Impacts of Global Change on the Dynamics of Snow, Glaciers and Runoff over the Himalayan Mountains and their Consequences for Highland and Downstream Regions

Background

The Himalayan range (Fig. 1) is literally the 'abode of snow' with glacier ice covering roughly 17% of the mountain area while seasonal snow cover every year an additional area ranging from 30-40%. The meltwater from the extensive snow cover and glaciers in the Himalayas drains into the perennial Himalayan river systems, so critical for the billions of people inhabiting the mountain slopes and plains in the south.

But increased deglaciation currently observed in the Himalayas due to climate change is leading to changes in the hydrology of the region (Barnett et al, 2005; IPCC, 2007) that are likely to cause a temporary increase in annual flow followed by a reduction of Himalayan river flows in the long run. This reduction in turn is likely to have a significant and broad impact on the livelihood of the people and economies of both the highland and downstream regions.

Due to the ruggedness of the Himalayan terrain and inaccessibility of its higher regions, there is however a great paucity of adequate scientific data leading to uncertainty and knowledge gaps in understanding and projecting such hydrological changes in the region.

A better and much more detailed knowledge of how future climate change will affect glaciological and hydrological systems in the Himalayas would be essential for any effective mitigation and adaptation strategies for sustainable development of the region (Shrestha, 2005 and 2006).

The APN project and its objectives

The project runs from September 2008 to August 2010, and is supported by the Asia Pacific Network for Global Change Research, APN, under Project ARCP2008-16NMY-Shrestha. It has been launched to investigate fresh water related issues in the Himalayas resulting from future global climate change.

The project's objectives are
- to assess the impacts of climate change on the dynamics of snow, glaciers and runoff in the Himalayan mountains,
- to assess the consequences for people's livelihoods and the economies and societies in the upland and downstream regions; and
- to provide scientific information to planners and policy makers for identifying and implementing adaptation and mitigation strategies for a sustainable development of the regions.

Participating countries and collaborating institutions

China, India, Nepal and Pakistan are participating in the project. The collaborating institutions are the Institute for Tibetan Plateau Research (ITP) in China, the Institute for Development and Innovation (IDI) in Nepal, the G. B. Pant Institute for Himalayan Environment and Development (GBPIHED) in India, and the Global Change Impact Study Centre (GCISC) in Pakistan. As shown in Table 1, each institution leads the basin study in its respective country and is responsible for collecting data, running models, and making desk and field studies for the respective basin. In addition the project works in close partnership with the various national and international organizations involved in similar research activities.

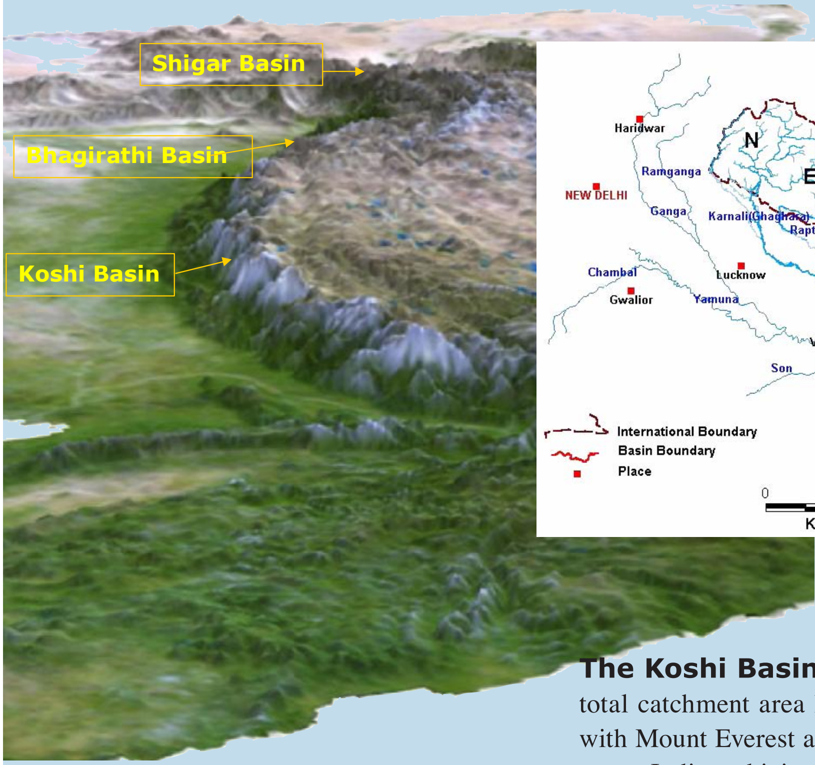
Project study sites

In the Initial Meeting of the Project Partner Institutions held on 13 to 14 November 2008 in Kathmandu, three representative research sites were selected to investigate the impacts of global change along the length of the Himalaya from east to west.

These research sites include the Koshi basin in the east, Upper Bhagirathi basin in the center and Shigar basin in the west and were selected on the basis of their locations, glacier coverage, socioeconomic importance and availability of past data. Their locations are shown in Figure 1, with a more detailed map and description of one of the basins, namely Koshi basin. The salient features of the selected sites are presented in Table 1.

Particulars	Selected river basins			
	Koshi River Basin		Upper Bhagirathi River Basin	Shigar River Basin
	Northern parts in Tibet (Pumqu, Poiqu and Rongxer River Basins)	Southern parts in Nepal (Sunkoshi, Arun and Tamor River Basins)		
Primary institution	ITP, China	IDI, Nepal	GBPIHED, India	GCISC, Pakistan
Latitude	27.49° – 29.05° N	27° – 28° N	30.75° – 31.25° N	35° - 37° North
Longitude	85.38° – 88.57° E	86.4° – 88.4° E	78.9° – 79.3° E	74° - 76.5° East
Basin area (km^2)	28,737	25,300	10,700	6,984
Altitudinal variation	2,000 m to 7,093 m	140 m to 8,448 m	465 m to 7,075 m	2,195 m to 8,611 m
Economic potential	Irrigation	Hydropower, irrigation, tourism	Hydropower, pilgrimage	Irrigation
Population	100,000 (Rural)	3,307,500 (96% Rural)	42,100 (78% Rural)	Sparse
Socio-economic structure	Agro-pastoral	Subtropical agriculture to agro-pastoral	Subtropical agriculture and agro-pastoral	Agro-pastoral and dry fruits
Vegetation	Trans Himalayan alpine meadows	Subtropical vegetation to alpine meadows	Subtropical vegetation to alpine meadows	Virtually devoid of vegetative cover
Major peaks	Kharta Changri, Xixiapama, DuokaPula and others	Mount Everest and other five out of 10 highest peaks in the world	Chaukhamba range (Satopanth and several peaks over 6,000 m)	Haramosh and Kanjut Sar peaks including K2, the second highest peak in the world
Glacierized area (km^2)	2,017.62	1,409.84	755.0	2,240.08
Numbers of glaciers	1,356	779	238	194
Major glaciers	YeBokangjiale, Poiqu Co and others	Solokhumbu, Imja and others	Gangotri, Dokriani and others	Baltoro, Baifo and others
Ice volume (km^3)	193.03	152.06	67.0	581.27

Table 1: General features of the selected basins and primary institutions involved in their study



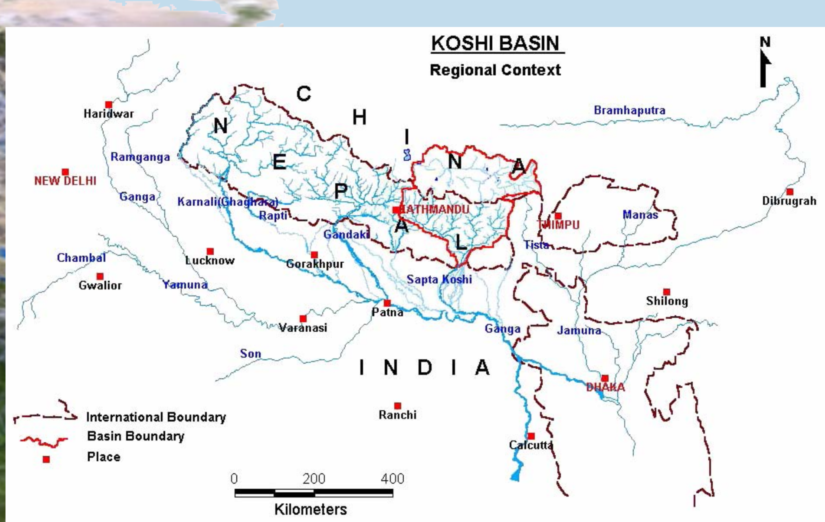


Figure 2: Koshi Basin in the regional context

Figure 1: Himalayan range and the selected river basins

The Koshi Basin: The northern part of the basin covering 54% of the total catchment area lies in Tibet, while the remaining part lies in Nepal, with Mount Everest almost at the centre of the basin. The Koshi river then enters India and joins the Ganges river which ultimately drains into the Bay of Bengal. As it causes flood havoc occasionally in the Indian State of Bihar, it is also known in India as 'sorrow of Bihar'. By the construction of a barrage in Nepal, a large area in Bihar is now irrigated with water from the Koshi river. While the replenishment of snow in the western basin Shigar happens mostly in winter due to the westerlies, the eastern basin Koshi gets its snow replenishment mostly in summer due to the south-westerly monsoon. Likewise, the northern and southern side of the Himalaya have different precipitation pattern which influence the hydrograph of the river.

Research framework and project activities

Figure 3 shows the project research framework. As the figure shows the project activities during the first year have been the following:

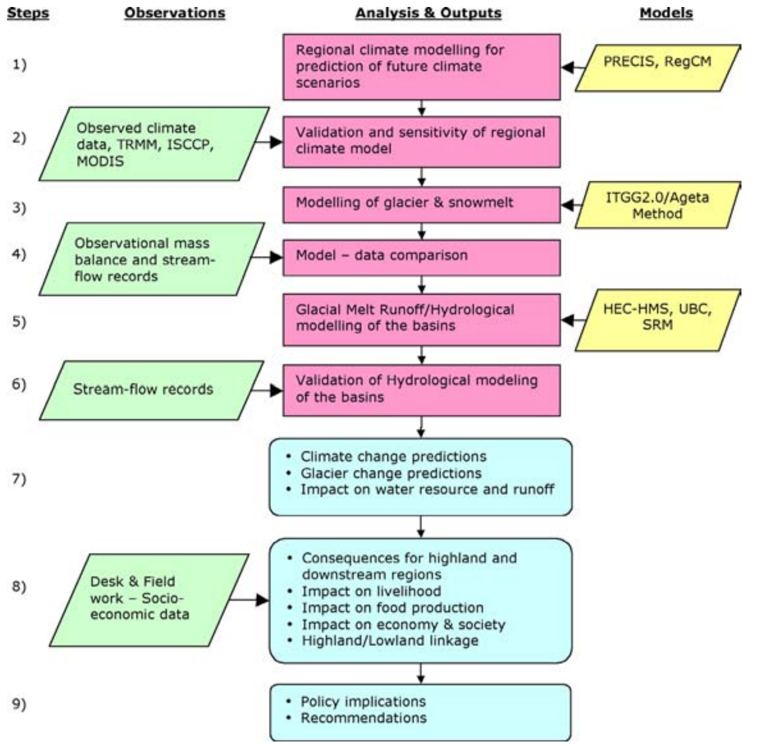


Figure 3: Project Research Framework

- The Department of Hydrology and Meteorology (DHM) and the Institute for Development and Innovation (IDI) in Nepal simulated for both the northern and southern part of the Koshi basin the present climate (1971–1980) and the future climate under IPCC SRES A1B scenario (2049–2061) at a spatial resolution of 25 km x 25 km using the PRECIS Regional Climate Model (RCM) nested within the Global Climate Modes (GCM) HadCM3. Likewise, they have also simulated the present climate (1961–1990) and the future climate under IPCC SRES A2 scenario (2071–2100) at a spatial resolution of 50 km x 50 km using the PRECIS Regional Climate Model (RCM) nested within the Global Climate Modes (GCM) HadAM3P.

- Meanwhile, the Global Change Impact Study Centre (GCISC) in Pakistan simulated the present climate (1961–1990) and the future climate under IPCC SRES A2 scenarios for the 21st century periods of the so-called "2020s" (2010 – 2039); "2050s" (2040 – 2069,) and "2080s" (2070 – 2100) at a spatial resolution of 50 km x 50 km, using the RCM PRECIS nested within the GCM ECHAM4 and RegCM3 nested within ECHAM5.

- Likewise the GBPIHED has accessed from the Indian Institute of Tropical Meteorology (IITM) Pune, India, the PRECIS derived RCM data at a resolution of 50 x 50 km for the upper Bhagirathi basin for the period 1961-1990 and for the A2 scenario for the period 2071-2100.

- The respective country study teams for the selected river basins acquired, pre-processed, and analyzed the necessary hydro-meteorological data, prepared the DEMs (Digital Elevation Models) using global datasets from the Shuttle Radar Topographic Mission (SRTM) / HYDRO-1K, and developed necessary hypsometric curves dividing the watershed into different elevation zones. The teams also extracted geo-physical characteristics for each elevation zone from the Land Cover Dataset from the United States Geological Survey (USGS). Acquisition and processing of satellite images from LANDSAT, MODIS Terra Snow, and other sources for determining snow and glacier covered areas are in progress. The country teams use the Positive Degree-Day (PDD)/Energy Balance Model (EBM), the Snowmelt Runoff Model (SRM) and the University of British Colombia Hydrological Model (UBC) for an estimation of the distribution of solid and liquid precipitation, and for an estimation of snow and glacial melt. Precipitation data from the Tropical Rainfall Measurement Mission (TRMM) are used to complement ground based precipitation data.

- The country study teams calibrate the various snow and glacial melt runoff models using the observed field data as well as current (1961-1990) climate data generated by using RCMs, namely RegCM3 and PRECIS. After the calibration and validation of the models, the teams will develop the future flow scenarios for the three periods namely the 2020s, 2050s and 2080s in the last year of the project.

Impact assessment

In the last year of the project each country study team will also work on the assessment of the implications of the predicted changes for the economies and social structures of the mountain and downstream regions of the selected basins in terms of food security, hydropower development potentials, and flood disasters. They will also elaborate potential adaptation and mitigation strategies for a sustainable development of the regions. The respective instruments will be developed in course of the impact assessment activities.

The project leader along with the country coordinators will collate the country studies in order to arrive at a regional picture of such impacts.

Consultative cum dissemination workshops involving researchers and policy makers will be held at the end of each year to deliberate on research results and to communicate those to the policy makers through presentations of technical and non-technical papers prepared for the purpose. The first such workshop will be held on the second week of October 2009.

The research results will be published at appropriate times in peer reviewed journals and mass media, for the use of researchers, end users, and stakeholders.

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References

Barnett, T.P., Adam, J.C., Lettenmaier, D.P., 2005. Potential impacts of a warming climate on water availability in snow-dominated regions. Nature 438: 303-309.

IPCC, 2007. Climate Change 2007: The Scientific Basis. Cambridge University Press, Cambridge.

Shrestha, K.L., 2005. Global Change Impact Assessment for Himalayan Mountain Regions for Environmental Management and Sustainable Development, Global Environmental Research 9 (1): 69-81.

Shrestha, K. L., 2006. Impact of Climate Change on Himalayan Glaciers. In: Muhammed A., M.M.Q.Mirza and B.A. Stewart (Eds.), Climate and Water Resources in South Asia: Vulnerability and Adaptation. APN, Fred J. Hansen Institute for World Peace and START (IHDP-IGBP-WCRP).Islamabad, 44-57.

Weblinks

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