciers, snow pack, and permafrost have been carried out in some areas, they have been scattered widely in space and time. There have been few or no detailed investigations of snow and ice processes or their relevance to climate in the high mountain ranges, and there are very few baseline studies and little long-term monitoring of perennial snow and ice.

Nobody Knows Best: Policy Matrix to Cope with Himalayan Uncertainty

	Scientific uncertainty	Adaptation	Mitigation	Public engagement
State	Regional cooperation, support long-term research, engage in research processes	Intersectoral collaboration, support for poverty alleviation and environmental conservation	Commitment to international treaties, develop good policies	Transparency in information and support for public debates
Market	Partnership in research, new hardware and software for monitoring	New technologies, support for community development and local education	Self-regulation and reducing greenhouse gas emissions	Green certification, support for civil society
Civil society	Participatory vulnerability analysis, link local to global, facilitate knowledge learning	Community preparedness, facilitate local learning and adaptation	Social auditing, green watch and monitoring	Access to information, awareness campaign, social inclusion, inter-cultural dialogues
Local community	Local indicators and monitoring, local knowledge, innovations and practices	Improved land/resource management, preparedness for surprises	Renewable energy, alternative livelihoods, and migration	Representation in dialogues and decision-making
ICIMOD's Role	Impact assessment, knowledge synthesis, regional database, forecasting, monitoring	Capacity building, support for mountain policies, pilot demonstration, optimise land-use patterns and livelihoods in mountain 'niches'	Facilitate carbon development mechanism (CDM) and carbon market place, design payments for environmental services	Regional dialogue, debate at international forums, channel funding support

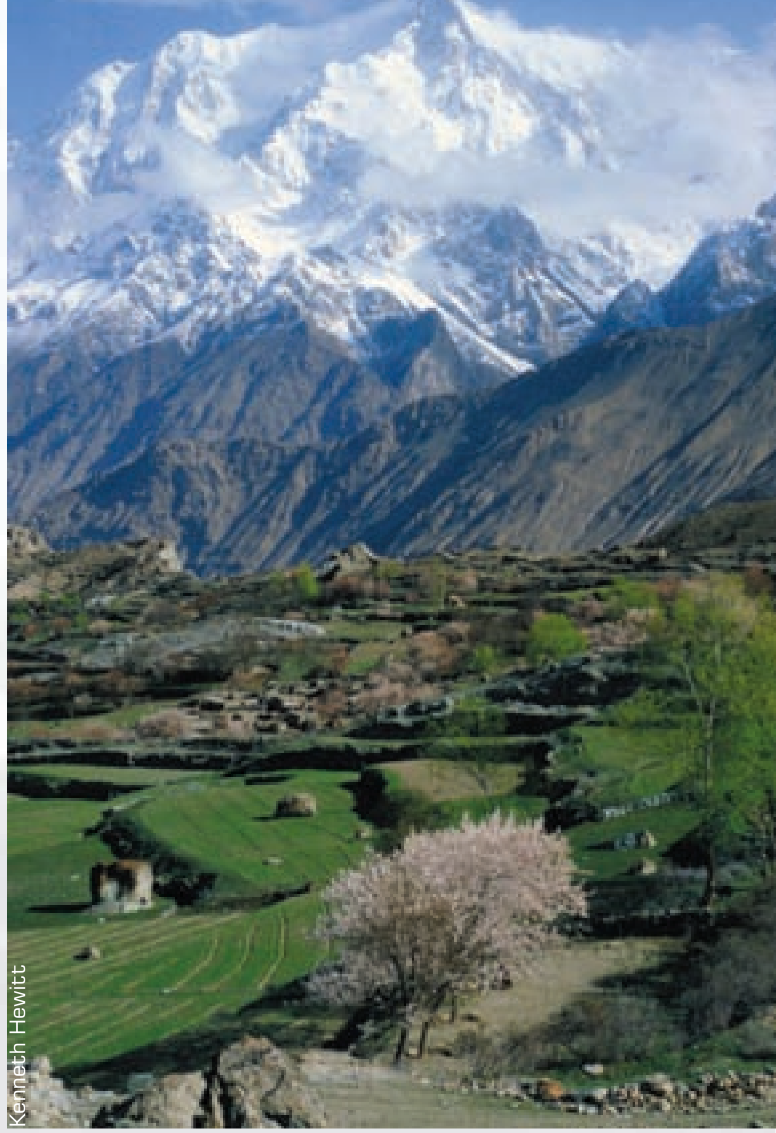
Recommendations and Policy Matrix

The Himalayas are one of the most dynamic and complex mountain ranges in the world due to tectonic activity, and they are vulnerable to global warming and increasing human activities. There is still considerable uncertainty about the rate and magnitude of climate change and potential impacts, but there is no question that it is gradually and powerfully changing the ecological and socioeconomic landscape, particularly in relation to water. Business as usual is not an option. It is imperative to revisit and redesign research agendas, development policies, management and conservation practices, and appropriate technologies. Responsibility should be shared among citizens and the private sector in the mountains as elsewhere, but mitigation measures must be identified and adopted ahead of, rather than in reaction to, dangerous trends.

Himalayan farmers and herders have a long history of adapting to uncertainties whether through mobility of people and land use, or flexibility in livelihood strategies and institutional arrangements. But climate change is exposing mountain societies and ecosystems to increasing natural hazards, environmental stress, and uncertainty of water resources at an unprecedented rate beyond the ability of natural adaptation. It is important to build the capacity to adapt and strengthen the social-ecological system. Adaptive policies and major efforts to reverse the human drivers of climate change have to be incorporated into all sectors.

Good science with credible, salient, legitimate knowledge can often lead to good policies. By credible, we mean knowledge that has been derived from field observations and tested by local communities; salient information is immediately relevant and useful to policy-makers; legitimate information is unbiased in its origins and both fair and reasonably comprehensive in its treatment of opposing views and interests. Policy is a formula for the use of power and application of knowledge. The question then is who has power and who the knowledge, scientific knowledge or local knowledge, or a combination of both? Scientific knowledge is useful but limited and full of uncertainties on the complex Himalayan scale; so then 'Nobody Knows Best' becomes the model (Lebel et al. 2004). The role of the different actors under this approach in contributing to resolving scientific uncertainty, adaptation, mitigation and public engagement can be summarised in the form of a matrix table.

Advances in technology and a rise in temperature enable Tibetans to establish greenhouses on the high plateau



Mountain communities face increasing natural hazards

Specific Recommendations

Reducing scientific uncertainty – Developing science programmes in civic and academic forums is essential for good policy. Science should follow standardised methodologies and use modern tools. Field study is important and local communities should be involved. Regional climate models are recommended for local impact assessment; and earth science needs to be developed for integrated research, disaster risk reduction, and flood forecasting.

Adaptation measures – The approach suggested for dealing with vulnerability and uncertainty in climate change is a bottom-up approach based on local knowledge. The focus should be on empowering local communities to monitor and take action based on their own decisions. Associated with these measures are national adaptation plans, which are currently being prepared in regional countries as a result of the UN Convention on Climate Change. Other recommended measures include integrated water resource allocation and management and an ecosystem approach to human health.

Mitigation measures –The recommended measures are land-use management for carbon sink and reduced emissions;