APN Project # 2001 - 17
 # 2002 - 03
 # 2003 - 03

Global Change Impact Assessment for Himalayan Mountain Regions:
Resource Management and Sustainable Development

FINAL REPORT

Asia **P**acific **N**etwork for Global Change Research

Global change **Sys**tem for Analysis **R**esearch and **T**raining

Institute for **D**evelopment and **I**nnovation

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Project Information

Project Title	**Global Change Impact Assessment for Himalayan Mountain Region for Environmental Management and Sustainable Development**
Project No. (Year)	**2001-17 (year 1), 2002-03 (year 2), 2003-03 (year 3)**

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Participating Countries

Participating countries	**India Nepal Pakistan**
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Abstract

Considering the need and importance of a study on the impact of global changes on the unique systems in the Himalayan Mountain regions and their regional significance, this collaborative and multidisciplinary project has been undertaken with the participation of researchers from Nepal, India and Pakistan.

The research study focused primarily on the observed and potential climatic changes in the Himalayan mountain regions as well as their impacts on water resources, food security and livelihood of the mountain people. The ongoing and long term effects of the process of globalization were also briefly considered. Four representative basins draining different parts of Himalaya, one each from India and Nepal and two from Pakistan were chosen for the assessment of impacts.

The various activities carried out during the project period as well as some of the results of the research study on the ongoing and potential climatic and socio-economic changes in the regions and their observed and possible future impacts are briefly described in this report and some of the products providing further information on them are given in annexes.

APN has funded this project, directly in organizing of a scoping workshop in the first year and through START in carrying out project activities in the subsequent two years.

Introduction

The mountain ecosystem provides goods and services sustaining the life of almost half of the human population. In addition, the mountain ecosystem is vital to sustaining the earth system by providing the following environmental services:

- Cold source and carbon sink to respond to the threat of global warming;
- Sources of water as the origin of all major rivers in the world;
- Genetic resources to the rest of the world and future generations with its richest ever bio-diversity;
- Indigenous knowledge of best practice managing fragile mountain environment;
- Cultural and spiritual assets derived from the local geography and history;
- Recreational sites for people all over the world.

The United Nations have hence, recognizing the crucial role of the mountains in global ecology, declared the year 2002 as the International Year of the Mountain (IYM) for promoting the conservation of mountain ecosystem and sustainable development in the mountain regions. Having received a good response of the celebration of IYM and the need to further reinforce the commitment, United Nations General Assembly has designated 11 December, from 2003 onwards, as 'International Mountain Day'. International Mountain Day thus provides a unique opportunity to move mountain issues higher on the global agenda and also help to serve as a springboard and catalyst for long-term, sustained and concrete action for the sustainable development of the mountain areas and the mountain people.

The Himalayan Mountain range, the youngest, largest and highest on earth and extending east–west in over 2,400 km long arch in the north of South Asia, are home for over 100 million people with some of them living at very high altitudes. The range triggers orographic precipitation and influences the region's weather including the South Asian Monsoon; stores water as snow and ice; acts as source of large rivers such as Indus, Ganges and Brahmaputra and thus constitutes the "water tower" for almost one billion people living downstream in the Indo-Gangetic plains. Moreover, due to their unique position and physical features, they act as a storehouse of valuable biodiversity resources and hold a mosaic of age-old human cultural diversity.

However, because of their young and fragile nature coupled with sharp gradients, the Himalayan Mountains are particularly vulnerable to climate change and variability. Further, due to the rapidly growing population pressure, natural and socio-economic systems in these mountain regions are at risk, in particular regarding the impacts of global change and globalization. The rapid change of the ecosystem, driven by both natural and anthropogenic determinants poses unprecedented threat not only to the livelihood of the local people, wildlife and culture, but also to the billions living in the downstream and ultimately to the global environment. The inherited environmental fragility and social economic vulnerability have thus put the Himalayan ecosystem on the

top of the World Summit on Sustainable Development (WSSD) and Bishkek Global Mountain Summit (BGMS) agenda.

Due to the rugged terrain and the thus posed strong barriers to transportation, communication, trade and political integration, the mountain regions traditionally used to be well known for their pristine ecology. And mountain people have survived and flourished in the past exhibiting resilience stemming from their sustainable use of environmental resources. But with the technological innovations in communication and transportation system combined with linkages to expanding market economy, use-intensification and over exploitation of environmental resources are leading to high rates of environmental changes in the fragile ecosystem and thus turning the mountain regions into 'critical regions'. Consequently, the traditional resilience is being rapidly breached leading to growing dependence on external inputs and over exploitation of selective resources threatening their sustainability. Thus the landscapes and human groups in the mountain regions are being simultaneously affected by environmental and socio-economic threats and perturbations leading to 'critical stage' as a result of global changes and globalization.

While the Himalayan Mountains are particularly susceptible to impacts of a rapidly changing climate often coupled with anthropogenic alternation of mountain landscapes due to population changes and economic activities, the region's politic and economic marginalization creates added vulnerability due to a reduced capacity to adapt to these changes. Research on global change issues has generally focused on uncertainties in climate projections and calculation of mitigation costs. The fragility of mountain ecosystems itself represent a considerable challenge to sustainable development due to the fact that the impacts of unsustainable development are more rapid, heavier and more difficult to correct than in other ecosystems. The most pressing issues associated with global change, furthermore, involve the potential effects on ecosystems and resources as well as the societies that depend on them. As many of these effects are interactive with some specific thresholds, vulnerabilities and adaptations, the understanding of response to global change is crucial especially for the sustainable development of mountain regions.

The identification and understanding of key ecological and socio-economic parameters of the mountain regions, including their sensitivities and vulnerabilities under global changes and cumulative changes due to ongoing human interventions have all become crucial for planning and policy making for environmental management and sustainable development of the mountain regions as well as the downstream areas. Furthermore, as food security and water availability are obviously the key elements in all the sustainable mountain development strategies, they naturally rank high in the priority list.

Meanwhile the mountain regions due to their steep altitudinal gradients coupled with sharp contrasts between areas of greater or lesser direct human impact also provide a unique and important setting within which to examine the interplay of global climate change and globalization as well as to detect and analyze global change process.

A collaborative project on 'Global Change Impact Assessment for the Himalayan Mountain Regions' was developed with the aim at an assessment of the impacts of and vulnerability to global change on food security, water resources and livelihood of people in the Himalayan Mountain regions. The APN supported for a Scoping Workshop in 2001 for its improvement and finalization.

This 2-year collaborative and multidisciplinary APN project described here is thus based upon recommendations and project proposal finalized at the APN Scoping Workshop held in Kathmandu, Nepal during 2-5 October 2001. The earlier Meetings of the South Asian Committee of START (SASCOM) held in Dhaka, Bangladesh in 2000 and in Kathmandu, Nepal in 2001 had also recommended for such a study for the Himalayan Mountain regions. The objectives of the project are as follows:

Objectives:

- To assess the relative importance of global change impacts on the Himalayan mountain environments in order to prioritize monitoring efforts and to anticipate consequences with respect to food security and water resources including transfer of resources between uplands and lowlands;
- Assessment of the vulnerability to and impacts of global change on food security and water resources, including transfer of resources between uplands and lowlands;
- To assess the vulnerability of mountain people to global change and to investigate the factors that promote resilience of these groups in the face of multiple and interacting environmental stresses; and
- To synthesize and aggregate national assessments and other pertinent studies to inform on the scientific basis the policymaking processes at local to regional scales regarding global change impacts on food security and water resources in the Himalayan Mountains as well as response strategies for coping/adapting with the changes.

Vulnerability concepts, which encompass both biophysical and socio-economic aspects of risks, provided a framework for integrating assessments of the impacts of global environmental change with the impacts of the ongoing economic, political and cultural changes associated with globalization.

For conducting the project in collaboration with the researchers from India, Nepal and Pakistan, the worked out phase-wise activity framework is presented below:

First phase **(year one: 2002 - 2003)**	***Second Phase*** **(year two: 2003 - 2004)**
■ Collection, compilation and collation of data sets; Start-up Workshop for developing protocols for cross-site comparisons; ■ Qualitative assessment and predictions/scenarios of interactions and sensitivities; highlight gaps in knowledge and data; assessment of relative contribution of different parameters in driving change; ■ Create common web site for project; ■ Synthesis activity; and ■ Project review meeting at end of first phase and developing detailed work plan for second phase.	■ Expanding transect in the second year if necessary with suitable site selection as guided by gap analysis in the first year; ■ Make database more quantitative through various measures including field surveys; ■ Model interactions and vulnerability assessment scenarios; ■ Identify within and between watersheds, villages and groups that have greater water and food security; qualitative analysis of institutional and other strengths that provide resilience; and ■ Workshop/Seminar for finalizing and disseminating the research findings among researchers, stakeholders and policy makers.

Activities Conducted

Year one

Outline of activities conducted

In the Year One, a Scoping Workshop supported directly by APN was held in Kathmandu on 2-5 October 2001 with the participation of experts from India, Nepal and Pakistan as well as two representatives from the MRI and one from the APN for deliberating and discussing as well as finalizing the project proposal on Global Change Impact Assessment for the Himalayan Mountain Regions for Environmental Management and Sustainable Development. The Workshop was preceded by an initial meeting of representatives from India, Nepal and Pakistan on 21-22 July 2001 for working out the framework and logistics for the Scoping Workshop. The proceeding of the workshop has been published as another output of the year-one activity.

Year Two

Outline of activities conducted

During the second year (2002/3) of the project, collection, collation and analysis of all relevant available data, information and recent experience on climate, climate variations and extreme events over the Himalayan regions together with initial assessments of vulnerability of and impact on water resource and agro-ecosystem and the mountain people were carried out by the three research teams for their respective countries.

At the very beginning of the Project, a preparatory/start-up workshop was organized in Kathmandu from 20 - 22 June 2002 with the participation of all the key researchers from all the three participating countries for finalizing the work plan and developing protocols for cross-site comparisons. The Start-up meeting discussed and came up with a common format and tools for the collection and analysis of relevant data and information.

The data collection and analysis activities covered the Himalayan mountain regions in the respective participating countries in general and focused in particular on the three selected watersheds, namely,

- Alaknanda Watershed in India
- Kaligandaki Basin in Nepal, and
- Siran Valley in Pakistan.

The project activities included:

1) Country reviews of recent climate variability and extreme events; water availability and agricultural practices and assessment of their sensitivities to climate change and variability;
2) Assessment of socio-economic vulnerabilities to climate change and variability as well as the process of globalisation;
3) Synthesis and aggregation of country studies highlighting the regional sensitivity and vulnerability to global change;

4) Developing common approach and sharing of research results and experiences within the involved group of researchers from the participating countries.
5) Publication of the Country Studies

A year-End Workshop was organised in Kathmandu on 10 - 12 January 2003 wherein all the key researchers from the three countries participated. In addition to exchanging their results and experiences, they discussed and worked out a programme of activities for the next year as well as a tentative framework for the final report.

Year Three

Outline of activities conducted

In the third year (2003-2004), project work focused on global change related vulnerability analysis and integrated impact assessment with respect to food security and water resources, including highland-lowland transfer of resources in the Himalayan Mountain regions. In order to capture the impact in the far western region of the Himalayas, where the effect of the Southeast Monsoon is least, an additional site viz. Hunza Watershed in Pakistan was also included in the study this year. Thus, the studied watersheds now included:

- Alaknanda in India;
- Kali-Gandaki in Nepal; and
- Siran and Hunza in Pakistan.

Studies focused on the identification of crucial factors that need close monitoring to reduce vulnerability of Himalayan water resources, agricultural systems and mountain peoples' livelihoods to global change. Activities conducted during the project period included the following:

1. Database generated during the first year was improved by collecting more data from concerned agencies, as well as through other measures including field studies and interviews with key-actors in the selected Himalayan river basins in the participating countries.
2. Earlier works on Himalayan glaciers were reviewed. All those indicated clearly a general trend of recession of glaciers in the region at rapid rates.
3. Field surveys, together with a number of participatory rapid appraisals (PRA's), were conducted at three altitudinal transects in each of the four selected watersheds to ascertain people’s perceptions on climate change and globalization as well as their vulnerabilities and coping mechanisms.
4. The field survey data were analyzed using suitable tools including the use of the SPSS package. The extracted data and information include altitudinal variations regarding the impacts of climatic extreme events on water availability, food security and peoples' livelihood together with their resilience capacity and coping mechanisms. Those also include information on peoples' perception about global change and the perceived requirements of adaptation/mitigation measures.

5. Hadley Centre RCM2 data, obtained with the help of the Indian Institute of Tropical Meteorology (IITM), for both controlled as well as potential GHG emission conditions on daily temperature, precipitation and relative humidity for selected grid points in the selected study areas over a period from 2041 to 2060 were utilized to get a gross view of the envisaged change in the Himalayan mountain region half a decade later. Monthly mean data for intermediate time slices for 2010s and 2020s obtained later were used to derive short term impacts. The model run data for 1990 were used together with the observed data for model validation.
6. For the Kaligandaki basin, the Tank and DSSAT models were used to study the impacts on water resources and agriculture, respectively. Due to unavailability of necessary and adequate data, the same could not be carried out for other selected watersheds. However general pictures were derived in suitable form for them with whatever data and information that could become available.
7. A very simple Ecological Health model has also been tried to develop socio-economic vulnerability and impact assessment scenarios for the Kaligandaki basin.
8. Model exercises for the other selected watersheds could not be carried out in the absence of necessary hydro-meteorological data. Inferences on vulnerability of water resource, food security and livelihood of mountain people were based on field survey data and HadRM2 climate scenarios.

Outcomes and Products

Some of the Research Results

Selected Basins

In the process of assessing the impacts of global change in particular on the water resources and food security in the mountains as well as the livelihood of the people living in the region, three selected watersheds in the three participating countries viz. Kali Gandaki basin (28^{o} N, 83^{o} E) in Nepal, Alaknada basin (30^{o} N, 79^{o} E) in India and Siran basin (34^{o} N, 73^{o} E) and Hunza basin (36^{o}N, 75^{o}E) in Pakistan, were chosen as representative mountain regions and basins draining different parts of the Himalaya. Some of the results of the research study to ascertain the ongoing and potential climatic and socio-economic changes in the regions and their observed and possible future impacts are presented and discussed.

Observed Climate Change and Variability and their Impacts

There are clear indications of climate change signature in the Himalayan Mountainous region of the sub-continent. There are perceptible trends of changes in the rainfall and temperature of varying magnitudes in the past three decades in the different study areas that are evident both from the analysis of available earlier meteorological data and also from the field survey carried out to ascertain people's perception of such changes.

All the available data on temperature and precipitation from the meteorological stations in and around the selected watersheds were collected and analyzed.

Temperature Change

A trend analysis on the available temperature data indicated the ambient temperature in the selected watersheds to be increasing at a rate ranging from 0.02 – 0.04 ^{o}C/year. The temperature rise was found higher in higher altitudes. The observed changes in the temperature at the various watersheds during the given intervals are tabulated below. It may be noted that a negative trend ranging from – 0.008 to -0.06 ^{o}C/year have been reported in some earlier study in the eastern Himalaya. This marked difference between the eastern and western Himalaya may well be due to more cloud coverage in the eastern regions that have much higher precipitation as compared to western Himalaya.

Glacier Retreats

A clear consequence and important indicator of this warming trend is apparently the observed retreat of Himalayan glaciers, which highlights the impact of global climate change at high elevations and the consequences for lowland agriculture, hydroelectric power generation, ecotourism and the society in general. T All the available records have clearly indicated that glaciers in the Himalayan region are retreating at a rate ranging from 5 to 30 meters per year and the amount and pattern of snowfall is also apparently changing in the region.

The change in snowmelt as well as the biological community covering the mountain watershed equally affect water storage and water yield to the down stream regions as

well. The increasing glacier retreat will cause dual effect on river hydrology. Large variations in river peak flows will increase quantity of glaciofluvial sediments transport due to excessive melting. It can cause large scale damage to downstream river valley schemes, agriculture and water supply. In addition, there are increasing threats due to the formation and outbursting of glacial lakes in the high altitudes causing Glacial Lake Outburst Floods (GLOFs).

Analyzed Changes in Temperature

- As reported in some other study

Country	Location	Year	Temp.	Observed Variation ^{o}C / year
Nepal	Kali Gandaki	1970s-1990s	T_{max}	0.0264
			T_{min}	0.0239
			T_{mean}	0.0246
	Nepal	1971-1994	T_{max}	0.06-0.12
				0.03
Pakistan	Siran	1961-200	T_{max}	0.017
			T_{min}	0.005
	Pakistan	1931-1960/ 1960-1990	T_{max}	0.026-0.04
			T_{min}	0.016-0.03
India	Alaknanda	1994-2002	T_{mean}	0.151
	Nainital	1987-1996	T_{mean}	0.0276
	North-East Himalaya*	1969-1990	T_{mean}	-0.008 to -0.06

Precipitation Change

Precipitation change and extreme events do not show any specific pattern and seem to change from place to place. But a decline in snowfall was reported by the respondents during the field survey in all the selected basins. The Table below gives a general trend of precipitation change in the selected Himalayan regions.

For Alaknanda, analysis of past rainfall data for the trend revealed that the rainfall of lower and middle transects was decreasing. The perception of local people also confirmed climate change in the form of reduction in snowfall and variations in rainfall pattern along all three transects. Lower transect experiencing moisture deficit and draught conditions in some years whereas more flood conditions in monsoon. Most populated Middle Transect showed largest decline –34.98 mm/year. If the same trend continues in the future, more chances of drought are expected.

In case of Kaligandaki basin, in general, an increasing trend of precipitation has been noted while a decadal pattern of change in precipitation extremes was observed with a lower extremes in 70s and distinctive higher extremes in 90s and in between in the 80s.

In Pakistan eight out of nine stations in and around Hunza valley show increasing trend in monsoon rains, although, the contribution of monsoon rains to the total precipitation is not large. The winter rains have dropped but not significantly. In Siran basin, both monsoon and winter rains on the average have increased slightly, while Oct-Nov which is already the driest months of the year appear to have become drier.

Changes in Precipitation

Country	Location	Year	Variation in mm/yr or in %
Nepal	Kali Gandaki	1971-2000	1.6-31.0
Pakistan	Siran Valley	1981-1998	40%
	Murree	1961-1999	25%
	Sub-tropical	1971-2000	-20%
India	Nainital	1965-2001	15%

Change in Hydrology

As a result of change in temperature and precipitation and other anthropogenic changes, the hydrology of the basins is also found changing. In Pakistan and India, there is a general increase in trend in the runoff in the studied areas. Snow fed rivers especially are found to have increased dry season flow whereas non-snow fed rivers have decreasing trend during dry season. The trends of hydrological change in the region are shown in the Table below.

In case of Alaknanda river, the maximum flow (during monsoon) and the minimum flow (during winter) showed increasing trend, while minimum flow indicated smaller variations. Also in case of Mandakini river, the main tributary of the Alaknanda, an increasing trend was observed in the maximum and minimum flow and the variation in the flow was higher than those in Alaknanda.

Changes in Hydrology

Country	Location	Year	Variation million m^3/year
Nepal	Kali Gandaki	1964-2000	142 (1%)
Pakistan	Siran	1968-2000	5.8 (1%)
	Indus (Pratap)	1968-2000	240 (13%)
	Indus (Qila)	1968-2000	120 (5%)
India	Alaknanda	1980-2000	1767 (2.8%)

Impacts on Water resources

The western parts of Himalaya in particular are found facing water shortage during winter dry period. The observed trend indicates that the drought conditions are getting worst. Similarly the flood incidences during the monsoon periods are showing increasing trends. Thus the impacts of climate change on water resources are aggravating the present condition by making the dry period drier and wet period wetter. With the increase in population and intense farming, the demand for water will increase in the mountain areas thus reducing the supply to the down stream areas. Incidence of soil erosion, land slides, etc. will increase with increase in frequency and intensity of extreme climate events and land use changes. Conventional planning of water resource for hydropower generation, irrigation, industrial use etc. based on past hydrological trends are no longer going to be valid in the context of global change.

While Himalayan River System and Himalayan Waters clearly depicts the role of the mighty mountains in regulating South Asia's climate and the region's water resource base, studies have revealed that global climate change can have a profound effect on the Himalayan water resource base. Sustainable development of the region demands rational use of this resource. At present, the models to forecast resources and define their optimal use are all defined on a national scale. Nevertheless, it should be acknowledged that such an approach should be complemented by a regional approach, since both water forecast and regional water consumption has transboundary, regional aspects and teleconnections to more global aspects such as global change. Such a regional approach that does not exist so far demands a concerted scientific regional integrated endeavors initiated through an enhanced and improved flow of information on Himalayan water resource and management issues.

Impacts on Food Security

All the mountain areas, in particular the mid and high mountains, are in general found food deficit areas. Their dependency on food supply from the plains have been found increasing further due to the change in population and food habits, the increased linkages with external markets and economy and the lack of appropriate technology.

Due to climate change, higher temperature at the lower altitudes beyond the growth limits of agricultural crops will lead to reduced production and productivity. As the elevation limits will move higher than the present 3,000 m, thus causing spatial shift of cultivated areas to higher elevation, and introduction of new crops in the high mountains and increase in cultivated area and crop productivity have already been noticed in the high mountains of the Kaligandaki basin. But meanwhile, incidence of pest and disease attack on crops are found to increase damage to crops, especially to fruit trees, on account of extreme climatic events.

Indigenous knowledge and traditional practices in the agricultural systems have been in existence in the Himalayan region for millennia. Farmers with their practical knowledge had developed several production systems suited to marginal and fragile mountain environments. The eco-friendly agriculture and sustainable soil management are practiced even in such harsh environments through terracing, composting, mulching,

mixed copping, mixed farming, etc. Traditional farming practices have been significantly contributing in maintaining a balance in the nature by promoting interdependence of agro-horticultural crops, forestry, animal husbandry and medicinal and aromatic plants in the mountains. They still have intrinsic value in the agricultural system of the region. Farming communities of the Himalayan region attach great value to the forest ecosystem as well as to the integration of livestock into the mountain farming system. The communities in the Himalayan mountain regions have thus been practicing traditional farming systems for harnessing ecological potential of land and conserving natural resources for millennia.

However, much to the dismay of these mountain farmers, the protection and promotion of such practices are not a national priority of the countries in the region. In the national plans and policies, they are, more often than not, ignored. In addition, in recent years, due to globalization and the World Trade Organization (WTO) system, new challenges are surfacing. Different WTO agreements deprive farmers from enjoying their right to exercise traditional farming practices. Countries in the region have not been able to devise appropriate policy instruments and legal mechanisms that protect and promote traditional farming practices. Such a policy and legal constraints has severely limited farmers' freedom and their ability to practice traditional farming systems, thereby directly affecting their rights and livelihood options.

To increase the agricultural production and productivity for economic gains and for feeding the increasing population, modern agricultural practices and systems are now being introduced in most of the areas. But monoculture agricultural practices and excessive use of chemical fertilizers and pesticides in the tea gardening in the eastern Himalayas for instance are causing problems of soil degradation and water pollution.

Meanwhile, as the subsistence agriculture in the mountains has not been able to meet the food requirements as well as other necessities of the households, at least one or more members in general are found to go to urban or foreign countries to work as wage labourer to supplement the household income. The current insurgency problems in the mountain regions have further aggravated the situation and there are greater exoduses of youths from the mountain areas to foreign countries. Income from remittances and wage labor and service has become the chief source of income and much of this is spent on to purchase of foodstuff and daily necessities.

Comparative advantage accrued from the overseas job, wage labor and service has caused labor shortage and decline in investment in agriculture and livestock sector in all transects, but most apparently in middle and high mountains. As a result, agricultural lands in the mountain slopes are getting abandoned that in turn are accelerating the process of soil erosion and landslides.

Perceived Global Change Impacts: Assessment of vulnerabilities and coping mechanisms

Field surveys and PRAs conducted in all the selected watersheds have revealed the notable decrease in amount and duration of snowfall in the regions where there used to be significant snowfall a few decades earlier. Likewise, increase in incidences of extreme climatic events like floods and droughts were reported invariably from the various survey sites. The mid-mountains were found more vulnerable as compared to low- and high-mountains. The coping mechanisms that relied on traditional systems are getting weakened as the social systems undergo rapid changes.

The rapidly growing population and greater physical, administrative and market integration of mountain and upland agriculture with mainstream systems have fundamentally altered local resource management practices leading to resource use intensification and overexploitation. Thus the landscapes and communities in the mountain regions are being simultaneously affected by environmental and socio-economic threats and perturbations.

All the mid- and high mountains are food deficit and rely on food supplied from the down-hill planes. Changes in food habits have made them more dependent on the downhill supplies. The mountain farming system is in general very complex and diverse and characterized by strong linkages between the three spheres of crop production, livestock and forest. Crop production cover in general 3-9 months of the annual household food demand and with little marketable surplus. Each household, for domestic needs and for some extra income, keeps small numbers of livestock. Certain section of people in highlands in proximity to pastureland still engages in transhumance. Transhumance is more prevalent in the western Himalayan regions. Forests are utilized for domestic, agricultural and commercial purposes. Off-farm employment opportunities are very limited locally. On an average, most of the households have some of their members engaged in temporal migration. A high rate of labour migration indicates the low local income opportunities as well as labour remittances being one of the important sources of income of local households. The marginal and rain fed crop fields are being abandoned by the people as further fragmentation of landholdings is not possible and as young people migrate out from the region for job elsewhere. Such incidences are now becoming more common. The abandoned fields have in turn become hot spots of land denudation, degradation and landslides.

Projected Potential Impacts

The fact that global change is projected to occur simultaneously and in concert with changes in population, technology, economics, and other environmental and social changes clearly adds to the complexity of the impact assessment and the choice of appropriate responses. The characteristics of sub regions and sectors of the Himalayan Mountain Regions suggest that neither the impacts of global change nor the response options will be uniform.

While the development of regional climate model development for the Himalayan mountains is itself a big challenge and will require greater regional efforts, the effects of climate change on the South Asian monsoon and the ENSO phenomenon, for instance, are among the major uncertainties in the modelling of the hydrological cycle. Similarly,

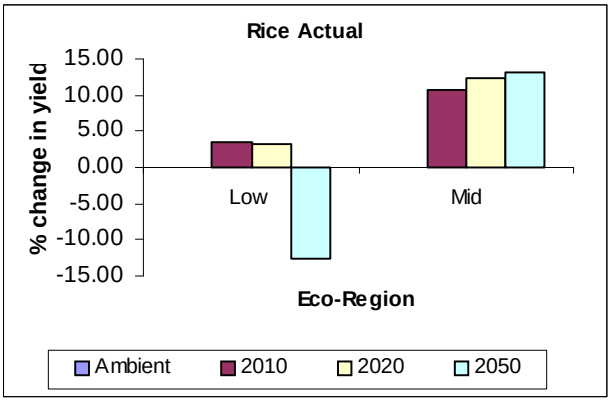
projections of agricultural crop yields are uncertain, not only because of the uncertainty in the hydrological cycle but also because of the potential positive effects of CO_2 and production practices. The major challenges in research in the Himalayan Mountain regions are therefore to better understand, describe and model the impacts of the ongoing global change processes in the region, their complex interrelations and interaction and to use the required integrated models (model systems) after their verification and validation with reference to recent and past observations and monitoring programmes for scenario-based simulations into the future. As a step towards that endeavour, available data for the selected watersheds were utilised to project potential impacts of climate change on the chosen sectors and some of the results are briefly described below.

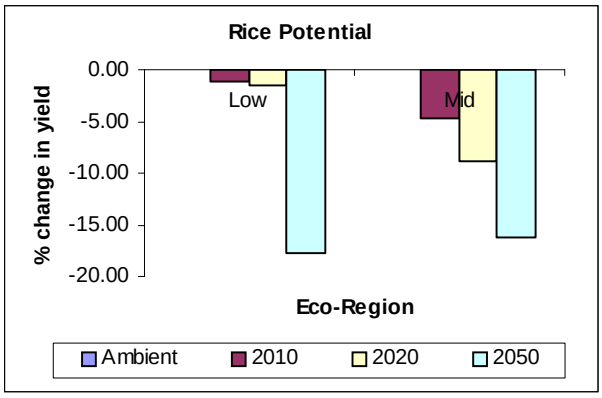
Future climate scenarios were generated by using the HadRM2 data for control (CTL) runs representing 1990s and for projected GHG emissions perturbed runs for the years 2041 to 2060. The daily rainfall and temperature data for different grid points are derived from the model, which has been used for trends and variability analysis. Monthly mean data for intermediate time slices for 2010s and 2020s were used to derive short term impacts. The model run data for 1990 were used together with the observed data for model validation.

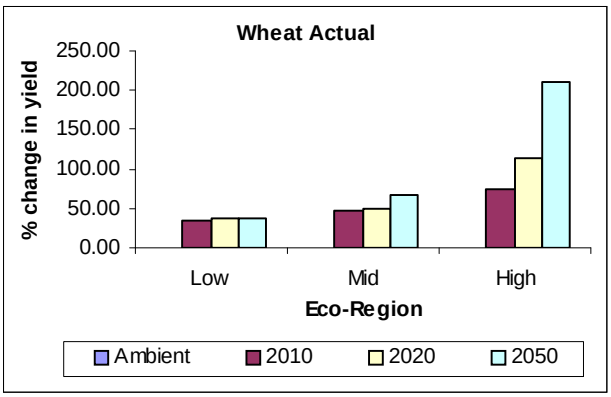
With reference to the year 1990, the projected temperature rise for the year 2050 in the Kaligandaki basin for instance ranges from 3^oC to 6^oC, the rise in temperature being more in the lower regions than those in the higher regions. Similarly, precipitation in the basin is projected to increase between 160 mm to 1200 mm annually with highest increase in the middle mountain regions. Projected temperature and precipitation changes for the other selected basins are also available. However, validation of the model indicates that uncertainties in the projected figures are in some cases quite high that demand improvement in the model and checking with other model results..

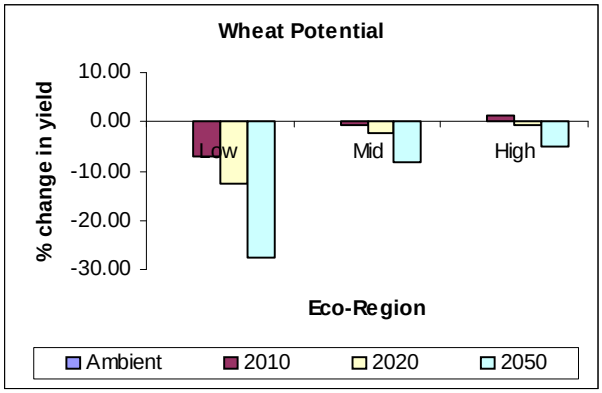
For studying the impact of climate change on water resources, the effect of climate change on the stremflows was simulated using tank model. For the Kaligandaki basin, it appears that the flood magnitude and frequency are likely to increase and low flows are likely to decrease. Thus the impact of climate change is going to pose a challenge in incorporating the uncertainty into future water resources planning and management.

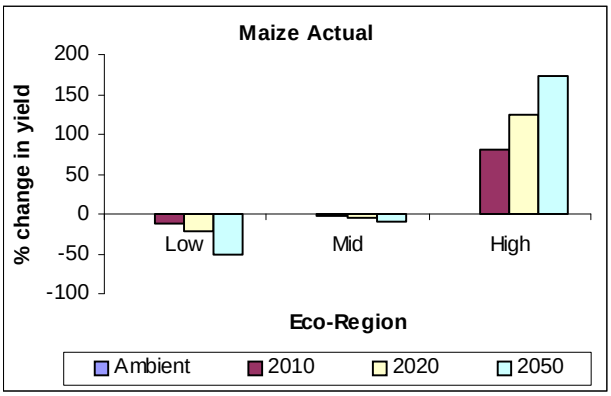
Similarly, validated crop models embedded in ICSA based DSSAT were used for scenario based impact analysis for important crops for the projected temperature and CO_2 rises. A graphical presentation of the percentage changes in yield for a few crops is shown below. The marked negative impacts on the various important crops in the low mountains are significant and clearly call for careful attentions. While the productivity in the mid mountains are projected to increase, the likely effects of increased loss due to pests and diseases due to warmer climate in those altitudes will need due attention. The opportunities for increased production and productivity of new crops in the high mountains would however be offset by the limited extent and slope of the available land area.

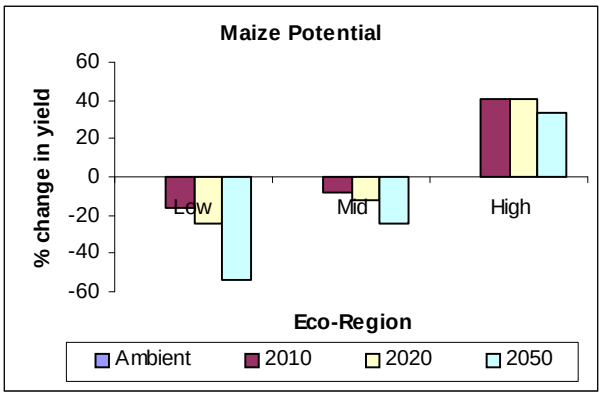












Yearwise Out comes

The yearwise outcomes of the project activities are briefly outlined below

Year one

1) Finalization of the Project Proposal on “Global Change Impact Assessment for Himalayan Mountain Regions for Environmental Management and Sustainable Development” for submission to APN

2) Publication of the Proceeding of the Scoping Workshop entitled "Global Change and Himalayan Mountains"

Year Two

1) Generation of an integrated regional database on science and society in the selected Himalayan regions relevant to global change impact assessment studies.
2) Creation of common web site www.idi.org.np for the dissemination of project results.
3) Training in 2002 of one research team member in AIACC Trieste workshop and initiation of local capacity building exercises by involving post-graduate students in the research studies.
4) In an intensive 3-day inception workshop held in Kathmandu, Nepal in June 2002, country team members made background presentations, prepared detailed work plans and timelines for year one activities and finalized outline of the country studies and data formats.
5) Country studies on recent climate variability and their impacts on water and agriculture as well as global change associated socio-economic impacts with adaptive responses (spontaneous and planned) in country specific sections of Himalaya and in the selected watersheds.
6) A regional background paper and a synthesis report based on the country studies.
7) An intensive 3-day year-end workshop was held in January 2003 in Kathmandu, Nepal wherein keynote background papers as well as results of country level studies and the draft synthesis report were presented and discussed.
8) Keynote papers and focused national studies were compiled and published.

Year Three

1. A general perspective on the trends of climatic, as well as socio-economic changes in the Himalayan mountain regions.
2. A general perspective of the retreating Himalayan glaciers and their consequences in terms of increasing threats of Glacial Lake Outburst Floods (GLOFs), as well as in terms of changes in the flow of snow fed rivers during the dry seasons, and their impacts on irrigation and hydropower development schemes.
3. Derived trends of changes of meteorological, hydrological, food provision, and socio-economic parameters at the selected representative watersheds in the different regions of the Himalayas.
4. Country reports including field survey results on the observed impacts of global change including globalization on water resources, food security and livelihood of mountain people as well as the current coping mechanisms.
5. Identification of villages and groups with greater water and food security as well as institutional and other strengths that provide resilience.
6. Country level workshops in Nepal and Pakistan with mountain stakeholders and policy-makers.
7. An intensive workshop held in Kathmandu on 16-20 December 2003 (in conjunction with the APN workshop on Water Resources in South Asia) to

discuss research findings as well as plan a strategy for bringing the project work to a logical conclusion.

8. Press meeting with national newspapers, press agencies and the electronic media convened on 19 December 2003 for disseminating APN project research.
9. A paper based on the synthesis report has been sent to the Journal on Global Environmental Research for publication.
10. Final report being published and disseminated through the Internet. Relevant papers based on the research to be sent for publication in peer-reviewed journals.
11. A *no cost extension* of the project period for six months has been requested and granted for the identification of model-based projected impacts through the synthesis of all collected information and data, and thus to bring the project to a logical conclusion. Tasks in this timeframe included:

    - Validation of the data as well as the development of short-term scenarios (HadRCM2 data for the selected grid points covering the periods from 1980 to 2030 have been obtained through IITM.)

    - Using RCM data and assuming certain development paths, a few scenarios for global change impacts have been developed and the policy and research implications under the various scenarios for environment management and sustainable development in the Himalayan mountain regions are ascertained and disseminated among the policy makers and researchers respectively.

Documents and CDs

S. No.	Title	Document	CD
1	**Global Change and Himalayan Mountains: Proceedings of Scoping Workshop, 2 – 5 October 2001**	√	
2	**Global Change Impact Assessment in the Himalayan Mountain Regions: Country Studies on Ecosystem Conditions and Trends** **a. India – A Case Study in Alaknanda Watershed** **b. Nepal – A Case Study in Kaligandaki Basin** **c. Pakistan – A Case Study in Siran and Hunza Valley**	*	√
3	**Global Change Impact Assessment in Himalayan Mountain Regions: Proceedings of the First Year-End Seminar / Workshop, 10 – 12 JANUARY 2003**	√	√
4	**Micro Level Field Surveys in the Selected Himalayan Mountain Regions on Global Change Impact Assessment**	*	√
5	**Global Change Impact Assessment in the Himalayan Mountain Regions: Scenarios, Response and Policy Implications**	*	√
6	**Proceedings of the Second Year-End Seminar/ Workshop on Global Change Impact Assessment in Himalayan Mountain Regions, 16 – 20 December 2003**	*	√
7	**Impacts of Global Change in Himalayan Mountains – Tools, Observations and Synthesis**	*	√
8	**National Workshop in Nepal on Global Change Impact assessment in Kaligandaki Watershed: Proceedings of the Workshop held in Kathmandu on 1 November 2003**	*	√
9	**National Workshop in Pakistan on Global Change Impact Assessment in Siran And Hunza Valley : Proceedings of the Workshop held in Islamabad on 7 August 2004**		√
10	**Proceedings of the Initial Meeting held in Kathmandu on 21 – 22 July 2001 on Organizing a Scoping Workshop on Global Change Impact Assessment for Himalayan Mountain Regions**		
11	**Proceedings of the Preparatory Workshop on Global Change Impact Assessment for Himalayan Mountain Regions held in Kathmandu on 20 – 22 June 2002**		

√ **- In the enclosed CD** * **- On the process of publication**

Conclusions

Data gaps, research imperatives and institutional support

Expansion of meteorological and hydrological network
Meteorological stations and their network in the Himalayan mountain region need to be expanded and their capacity and efficiency enhanced for monitoring temperature, rainfall, snowfall and other meteorological parameters, the crucial indicators of the global climate change. Similarly a closer network of hydrological stations for regular monitoring of water and sediment discharge, and water quality need to be extended covering all the major river basins. All these are so essential for projecting future scenario and associated risk and vulnerabilities due to climate change and variability.

More research to reduce knowledge gaps
Although this study, within its limited scope and constraints, has tried to cover on a sectoral basis the wide spectrum of global change impact assessment, associated vulnerabilities and adaptation in the Himalayan mountain regions; more focused and in depth scientific researches on global change impact on the mountain system need to be promoted through an integrated regional approach.

Institutional arrangement and support for promoting global change researches
An institutional arrangement and support system both at the country and regional levels may be developed to facilitate greater understanding of the emerging impacts of climate change and globalization processes on mountain areas and communities through information exchange and dissemination and systematic researches. This could also aim to bridge the gap between such scientific findings and policy making process towards minimizing the associated risk and vulnerabilities.

Institutional efforts for enhancing resilience and coping capacity
The notable development in service and infrastructures in the mountain areas by the government and the growth of NGOs and local institutions in the last few decades have to some extent improved the quality of life, reduced the physical hardships, and increased the resilience and the coping capacity of the people living therein against the mountain adversities. But they are still inadequate and less capable to addresses the needs and aspirations of the mountain people and to cope with the risks associated with global change and globalization.

Monitoring

Snow cover and glacier monitoring
A regular monitoring of snow covered areas, glaciers and glacial lakes, land use and land cover change based on remote sensing combined with field verifications requires to be initiated at both the national and regional levels.

River flow, sediment flux and river water quality monitoring
A regular monitoring of river flow, sediment flux and river water quality would be valuable not only for water resource planning but also provide valuable inputs to assess ongoing and potential future changes.

Cropwise agricultural yields at various altitudes
Cropwise agricultural yields at various altitudes need to be monitored for assessing changes due to global warming and taking necessary adaptive measures.

Enhancing Resilience and strengthening Coping Capacity

Integration of climate change considerations in sustainable development planning
Approaches toward exploiting synergies between environmental policies and key national socio-economic objectives like growth and equity could help mitigate and reduce vulnerability to climate change, as well as promote sustainable development.

Mountain specificities and development opportunities

By making use of traditional knowledge and comparative advantage of mountain niche products and services, mountain people should be enabled to make the best of the development opportunities in the mountains while protecting the mountain interests from negative impacts of globalization.

Environmental management and sustainable development

As a result of comparative advantage accrued from the overseas job, wage labor and service, agricultural lands in the mountain slopes are getting abandoned due to labor shortage and decline in investment in agriculture and livestock sector in all transects, but most apparently in middle and high mountains. Appropriate land use practices including the use of traditional agricultural practices need to be promoted for checking the accelerating process of soil erosion and landslides.

Sustainable development of the Himalayan region and down stream areas demands rational use of water resource of the region. As global climate change can have a profound effect on the Himalayan River System and Himalayan Water Resource Base and since both water forecast and regional water consumption has transboundary, regional aspects and teleconnections to more global aspects such as global change, current national approach towards water resource assessment and use needs to be complemented by a regional approach.

Such a regional approach through scientific regional integrated endeavors to begin with through an enhanced and improved flow of information on Himalayan water resource and management issues need to be initiated and eventually institutionalized.

Future Directions

Although the Himalayan mountain ecosystem is extremely important for the South Asian sub-continent for the goods and services it provides, integrated studies on the mountain ecosystems have, thus far, been meager. The present initiative is one of its own kinds where a multidisciplinary and multi-national approach has been adopted to identify the signatures of global change and its impact on the Himalayan mountain environment, as well as on the population living in the region. Hence, as a prerequisite to institutionalize this program in South Asia, certain necessary follow-up measures are required.

The outcomes and research results of the present study will be disseminated widely amongst the concerned stakeholders through appropriate measures including research papers published in peer reviewed journals.

Assessment of current impacts of global change individually on any one of the few subregions or sectors and choice of response could be within the present capabilities. The fact that they are projected to occur simultaneously and in concert with changes in population, technology, economics, and other environmental and social changes, as well as the chosen development paths, however, adds to the complexity of the impact assessment and the choice of appropriate responses. Furthermore, due to the marked variations in the Himalayan mountain regions in terms of latitude, longitude and altitude, as well as biophysical settings and socio-cultural set ups, neither the impacts of global change nor the response options will be uniform.

As there are still large uncertainties in the potential impacts of global change on the studied processes, as well as the interactions between them, the need for further detailed studies is apparent. The projection of climate change for the Himalayan mountain regions with contrasting variations of altitudes, surroundings, slopes and aspects over the small spatial scale; the effects of climate change on the South Asian monsoon and the ENSO phenomenon; etc. are among the major challenges and uncertainties in the modeling, for instance, of the hydrological cycle. Projections of agricultural crop yields are uncertain, not only because of the uncertainty in the hydrological cycle but also because of the potential positive effects of CO_2 and production practices. Integrated impact studies considering multi-stress factors are needed to better understand, describe and model the impacts of the ongoing global change processes in the region, their complex interrelations and interaction and to use the required integrated models (model systems) after their verification and validation with reference to recent and past observations and monitoring programmes for scenario-based simulations into the future.

In recognition of these issues, SASCOM has adopted Mountain Ecosystems as one of its four priority research areas during this decade for South Asia. Mountain ecosystems have also been identified as a major research component for the Earth System Science Partnership (ESSP)/START Monsoon Asia Integrated Regional Studies (MAIRS). In view of the aforementioned unique features of the Himalayan Mountains, international programmes such as the ‘Mountain Research Initiative' of the International Geosphere-

Biosphere Programme (IGBP) and the International Human Dimensions Programme on Global Environmental Change (IHDP) have also recognized the importance of and willingness to support regional programmes in such research initiatives.

Appropriate follow-up works will be carried out including the development of necessary follow-up project proposals focusing on related issues including those related to integrated modeling for the assessment of the global change impacts in the Himalayan mountain regions and also looking out for the funding resources.

Appendix

Appendix A: Conferences/Symposia/Workshops

S. No.	Seminar/Workshops	Dates	Venue	No. of Participants	Countries/Agencies Represented
1.	Initial Meeting on Proposed Scoping Workshop on Global Change Impact Assessment for the Himalayan Mountain Regions	21 – 22 July 2001	Kathmandu	13	India, Nepal and Pakistan
2.	Scoping Workshop on Global Change Impact Assessment for the Himalayan Mountain Regions	2 – 5 October 2001	Kathmandu	40	India, Nepal, Pakistan, APN and MRI
3.	Preparatory Meeting for the Implementation of the Project on Global Change Impact Assessment for the Himalayan Mountain Regions	20 – 22 June 2002	Kathmandu	17	India, Nepal and Pakistan
4.	First Year-End Workshop on Global Change Impact Assessment for the Himalayan Mountain Regions	7 – 12 January 2003	Kathmandu	24	India, Nepal, Pakistan, APN and Univ. of Gueleph
5.	National Workshop in Kathmandu on Global Change Impact Assessment for the Himalayan Mountain Regions in Nepal	1 November 2003	Kathmandu	28	Nepal / concerned Nepalese Stakeholders
6.	Second Year-End Workshop on Global Change Impact Assessment for the Himalayan Mountain Regions	16 – 20 December 2003	Kathmandu	26	India, Nepal, Pakistan and MRI

7.	National Workshop in Islamabad on Global Change Impact Assessment for the Himalayan Mountain Regions in Pakistan	7 August 2004	Islamabad	20	Pakistan / concerned Pakistani Stakeholders

Funding Sources outside APN

Other funding source

- The Institutions in the participating countries provided necessary inputs in kinds and manpower.
- START funded the participation of two representatives from Mountain Research Initiative (MRI) in the Scoping Workshop held in Kathmandu on 2-5 October 2001.
- START funded training in 2002 of one research team member in AIACC Trieste workshop
- The Gueleph University of Canada funded the travel of one of the paper presenter, Ms. Archana Shrestha in the year-end meeting in Kathmandu, Nepal on 6-10 January 2003.

Glossary of Terms

AIACC	- **A**ssessments of **I**mpacts and **A**daptation to **C**limate **C**hange APN - **A**sia **P**acific **N**etwork for Global Change
BGMS	- **B**ishkek **G**lobal **M**ountain **S**ummit
DSSAT	- **D**ecision **S**upport **S**ystem for **A**gro-Technology **T**ransfer
ESSP	- **E**arth **S**ystem **S**cience **P**artnership
GCM	- **G**eneral **C**irculation **M**odel
GLOF	- **G**lacial **L**ake **O**utburst **F**lood
IGBP	- **I**nternational **G**eosphere-**B**iosphere **P**rogramme
IITM	- **I**ndian **I**nstitute for **T**ropical **M**eteorology
IPCC	- **I**ntergovernmental **P**anel on **C**limate **C**hange
MAIRS	- **M**onsoon **A**sia **I**ntegrated **R**egional **S**tudies
MRI	- **M**ountain **R**esearch **I**nitiative
PRA	- **P**articipatory **R**apid **A**ppraisal
RCM	- **R**egional **C**limate **M**odel
SAARC	- **S**outh **A**sian **A**ssociation for **R**egional **C**ooperation
SASCOM	- **S**outh **A**sian **S**TART **Com**mittee
SAWTEE	- **S**outh **A**sia **W**atch on **T**rade, **E**conomics & **E**nvironment
SPSS	- **S**tatistical **P**ackage for **S**ocial **S**cience
START	- Global change **S**ys**T**em for **A**nalysis **R**esearch and **T**raining
UNFCCC	- **U**nited **N**ations **F**ramework **C**onvention on **C**limate **C**hange
WSSD	- **W**orld **S**ummit on **S**ustainable **D**evelopment
WTO	- **W**orld **T**rade **O**rganization

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