APN

Asia-Pacific Network for Global Change Research

Water Resources in South Asia: An Assessment of Climate Change -associated Vulnerabilities and Coping Mechanisms

Final report for APN project 2004-02-CMY-Muhammed

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START

IHDP • IGBP • WCRP

National Physical Laboratory, New Delhi

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Final Report submitted to APN

Overview of project work and outcomes

Non-technical summary

Among the regions of the world, South Asia is most sensitive to global climate variability, change and extremes. This region depends very heavily on the precipitation of the variable regional monsoon as well as water derived from the snow and glacier melt in the Himalayas; both of these are affected by climatic change.

This three-year project focused on the following activities:

- Analyzing recent experience in climate variability and extreme hydrological events, and their impacts on regional water resources;
- Assessing the impacts of projected climate change and variability and associated extreme hydrological events, and socio-economic changes on the water resources of Pakistan, India, Nepal, and Bangladesh;
- Determining the vulnerability of regional water resources to climate change; and identifying key risks to each sub-region and prioritizing adaptation responses;
- Evaluating the efficacy of various adaptation strategies or coping mechanisms that may reduce vulnerability of the regional water resources; and
- Providing inputs to relevant national and regional long-term development strategies.

Objectives

The main objectives of the project were:

First year (2002/3): Analysis of recent experience in climate variation and extreme events was conducted including impact and vulnerability assessments.

Second year (2003/04): The project focused on adaptation analysis and assessment. Field studies were conducted in the pre-identified Selected Hydrological Units (SHUs) in Bangladesh, India, Nepal and Pakistan.

Third year (2004-05): The focus was to provide stakeholders with information needed to reduce vulnerability of the region's water resources to climate and socio-economic change and to development of national and regional strategies.

Amount received for each year supported and number of years supported

Year One	Project Reference APN# 2002-12	$60,000
Year Two	Project Reference APN# 2003-04	$60,000
Year Three	Project Reference APN# 2004-02	$60,000

Participating Countries

Bangladesh, India, Nepal, Pakistan and United States

The participants were funded through the APN grant for the year-end meetings in Kathmandu, Nepal in January 2003 (year one), December 2003 (year two) and in Chiang Mai, Thailand in February 2005 (year three). The International START Secretariat and the Fred J. Hansen Institute for World Peace (HIWP) funded participation in an initial start-up meeting in Dhaka, Bangladesh in May 2002 and supplemented participation in the three year-end meetings. In addition, the HIWP funded an interim meeting in San Diego in May

2003 and another meeting in Dubai, UAE in August 2004. The purpose of the interim meetings was to finalize work plans and survey questionnaires for completing APN project activities. In addition, the details of the work plans for the HIWP complementary program were finalized.

Work undertaken & Results

Year One
(Project Reference #APN 2002-12)

During the first year (2002/3) analysis of recent experience in climate variation and extreme events was conducted. This focused on climate variability & impact, and vulnerability assessment.

Outcomes and Products

- An intensive 3-day inception workshop was held in Dhaka on May 23-26, 2002. This workshop was funded by the Hansen Institute for World Peace and the START Secretariat. At this workshop, background presentations were made by country teams, detailed work plans for year one activities were developed, outline of the country studies and data formats were finalized, timelines were established and the agenda was developed for the year-end meeting.
- Collaboration was made with the GEF-funded project on "Assessment of Impacts of- and Adaptation to Climate Change in Multiple Regions and Sectors." (AIACC) One member received training in April in the Tyndall Center, University of East Anglia, Norwich, UK. Two additional team members were trained in the AIACC June workshop held in Trieste, Italy.
- The participating countries in South Asia each produced national scale studies based on climate variability and impact assessment using historical record. These studies collated and analyzed pertinent data from various sources to identify extreme hydrologic events with adaptive responses (spontaneous and planned). A synthesis report for the South Asia region was prepared based largely on the information in the country studies.
- A regional background paper was prepared.
- An intensive 3-day year-end workshop (January 7-9, 2003) was held in Kathmandu, Nepal. Keynote background papers as well as results of national scale studies and the draft synthesis report were presented and discussed. Focused national studies were compiled for future publication.

Year Two
(Project Reference #APN 2003-04)

During the second year, the project focused on adaptation analysis and assessment. Field studies were conducted in the pre-identified Selected Hydrological Units (SHUs) in Bangladesh, India, Nepal and Pakistan.

Outcomes and Products

- An intensive 4-day year-end meeting was held in Kathmandu on 15-19 December 2003 in conjunction with the APN project on Mountain Environment in South Asia (APN 2003-03). Presentations on field level case studies were made by country teams. Detailed work plans and timelines for year three activities were developed.

- Proceedings of the first year-end workshop entitled "**Climate Change and Water Resources in South Asia**" were printed and distributed among the participants and other stakeholders. It included six chapters on country reports and year one synthesis and four chapters on keynote papers **Figure 1.**
- The Hansen Institute for World Peace (HIWP) organized and sponsored a meeting in San Diego, Calif. during 14-16 May 2003 to design and finalize the survey methodology and questionnaire for the case studies to be conducted in the SHUs identified in Year-1 of the project. Key actor interviewees were also identified in the meeting.

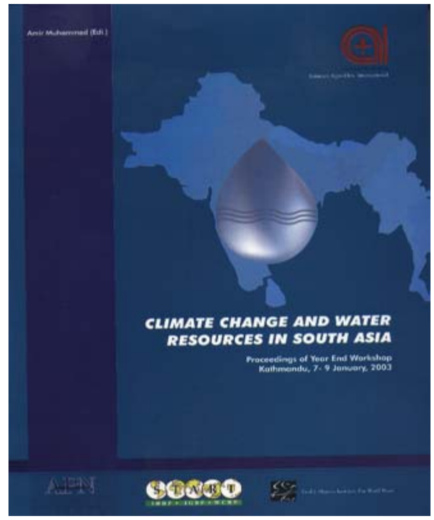

Figure 1. Proceedings of the first year-end workshop

- HIWP designed and implemented a collaborative program on dissemination of agriculture information to resource-poor farmers with the South Asia Water Project. The multi-media extension package is an attempt to bring some of the results of the APN work to an applied level to assist farmers (especially illiterate farmers) in planning crop plantation, nursing and production decision-making in times of extreme hydrological conditions. The user-friendly multi-media CD will include illustrations, graphics, pictures and video clips on best management practices geared to overcome the barriers of illiteracy.

Year Three

(Project Reference #APN 2004-02)

During the third year of the project, attention was focused on providing information needed to reduce vulnerability of the region's water resources to climate and socio-economic change and development of national and regional strategies.

Activities Conducted

- Preparation of regional maps of climate variability and change to identify areas at risk in terms of water availability and agriculture.
- Preparation of draft project report.
- Stakeholder meetings at national level with participation of experts and policy makers
- Final project meeting in Chiang Mai, Thailand on February 10-12, 2005 to discuss the results of stakeholders meetings and plans for preparation of the final project report.
- Peer-reviewed articles have been prepared for publication in a special issue of "Science and Culture" to be published from Kolkata, India.
- The synthesis report of the project for the entire period is under preparation and will be published as a book for wider dissemination.

Outcomes against original Proposal Objectives

All objectives of the project for the third year except the organization of an exposure meeting of technical experts and climate modelers in the Indian Institute of Tropical Meteorology (IITM), Pune, India, were achieved.

Product Outputs against original Proposal Objectives

- Regional maps of climate variability and change with areas at risk identified.
- Draft project reports for annual activities.
- Stakeholders' meetings organized in Dhaka (Bangladesh), Kolkata (India), Islamabad (Pakistan) and Katmandu (Nepal).
- Presentations made out of the final reports and presented in the stakeholders meetings.
- Articles are ready to go in the special issue of "Science and Culture".
- Synthesis Reports on floods and droughts have been prepared.
- Findings of the project are being compiled for publication as a book for wider dissemination. Outline of the book **(Annex A)**, selection of authors and time-line have been finalized.

Relevance to APN scientific research framework and objectives

The project is entirely relevant to the APN mission "that scientists and institutions within the countries of the Asia-Pacific region will together conduct high quality, cooperative, multi-disciplinary research on the region's key global environmental change issues and that the countries will use the results of that research in their policy making processes". The research framework of APN has 4 main thrusts one of which is "Climate Change and Variability" The framework requires the integration of the findings of natural science with social and economic factors with the eventual objective of making an input to policy making and implementation. This project meets all the objectives of the APN research framework.
The project analyzed the climate change during the last about 60 years and projected the trends towards future climate during the first half of the 21st century. Based on these climate changes, the likely impact of the anticipated climate changes on water resources in the countries of South Asia region were projected. Field studies on the impact of extreme events-draught in western India and southern Pakistan, and floods in Bangladesh, Eastern India and Nepal, were conducted in typical villages of the affected regions, through stakeholder surveys. The impact of previous extreme events and stakeholders' perception for mitigation measures for anticipated future events were analyzed in consultation with administrators and policy makers. During the final year of the project, the results of climate change analysis and field studies were discussed with the selected stakeholders including policy makers in order to prepare actionable recommendations for future.

Self evaluation

The project brought together scientists from several disciplines-meteorology, climate science, hydrology, economics, agriculture, to study the climate change in the participating countries of the region during the last century and trends for the next 25 years, the impact of climate change on water resources, and the incidence of extreme events. Policy makers have evinced keen interest in the project because of its importance in planning the harnessing of future water resources in light of anticipated climate change. Because of likely shortages of water to meet the requirement for agriculture products in a large part of the sub-continent, the urgency to develop new techniques to improve water use efficiency for crop production has been widely appreciated. Use of multi-media techniques developed as a part of the project activities to disseminate the improved technology especially to illiterate farmers, is likely to prove very effective.
For the flood prone regions, the project analyzed the incidence of past floods and trends for the future and discussed mitigation measures for the future in order to forewarn the threatened population about the incidence of flood and make arrangements to minimize the damage to life and property.

Potential for further work

Preparation of final project report is underway. The project findings will be published in a forthcoming issue .of the journal "Science and Culture" It is also planned to publish a book based on the activities of this project for wider distribution to scientists and policy makers. A two-page summary for policy makers is also planned which will be used to communicate the findings of the project to policy makers for incorporating in the national policies.
The project activities need to be continued in the region especially with respect to collecting more extensive meteorological data especially in the mountainous regions, analysis of climate variability and projected change. Special emphasis needs to be given to forecasting of extreme events in light of more elaborate meteorological data and analysis. The dynamics of Himalayan glaciers which play a crucial role in determining the availability of overall water resources need to be studied in more detail. Finally, more research is needed on efficient use of scarce water resources for crop production especially to meet the acute water shortage especially in the vast arid to semi-arid regions.

Publications

1. "Climate Change and Water Resources in South Asia" Proceedings of Year One activities.
2. Science and Culture Special Issue 2005
3. APN Newsletter article volume 9, #2, 2003
4. APN Newsletter article volume 11, #3, 2005
5. Final Book Publication of the project 2005

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Muhammed, A., (Ed.), 2003. Climate Change and Water Resources in South Asia. Asianics Agro Dev International, Islamabad, Pakistan.

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Acknowledgments

The international START Secretariat worked closely with the project team from inception until the final report and managed the APN grant. START also provided partial financial support for organizing the inception workshop in Dhaka in May 2003 and participated in the year-end meetings of the project.

The Hansen Institute for World Peace, San Diego State University played a key role in the initial development of the project proposal and subsequent planning and review meetings thru participation of experts and financial support. The Executive Director of HIWP also acted as project manager especially for management of funds.

Technical Report

Preface: The project was identified as a high priority subject during the Regional Capacity Building workshop in Islamabad held in November 2000. In the summer of 2000, several parts of southern Pakistan and western India experienced the worst and prolonged drought because of failure of the monsoon rains, which caused staggering economic losses besides loss of human and animal lives. Eastern part of the sub-continent had also suffered from devastating floods related to unprecedented atmospheric and terrestrial changes. These factors prompted the concerned scientists of the four main countries of the sub-continent to undertake research on climate change and its impact on water resources of the region.

1. INTRODUCTION

South Asia is marked with a large population and high incidence of poverty. The countries of the region have been struggling to achieve sustainable development and economic prosperity which are often frustrated due to a number of economic and social factors, along with their high vulnerabilities to natural disasters such as floods, droughts, salinity ingress, cyclone, storm surge, etc. Vulnerabilities to water-related disasters are predominantly due to acute climate variability and extremes which are manifested by both spatial and temporal distribution of water resources available throughout the region. In the Indo-Gangetic Plains (IGP)- the most densely populated part of the region consisting Bangladesh, India, Nepal and Pakistan, two specific climate related problems may be observed: the western parts suffer from frequent droughts, while the eastern parts face frequently occurring high intensity floods.

Following the publication of the Third Assessment Report (TAR) of the Inter-governmental Panel on Climate Change (IPCC) in 2001, it is evident that the climate system of the planet Earth is about to change significantly. It is understood that the anticipated changes will not be evenly distributed, rather it would induce abrupt and shocking events to take place in different parts of the world. The TAR also prognosticated that, a general warming superimposed on erratic monsoon activity in the dry season over the semi-arid (western) parts of IGP would lead to increased susceptibility to droughts, while increased monsoon activity over the eastern parts of IGP would cause higher floods in terms of both extent and frequency. It is also understood that crop agriculture, which is still the largest contributor to the national economies of the four countries, would be severely constrained due to adverse effects of climate change. Given that the countries of South Asia representing IGP have limited capacity to cope with such disasters, climate change induced increased climate variability and extremes would accentuate the plight of the poor of South Asia.

1.1 Climate Vulnerability and Water Resources in South Asia: Reasons for Concern

South Asian nations and their economies are highly dependent on the onset and retreat of monsoons and water supplies from glaciers and snowmelt. However, excessive and inadequate rainfall causes floods and droughts, respectively which have damaging effects on the South Asian economies. Global climate change is an emerging concern, which may cause serious impacts on the monsoons, frequency and distribution of rain spells, accelerated melting of glaciers and increased number of floods and droughts.

1) *Global mean temperature increase and damage to unique and threatened water systems*: Some unique and threatened water resources systems such as glacial lakes, Himalayan snow and glaciers and coastal and inland wetlands may be irreparably harmed by changes in climate beyond certain thresholds. **Figure 2** demonstrates how unique and threatened systems will face a substantially increased risk with increases in global mean temperature. Note that the magnitude of risk will vary from place to place and region-to-region depending on the magnitude of climate change and resiliency of a particular unique and threatened system.

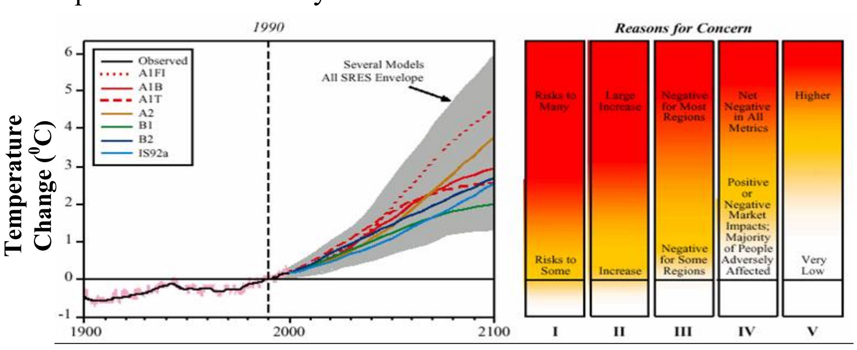

Figure 2. Global mean temperature change and risks of damages. I. Unique and threatened systems; II. Extreme climate events; III. Distribution of impacts; IV. Global aggregates impacts; and V. Large scale, high impact events. *Source: IPCC, 2001a.*

2) Global mean temperature increase and the distribution of water resources impacts and vulnerability: Depending on climate and hydrological dynamics and geographical, population and ecosystem distribution, regional difference in impacts and vulnerability may be conspicuous.

At present, the great pressure on water resources is from rising human population, particularly growing concentrations in urban areas. **Figure 3** shows the impact of expected population growth on water usage by 2025, based on the UN mid-range population projection and the current rate of per capita water use (UNEP and Earthscan, 1999). Possible increases in water use due to economic growth or improvements in water use efficiency have not been taken into account. With these two factors, the scenario would likely to be worse.

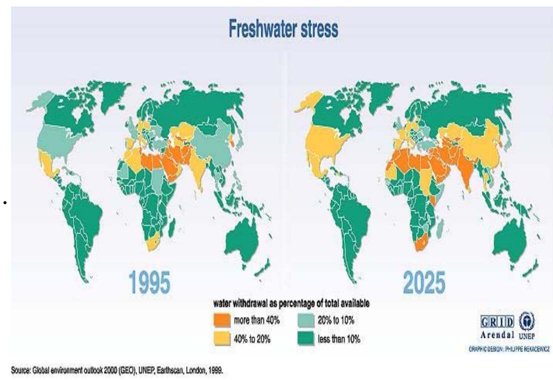

Figure 3. Freshwater stress in 1995 and 2025. *Source: UNEP and Earth scan, 1999.*

The impacts of climate change - including changes in temperature, precipitation and sea levels - are expected to have varying consequences for the availability of freshwater around the world. Current indications are that if climate change occurs gradually, the impacts by 2025 may be minor, with some countries experiencing positive impacts while most experience negative ones. Climate change impacts are projected to become increasingly strong during the decades following 2025.

Major parts of the Indian sub-continent have been experiencing a warming trend in their climate and a change in the monsoon pattern which is a crucial factor in the economic development of these countries. Western parts of the sub- continent including the deserts of Cholistan in Punjab, Thar in Sindh and major parts of Balochistan province of Pakistan, and the adjoining Rajputana desert and Gujrat state of India are draught- prone regions. However the draught of 1997-2002 was the most prolonged and most severe resulting in staggering losses of life and property. Almost simultaneously, parts of Bangladesh, Nepal and India also suffered from devastating floods of unprecedented magnitude. These phenomena prompted the policy makers and scientists of these countries to undertake studies on the phenomena of climate change and its impacts on water resources of the countries. The APN-sponsored regional workshop on Capacity Building in Global Change Research held in Islamabad in November 2002 identified regional climate change and its impacts on water resources as the highest priority subject for submission to APN as a project proposal from the South Asia region. The scope of the project was further defined during a technical meeting sponsored by the Hansen Institute for World Peace held in San Diego, California in May 2001 and a draft of the proposal prepared for submission to APN. The project was finally awarded by the APN in March 2002.

2. METHODOLOGY

The overall structure for research for this project was based on the methodology originally proposed by Burton (2001) as shown in **Figure 4**.

Vulnerability Assessment	Adaptation Assessment	Information for Policy Makers
• Analysis of recent climate variability and extreme events • Impacts of above on water and related sectors • Climate change and socio-economic scenarios • Projected impacts and vulnerabilities	• Case studies: field surveys, key actor interviews • Evaluation of adaptive measures, economic efficiency, acceptability and technical feasibility • Lessons learned and experience sharing	• Draft final report • Stakeholder meetings • Inputs to national development strategies • Final report dissemination • Capacity building meetings
YEAR 1: 2002/3	YEAR 2: 2003/4	YEAR 3: 2004/5

Figure 4. Conceptual Research Structure for the Project (based on Burton 2001)

Year 1

- Hydro-meteorological data were collected from national data sources. These data were cleaned up to fill up the missing values and consistency. Statistical (regression) and graphical methods were applied to detect changes in the climate data.
- Impacts of general climate change trend and extremes on the socio-economic sectors were analyzed by employing damage and economic analysis.

Year 2

- Hydrological Units **(Figure 5)** were selected based on information of current vulnerability to floods and droughts in various river basins. There is a likelihood that these areas will continue to be vulnerable to extreme hydrological events in future.
- Questionnaires were prepared to unveil vulnerability of population, agriculture, infrastructure, etc. to extreme hydrological events and adaptation measures and coping strategies. The questionnaires were pre-tested and finalized accordingly. Field surveys were conducted based on the final questionnaire and the collected data were processed using Statistical Software SPSS.

Year 3

- Climate and hydrological change scenarios for 2020 and 2050 for selected hydrological units (SHUs) were constructed using GCM scenarios.

Stakeholders were identified through consultations, background presentations were prepared and consultation meetings were organized to brief the stakeholders about climate change and key concerns for the water sector and necessity and strategies to involve adaptation in the planning process.

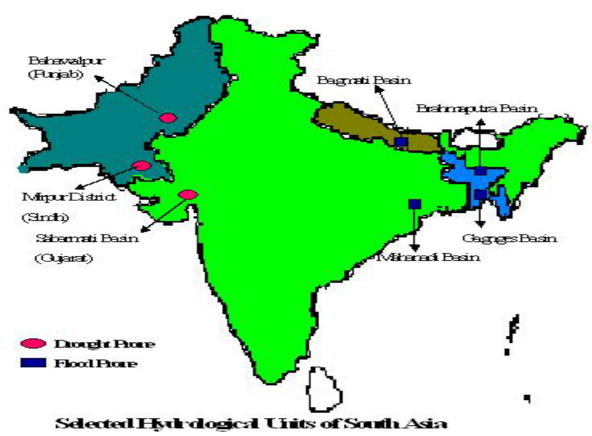

Figure 5. Selected Hydrological Units (SHUs) in India, Bangladesh, Pakistan and Nepal.

The basic data for the project relating to climate change and water resources for the participating countries, including the occurrence of extreme events in the past, was obtained from the climate records of the meteorological departments and the central water resources development organizations of the participating countries of South Asia region. The historical climate records of selected meteorological stations for 1931-1960 and 1961-1990 were compared and analyzed to determine the trends in change in various climate parameters relating to temperature and precipitation. These trends were projected for 2020 and 2050 in order to get an idea of the anticipated climate changes for the future about half a century. Maps showing the trends in temperature and precipitation in the sub-continent based on the data from the participating countries were prepared. During year two of the project, detailed field surveys were conducted in the villages in the selected hydrological units to get the basic information about the impact of the extreme events and the measures adopted by the affected population and the government to mitigate the negative impacts. Besides stakeholder interviews with representative dwellers of the SHUs, an attempt was also made to get a feedback from local administrators about the effectiveness of the mitigation measures already adopted and plans for the future.

The main activity during the third and final year was compilation of the results of climate data and analysis, and the field survey data from the SHUs for presentation in the stakeholders meetings to which a wide range of stakeholders including policy makers and senior administrators from a wide range of government departments and selected farmers from the target areas, were invited. Results of climate analysis and trends for climate change, likely impact on water resources and projections for occurrence of extreme events, as well as the highlights of the field survey and socio-economic impacts of previous extreme events were presented to the stakeholders groups in each of the participating countries. The comments and suggestions of these meetings were compiled and communicated to the selected government agencies for incorporation in their plans for developing measures to cope with the disasters in future. The final meeting of the project collaborators and other interested colleagues was held in Chiang Mai in February 2005 to review the total project activities especially the activities of the final year and develop plans for preparation of the final report and other follow-up activities.

3. HYDROLOGY AND WATER RESOURCES-OBSERVATION OF CLIMATE VARIABILITY, CHANGE AND IMPACTS

3.1. Synthesis of Observed Changes

3.1. a Hydro-Meteorological Systems: Monsoon governs the hydrologic systems of South Asia region. Two monsoon systems operate in the region: the southwest or summer monsoon and the northeast or the winter monsoon. The summer monsoon accounts for 70-90% of annual rainfall over most of mainland South Asia, while the northeast monsoon is dominant over Sri Lanka and Maldives. The northern part of South Asia also receives considerable precipitation from the Western disturbances.
There exists a considerable spatial and temporal variability in both temperature and precipitation over the region. There is also a clear association between El Niño events and weak monsoons (Mitra, 2002). Over the period 1871-1988, 11 of 21 drought years were El Niño years. During the 90-year period between 1901 and 1990, rainfall deficiency has been observed in all 7 strong El Niño cases.

i. Air temperature: During the latter half of the past century, air temperatures have shown slow increase in all the countries of South Asia. For *India,* which constitutes about 75% of land area, a recent estimate reported a significant warming of 0.4^{o}C/100 years in the mean annual temperature during 1901 and 1982 (Hingane *et al.*, 1985) . However unlike the other countries of the region, increase in temperature is seen mainly in maximum temperature (T_{max}) thus showing an increase in the diurnal range of temperature. The reported changes in temperature over India, however, are not spatially uniform. There have been large areas of significant warming along west coast (with an exception of the middle reaches), the interior peninsula and northeast India, Northwest India has been observing significant cooling. The diurnal variability in temperature has also showed significant changes. In general, there has been an increase in diurnal range of temperatures. A systematic analysis of daily maximum and minimum temperature revealed that, the former increased by 0.6^o/100 yrs over the period between 1881 and 1997 (Pant & Kumar, 1997). Moreover, the observed increase in all India mean temperatures is almost solely contributed by the increase in maximum temperatures, while no appreciable change has been observed for daily minimum temperatures.

A trend analysis of the past temperature in *Bangladesh* shows that, during the past three decades a warming has indeed taken place: the minimum temperature of the winter and post-monsoon seasons has been increasing in most parts of the country, while the maximum temperature of winter shows weaker warming compared to the minimum temperature (Choudhury *et al*., 2003). The overall trend suggests that, the winter is growing milder and the amplitude of diurnal variation during winter is also decreasing. Post-monsoon exhibits strong warming in the maximum temperature. A trend analysis with mean annual temperature shows that it has been increasing over central and southern Bangladesh at moderate to high rates. For monsoon season a strong warming of about 0.1 to 0.3°C/decade has taken place over the past thirty years.

In *Nepal* the trend is higher at the higher latitudes – in the middle mountains and in the Himalayan region warming occurred at rates ranging 0.6^o to 1.2^oC per decade, while warming at a rate of $<0.3^oC$ has been observed in the Shivalik and Tarai region (Mitra, 2002). For Nepal, the maximum temperature shows a continuous increase after late seventies. In general, the amplitude of variation in minimum temperature is found higher than that for the maximum temperature (Nepalese Team, 2003).

In contrast to the other three South Asian countries, *Pakistan* experienced both warming and cooling in recent decades (i.e., during 1961-90) compared to earlier decades of the past century. Maximum temperature recorded warming of 0.1 to 4.0^oC in 17 of 37 stations, while in 14 other stations cooling of about -0.4 to -2.6^oC has been observed. Given the mixed results one can only conclude that there has been significant change in maximum temperatures for Pakistan. In terms of minimum temperature, another mixed signal has been obtained, where the decrease in minimum temperature was higher than the observed increase. For the two selected locations in Pakistan, Bahawalpur and Hyderabad, despite a decrease in maximum temperature there have been increases in winter temperatures (Muhammed et al., 2003).

ii. Rainfall: In *Bangladesh*, occurrence of rainfall has increased by some 18% in the north, west and southwest region of the country since 1970s. However, a withdrawal of annual mean rainfall has also been observed in the southeast region of the country. In general, the pre-monsoon rainfall has increased significantly over the northern parts of Bangladesh. Choudhury (1994) found a correlation between extreme rainfall events and a rapid change in Southern Oscillation Index (SOI), especially when *La Nina* phase (i.e., positive SOI values) takes over from *El Nino* (i.e., negative SOI values).

Analysis of mean annual rainfall over *Nepal* suggests that, the middle mountains around central Nepal receive the highest amount of rainfall, on an average over 5000 mm per annum, while rainfall decreases northward and in the high mountains. From historical data, no trend has been observed in relation to positive or negative anomaly in mean annual temperature. However, there has been high degree of spatial distribution of rainfall anomaly during the past three decades in Nepal. In case of *Pakistan*, majority of the stations exhibit an increase in extreme rainfall events. However, decrease in rainfall on extremely rainy days is also observed in a number of stations. In general, drier years were found increasingly

drier and wet years wetter during the period 1961-90 compared to 1931-60. For Bahawalpur, a selected station, there has been a slight rise in monsoon rainfall for 25% rainfall probability.
All-*India* rainfall variability does not exhibit any significant change since 1871. However, on smaller spatial scales significant areas have observed long-term rainfall changes. The west coast, north Andhra Pradesh and northwest India experienced increased monsoon rainfall ranging 10 to 12% per century, while east Madhya Pradesh, its adjoining areas, northeast India and parts of Gujarat and Kerala experienced decreased rainfall ranging 6 to 8% per century. Weak monsoon has been associated with a large negative SOI – 11 of 21 drought years between 1871 and 1999 were El Nino years. The periods 1895-1932 and 1965-1987 were characterized by frequent drought events. An examination of extreme rainfall patterns of the past century over the mainland Indian sub-continent, one can isolate two sub-regions: one in the northwest (Indus-basin Sub-region) involving Pakistan and Indian states of Gujrat, Hariyana and part of Punjab and the other in the northeast (Ganges-basin Sub-region) involving southern Terai parts of Nepal along the Kosi-Gandaki-Bagmati basins, Indo-Gangetic plains, Sabarmati basin, Assam, and Bangladesh. The former sub-region is characterized by scanty rainfall, particularly during the winter season, while the northeastern sub-region is characterized by abundance of rainfall during monsoon. Bangladesh' case is perhaps peculiar: it suffers from both the phenomena of too much water in monsoon and too little water in winter and pre-monsoon months. Therefore, both floods and droughts are common in Bangladesh.

<u>iii. Runoff</u>*:* River flows are affected by climate changes. Study of river flows over time is important especially to determine the sustainability of the irrigation system and ground water recharge. The impact of climate change on flows of 4 major rivers from different climatic zones in South Asia (Indus, Ganges, Brahmaputra, and, Sabarmati) is briefly described below:

Indus: The Indus River basin geographically lies in Pakistan. The Indus River system includes the western tributaries Indus, Jhelum and Chenab and the floodwaters of the eastern tributaries Ravi and Sutlej. There is a high variation of rainfall from north to south in the basin (hyper-arid to humid, sub-humid, semi-arid and then to hyper arid). The average annual rainfall in the country is 289 mm ; the rainfall trend for the last 41 years calculated by Pakistan Meteorological Department (2002) is given in **Figure 7** .

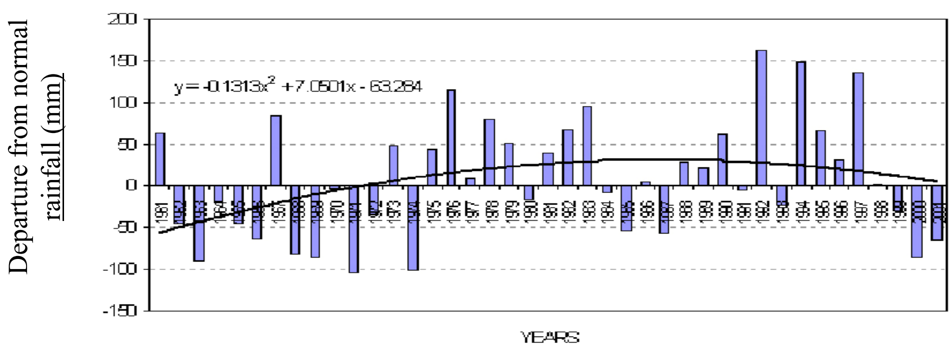

Figure7. Annual Rainfall Departure from the Normal Annual Rainfall of Pakistan 1961-2001*.

**Normal Annual Rainfall based upon the data of 1961-90 is 289mm*

Analysis of the discharge data for the Indus River at Tarbela (Ahmed, Bari & Muhammed, 2003) shows a declining trend in river flow (**Figure 8**). Significant contribution to the river flow comes from glacier melt (around 30%) and from snow-melt. Detailed information regarding snow-melt is limited and not readily available. Physical verification of rainfall and discharge data shows that they are highly correlated. For example, during 1998-2004 rainfall was 20-30% below the normal and the corresponding discharge shows –25% maximum change.

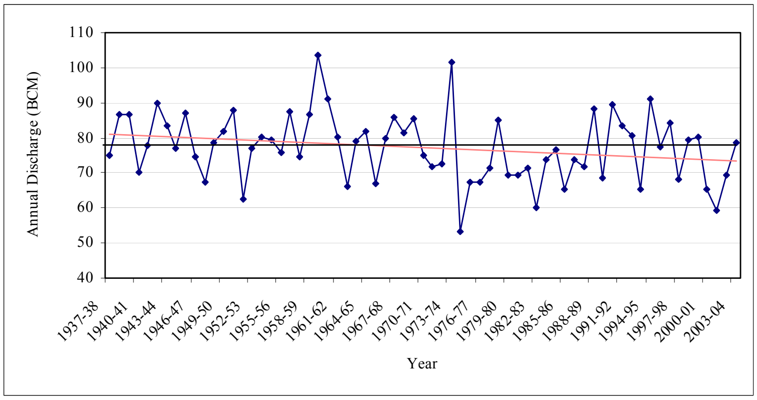

Figure 8. Annual Flows of Indus River at Tarbela, Pakistan 1937-2004.

Ganges: The Ganges River basin is shared by China, Nepal, India and Bangladesh. There is a high variation (semi-arid to humid) of rainfall from north to the south direction of the basin. The average annual precipitation in the basin is 1,070 mm. In India, Nepal and Bangladesh, the mean annual precipitation is 908, 1,860 and 1,568 mm, respectively. Mirza et al. (1998) analyzed 124 years precipitation data for the Ganges basin to detect trends (**Figure 9**). Although, the graphical presentation of the data shows that 70 years precipitation was above the normal, statistical test (Mann-Kendall rank statistic, τ) does not show any significant trend. Mirza (1997) also analyzed discharge data for the Ganges at Farakka for the trend analysis. Note that flow of the Ganges is regulated here, therefore, downstream stations in Bangladesh have not been considered. The analysis does not reveal any statistical change in annual runoff (**Figure 10**). Physical verification of precipitation and discharge data shows that they are highly correlated. For example, in 1979 precipitation was 40% below the normal and the corresponding discharge shows –35% change.

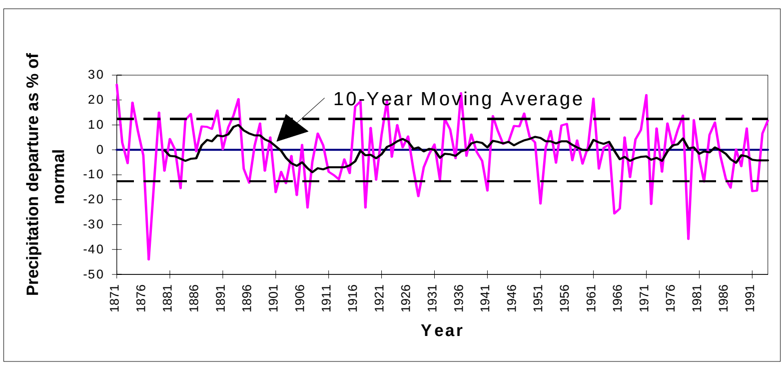

Figure 9. Annual precipitation departure in the Ganges basin in India (1871-1994). The solid line and the dashed lines indicate mean and one standard deviation departure (in %) from the mean, respectively.

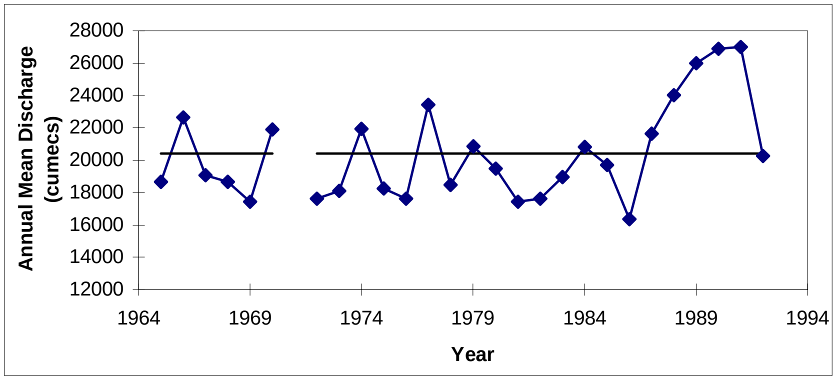

Figure 10. Annual mean discharge of the Ganges River at Farakka for the period 1949-1985. The horizontal solid line indicates mean annual discharge of 12,323 m^3/sec.

Brahmaputra: The Brahmaputra basin is shared by China, India and Bangladesh. The basin is very humid and the average annual rainfall is 2,000 mm. In India, the mean annual precipitation within the basin is 2,500 mm and in Bangladesh it is about 2,400 mm. In Bhutan, the average annual precipitation varies from less than 500 mm high in the Himalayas to between 2,500 mm and 5,000 mm in the southern foothills. The inner valleys receive between 500 mm and to 1,000 mm of rain each year (BBJTO, 1989). Mirza et al (1998) analyzed precipitation data for the trend analysis and could not detect any statistically significant trend (**Figure 11**). Like the Ganges River, precipitation and discharge for the Brahmaputra show strong correlation. For example, in 1976, precipitation was 15% lower than the normal. The corresponding discharge shows a –17% change (**Figure 12**).

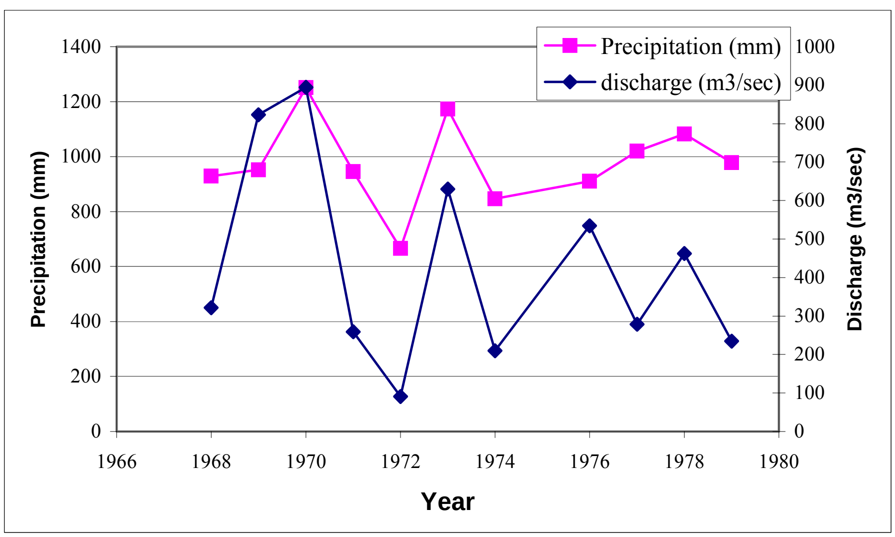

Figure 11. Annual precipitation departure in the Brahmaputra basin in India during 1901-1981. Dashed lines indicates ± 1 standard deviation of departure (% of the normal).

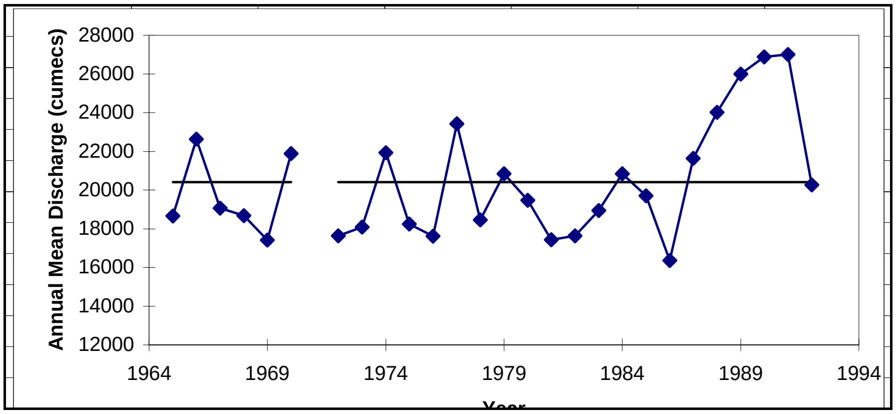

Figure 12. Annual mean discharge during 1965 - 1992 for the Brahmaputra River at Bahadurabad. The solid horizontal line indicates mean annual discharge of 20,398 m^3/sec.

Sabarmati: The Sabarmati River has a length of 300 km. The catchment area of the Sabarmati basin is 21674 km^2 and has an annual average runoff of 3200 million m^3.. The average flow is 1271 m^3/sec with a maximum of 11570 m^3/sec and a minimum of 1 m^3/sec. The Sabarmati Basin has 1548 thousand hectares of cultivable land with a gross sown area of 1403 thousand hectares and a gross irrigated area of 318 thousand hectares. The basin is mainly characterized by a normal annual rainfall of 200 mm to 750 mm with one small area receiving as much as 2000 mm. The basin experiences 30 to 40 rainy days per year. The onset of monsoon is between June 10th and June 15th and the withdrawal is near the end of September. Time-series data of precipitation and discharge are plotted in Figure 13 which shows proportional relationship between the variables. To reveal their empirical relationship, regression analysis was carried out (**Figure 14**) which demonstrates that only precipitation explains 70% variation in discharge.

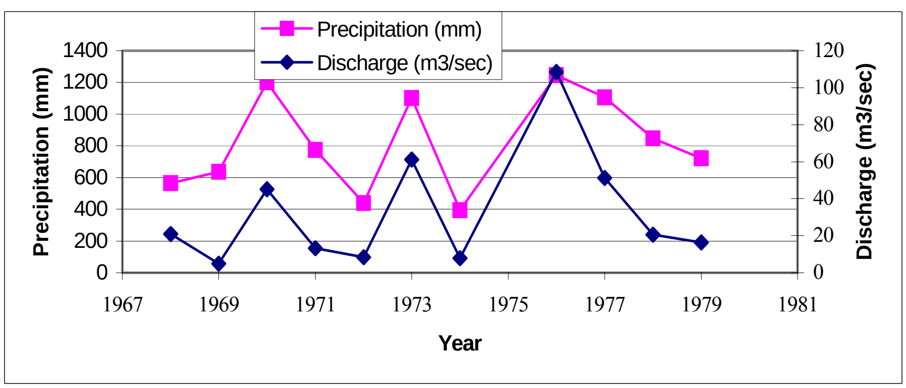

Figure 13. Precipitation and discharge time-series of the Sabarmati River at Ahmedabad.

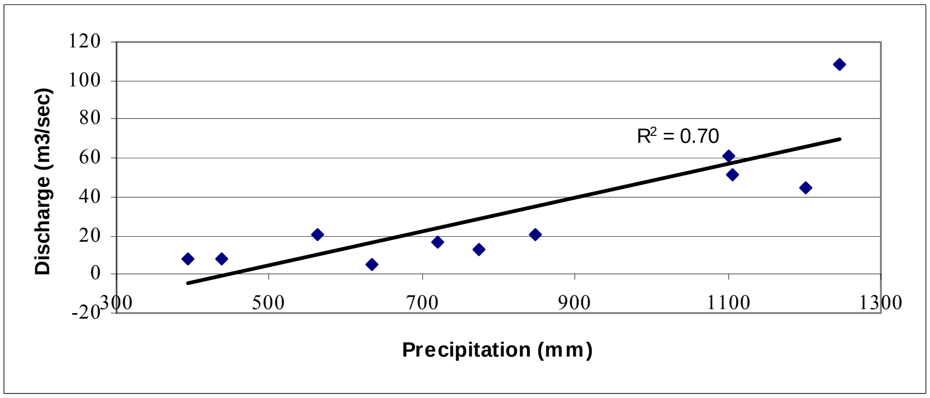

Figure 14. Result of regression analysis of precipitation and discharge of the Sabarmati River at Ahmadabad. X and Y coordinates denote precipitation and discharge, respectively.

iv. Floods: Eastern part of South Asia especially Bangladesh, Nepal and parts of India are flood-prone regions. The floods are frequent and cause a great deal of damage to life and property. Geographically *Bangladesh* is located at the lowest part of the GBM region, just south of the Meghalaya Hills and Cherapunjee. Bangladesh possesses only about 7 per cent of the catchment area of the GBM systems, while over 92 % of the water volume is discharged through it. Such an imbalance in the draining of the regional surface water causes abundance of water in the monsoon months. Furthermore, a decline in drainage gradient along the Ganges and other rivers results in severe drainage congestion close to the estuary. As a result, an estimated average of around 25% of the landmass of the country is flooded every year, while about 60% landmass is prone to flooding.

Recent analysis suggests that the frequency of devastating floods in Bangladesh is on the increase (Ahmad *et al.*, 2000). Four of the most severe floods have occurred in the past 30 years, whereas only two floods with comparable intensity visited Bangladesh during the preceding 70 years. Since the number of people living in the flood prone areas is increasing with increasing population and more assets are being placed in those areas, it is likely that the damages due to floods will increase manifold in future. Furthermore, the possibilities of adverse impacts of climate change would exacerbate the flood vulnerability of the country in the early next century.

India is the largest country in the region. It shares most of the major rivers of the region with its neighbouring countries. In northern and north-eastern India floods are caused by a number of factors such as excessive precipitation, inadequate drainage capacity, land use changes, natural denudation, excessive siltation, etc. The maximum rainfall in India is observed in the Brahmaputra valley, about 2500 mm. The Brahmaputra and Barak along with their tributaries cover Assam and other north-eastern states and northern portion of West Bengal. The region is interspersed with a large number of streams that inundate the narrow valley. The north bank tributaries of the Brahmaputra are very flashy, bring down heavy loads of sediments, sometimes even boulders, and have a tendency to change their courses. The hillsides are prone to earthquakes and susceptible to landslides and erosions, interfering with the drainage systems. The effect of the 1950 earthquake on the water levels of the Brahmaputra in India is significant. The lowest water level was reported to have increased by 3 m (Goswami, 1998). Thus, the main problems of the Brahmaputra and its tributaries in India are those of over-bank spillage, drainage congestion, bank erosion, landslides, and change of river courses.

In the western arid region of India and adjacent Pakistan, rainfall is highly erratic. In successive years there might not be any appreciable rainfall leading to extremely arid condition, while in other times rainfall amounting to >90% of the annual mean may occur within one single month causing devastating short-duration floods. Unlike the Himalayan rivers, the peninsular rivers in the central India are by and large stable. In India, the general trend of devastation due to floods has been increasing over the years. From 1972 onwards, there has been a steadily increasing trend of flood vulnerability marked by sharp annual fluctuations (Mirza, 2002).

Although there are about 6000 rivers in *Nepal*, only a small number of them are closely linked to the livelihood of the Nepalese, a large proportion of whom are concentrated in the Terai while others are dispersed in other parts of the country. The major rivers include Sapta-Koshi in the eastern, Gandaki (Narayani) in the central and Karnali and Mahakali rivers in the western parts of Nepal. All these rivers originate in the Himalayas and feed the Ganges system. The rivers are more influenced by snow-melt and, therefore, they exhibit significant flows even in winter months. But the swelling rivers can engulf flood plains when they receive rainfall-runoff in the monsoon The steep slope of the mountains generates high kinetic energy that devastate the plains in the valleys both in Nepal and India. The rivers rising from the Siwalik range in Nepal experience floods caused by burst of rainfall on the southern slopes. These floods cannot be predicted, but they often bring down voluminous loads of water that virtually sweep the plains of Nepal and adjacent plains of India. Water levels in the main channel fluctuate so suddenly that people hardly get any time to move to safer places. All the Himalayan rivers carry sediments that are deposited in the plains to reduce the drainage gradient in the downstream.

As mentioned earlier, floods in *Pakistan* and northern parts of India are caused primarily by the Indus river system. Indus has originated in Tibet and it flows through Ladakh and Zanskar ranges of the Himalayan mountains. It hits the plains at Attock in Pakistan and flows southward into the Arabian Sea at Thatta. The river and its tributaries in vast plains of the northwestern part of the sub-continent are being harnessed in the upper reaches. The Indus system supports the largest irrigation system of the world. Despite large-scale utilisation of surface water from the rivers, the system causes severe floods in the plains. It is believed that changes in climate systems and, more importantly, extensive deforestation in the Himalaya are the major causes of floods in Pakistan. Records of the past 100 years show that seven of the ten worst floods in the Ravi have occurred in the last 25 years. In 1992 an exceptionally high flood of about 31,000 m^3/sec occurred in the Jhelum River at Mangla. This was the worst flood since 1959 (Sheikh, 2002). The pre-monsoon heavy floods in Pakistan occurred in June 2005 after a period of about 100 years. These floods were caused by unprecedented melting of snow on the glaciers due to increase in temperature. There was no contribution of rains to these floods./

v. Glacial Lake Outburst Floods (GLOFs): In the higher mountain areas in Bhutan, India, Nepal and Pakistan floods occur due to Glacial Lake Outburst. Glacial lakes that pose this type of danger are formed by the retreat of the glacier; water from the ice melt is retained by the glacier's terminal moraine. Eventually, either the volume of water becomes too great for the moraine to support or an event such as melting of ice cores, rock/ice avalanches cause detachment and catastrophic failure of the moraine. Such glacier-induced events are highly unpredictable and damaging. In the upper Indus River system, 35 destructive GLOF events were recorded in the past 200 years; however, there have been few catastrophic floods in the recent past. A GLOF from the Shyok area in August 1929 extended 1300 km downstream to Attock and had a discharge greater than 15,000 m^3/sec. GLOF events from the Lunana area of northwestern Bhutan damaged the Punaka Dzong in 1957, 1969 and 1994. The GLOF event that occurred on 4 August 1985 from Dig Tsho (Langmoche) glacial lake in Nepal destroyed the nearly complete Namche Small Hydropower Plant (estimated cost of $1.5 million), 14 bridges, cultivated land and other valuable infrastructure. Five GLOF events occurred in Nepal in the period 1977-1998, evidence of other occurrences in the past was also found (ICIMOD, 2003). Nepal has 2315 glacial lakes and 26 are considered to be potentially dangerous (**Figure 15**) (Pradhan *et al*, 2002).

Figure 15. Glaciers and potentially dangerous glacial lakes in Nepal.

vi. Droughts: In the four South Asian countries, devastating droughts are common in Pakistan and northwestern India, while it is less commonly recognized is case of Bangladesh. Indian states of Gujrat, Haryana, and Punjab are highly susceptible to drought, particularly agricultural drought due to reduced rainfall in post-monsoon months and inadequate availability of groundwater. Similarly, the provinces of Sindh and Balochistan of Pakistan are highly susceptible to drought.

Pakistan has experienced several droughts in the recent past, of which the most severe one occurred in 1998-2002. Surface water availability was reduced by over 30%. The drought condition persisted all along during the dry period in 1999-2000. During that time, the total surface flows in the major rivers declined from 162.1 billion cubic meters (BCM) to 109.4 BCM, while rainfall was below normal. The drought reduced canal diversions significantly, causing a net shortage of about 51% of canal supply with respect to 'normal' years. As a consequence, irrigation based agriculture suffered to a great extent during the drought.

In *India* around 263 million people live in drought prone areas spanning to about 108 million hectare, which is roughly 1/3rd area of the country. Thus, more than 26% of its total population faces the consequences of recurring droughts (India Country Report, 2003). In the last 200 years India suffered 41 drought years (slightly over 20 drought years in each century) (Kulshrestha, 1997). Recently (the year 2002), the Indian state of Gujarat was severely hit by a drought when it received deficient rainfall in 24 out of its 25 districts. The monsoon onsets in Gujarat in the 4th week of June 2002. The second spell of rains that were expected between mid-July to the last week of August failed, resulting in severe loss of crop and scarcity of drinking water and fodder in most parts of the state

3.1.b Impacts of extreme events on agriculture

Draughts and floods cause colossal damage to life and property and devastate the economy of the affected countries. Floods cause tremendous losses to infrastructure and industry and result in spread of diseases that sometimes result in epidemics. However, the losses to agriculture caused both be floods and draughts are staggering and affect a vast majority of the population who depend on agriculture for their livelihood. The impact of the extreme events on agriculture sector is therefore discussed below in some detail.

a. ***Floods and Agriculture:*** The major food grain produced in South Asian countries during monsoon is paddy. Rice is the staple food for over 300 million people in the Indo-Gangetic plain. Although paddy is a water-loving plant, long standing floodwaters can ruin plant metabolism and other biotic activities and adversely affect growth of the plant. Consequently, a significant proportion of the production can be reduced. Sometimes, prolonged inundation does not allow early transplantation of paddy and thereby adversely affect the production of the next cropping season (Ahmed, 2000). Jute, the other traditional monsoon crop grown in the Ganges basin, grows well in inundated conditions. South Asian countries, particularly Bangladesh and India, used to grow a significant quantity of jute – mostly for export to international markets. Due to its poor market acceptance in recent decades, it is no longer an economic crop.

Crop agriculture, the lifeline of the subsistence economy, suffers the most during a high intensity flood. In the low-lying lands that undergo early monsoon flooding, crops of high economic opportunity cannot be grown. As a result, opportunities for a significant amount of food-grains are lost every year. In marginal lands, however, people deliberately take risk and cultivate high yielding varieties of food-grains (mainly rice) and sometimes suffer losses. During high intensity floods Bangladeshi farmers face colossal losses in agricultural production, which put national food security at risk. The flood of 1974, although a moderate one, severely damaged the *Aman* crop. During that period, national food supply was mainly dependent on *Aman* and the contribution of Boro was not as much as it is today. A loss of about 1.4 million tons of rice, consequent reduced availability of foodgrains in local markets followed by lack of access to food by the poor due to price hike resulted in a famine in Bangladesh (Sen, 1981; Alamgir, 1980). Mortality estimates for this famine very widely, but some experts estimate that the excess death toll grew to be over one million (Sen, 1981).

Flood is a common phenomenon in the Nepalese Terai (flat land). However, floods do occur in the foothills, where these are associated with landslides. The loss from floods in Terai seems to be quite higher than that of landslides and floods in the hills and mountains. Floods affect monsoon crops, primarily paddy and maize in Nepal. The flood of 1993, one of the worst in living memory, damaged over 128 thousand hectare of agricultural lands and caused a net reduction of production by 12%. Of the estimated damages, over 68% occurred in Terai, while the rest was in hills and mountains. Floods also cause death of livestock, which constitute a significant part of Nepalese agriculture. The devastating flood of 1993 took away some 25,000 livestock, most of which were drowned in Terai region. On an average, about 2,300 livestock perish per annum as a direct consequence of flood. Sarlahi district is the most flood-prone, registering over 50% of all losses due to floods.

b. *Droughts and Agriculture*: Droughts are caused due to lack of precipitation during a length of period, which affects the human lives, crops and other economic activities. During a long lasting drought, the strong evapo-transpiration causes the loss of surface water and soil moisture, which aggravates drought situation. The situations may grow even worse, if the flow interventions take place in the upstream parts of the rivers. The groundwater recharge is slow and inadequate during in the drought year due to reduced precipitation and lower discharge through the rivers. Drought usually affects agriculture the most. Adverse effects of floods in *Pakistan* are predominantly observed in urban areas and not so much on crop agriculture. Droughts, in contrast, affect agriculture severely. The worst drought occurred in 2000-01 affected several districts of the provinces of Sindh and Balochistan. As a consequence of the drought, the major crops registered a negative growth of about 10%, while the overall agriculture sector suffered a negative growth rate of about 2.6% against a target of 3.9%. The significant reduction of agriculture affected the overall economy, registering GDP growth rate of only 2.6% against a target of 5.0% (Muhammed *et al*., 2003).

In *Bangladesh*, severe droughts mostly occur in the pre-monsoon period and post-monsoon period. However, the pre-monsoon droughts are occasionally found to extend throughout the monsoon period due to late onset of monsoon and week monsoon activities. The droughts occurring in the monsoon period severely affect the rice crop production. Very severe droughts hit Bangladesh in 1951, 1957, 1961, 1972, 1976, 1979, 1986, 1989 and 1997. Past droughts have typically affected about 47 % of the country and 53 % of the population (Task Force, 1991).

In *Nepal,* acute drought condition is not a frequent phenomenon. Moderate drought, however, is observed due to rainfall variability over space and time in monsoon. In 2002, while flood occurred in the eastern parts of Nepal, drought conditions prevailed in the western parts. Some 20,000 hectare land was under the grip of drought in 2002, causing a decrease of paddy production by about 0.64 Mmt compared to that in the previous year. Khanal (1996) reports that when the monsoon rainfall falls below 1000 mm drought severely affects the production of major crops in Nepal. Droughts of 1982, 1986 and 1992 in two selected districts in eastern Terai markedly reduced rice production, while hectarage of those drought-years were comparable with that of 'normal' years.

4. IMPACTS ON UNIQUE AND THREATENED SYSTEMS

Unique systems are restricted to a relatively narrow geographical range but can affect other entities beyond their range (IPCC, 2001b). Many unique systems have global significance. These unique systems are restricted geographically points to their sensitivity to environmental variables, including climate, and therefore they are potentially vulnerable to climate change and variability. Unique systems can be divided into physical and human systems. In South Asia, three such unique systems pertinent to hydrology and water resources have been identified. Himalayan glaciers and ground water system of Pakistan are two unique physical systems. The Himalayan glaciers are the source of water of many large rivers in South Asia. Agriculture and domestic water supply sector are highly dependent on ground water system in Pakistan. Both systems are found to be sensitive and vulnerable to climate variability and will likely to be more vulnerable to future change in climate and variability. Mountain communities in South Asia have been found to be especially vulnerable to natural disasters and may be susceptible to higher vulnerability due to climate change in future.

a. Himalayan Glaciers: The Himalayan glaciers lie astride the boundary zone between monsoonal and westerly atmospheric influences, strongly affecting precipitation (in the form of rain and snow) and hydrological (runoff) conditions in the region (Bahadur, 1998). The Himalayan glaciers cover around 100,000 km^2 and the maximum seasonal snow cover could be as high as 1.5×10^6 km^2. The amount of water in the glaciers and snow cover has been estimated to be 12,000 km^3 (Bahadur, 1998). Snow covers, glaciers and permafrost contributes significant amount of melt water to the Himalayan perennial river systems through a network of mountain streams. The Himalayan rivers supply an estimated 8500 km^3 of water annually. Roughly about 10 % of this volume of water comes from the melt water contribution. The remaining amount is generated from rainfall. The glaciers act as buffers and regulate the runoff water supply from high mountains to the plains during both dry and wet spells (Bahadur, 1998).

Recession of the Glaciers: Himalayan glaciers that feed the Ganges River appear to be retreating at a fast rate (Table 1). The estimated retreat of the Dokriani glacier in 1998 was 20 metres compared to an annual average of 16.5 metres over 1993-1998 (Down to Earth, 1999). Dokriani is just one of the several hundred glaciers that feeds the Ganges. The 26 kilometer long Gangotri glacier has also been retreating. From observations dating back to 1842, the rate of recession of the snout (the point at which the glacier end) has been found to be have increased more than two-and-a-half fold per year. Between 1842 and 1935, the glacier was receding at an average rate of 7.3 m every year, whereas between 1935 and 1990, the rate of recession had gone up to 18 m a year.

Table 1. **Record of retreat of some glaciers in the Himalayas**

Glacier	Period	Retreat of Snout (metre)	Average retreat of Glacier (metre/yr)
Triloknath Glacier (Himachal Pradesh)	1969-1995	400	15.4
Pindari Glacier (Uttar Pradesh)	1845-1966	2,840	135.2
Milam Glacier (Uttar Pradesh)	1909-1984	990	13.2
Ponting Glacier (Uttar Pradesh)	1906-1957	262	5.1
Chota Shigri Glacier (Himachal Pradesh)	1986-1995	60	6.7
Bara Shigri Glacier (Himachal Pradesh)	1977-1995	650	36.1
Gangotri Glacier (Uttar Pradesh)	1977-1990	364	28
Zemu Glacier (Sikkim)	1977-1984	194	27.7

Implications of recession: Glaciers in the Himalayas are receding faster than in any other part of the world and, if the present rate continues, the likelihood of many of them disappearing by the year 2035 is very high (Kotlyakov, 1999) (with less than 1^{o}C increase in temperature). The world may be 0.3-1^{o}C warmer by the year 2035 (IPCC, 2001a). Global warming and glacier retreat in the Himalayas will have four broader implications. *First*, in the short-run, in the process of continued retreat, more water will be supplied to the glacier dependent perennial rivers in the Himalayas (Singh, 1998). This may generate positive effects on dry season water availability. *Second*, chances of glacier lake outburst flood (GLOF) may increase (Hasnain, 1999). *Third*, in the long-run, dry season flow in the upstream of the Himalayan rivers could be greatly reduced, posing serious eco-environmental problems (Hasnain, 1999). Note that with increase in population, water demand will likely be higher in the long run. Therefore, the gap between demand and supply will likely to be higher in the long run. Therefore, the gap between demand and supply will be wider. *Fourth*, in the short run, with increase in dry season discharge, sediment supply in the rivers may increase. This may pose a threat to the existing dams and reservoirs in the region. More melting means higher silt loads, which reduce the life of dams and reservoirs

b. Ground water system in Pakistan: Agriculture in Pakistan is heavily dependent on ground water irrigation especially where surface water scarce. During 1976-1997, the groundwater contribution to irrigated agriculture has doubled from 31.6 to 62.2 billion M^3 (GoP, 1998) demonstrates its increasing reliance over the uncertainties of surface water availability due mainly to climatic reason. Figure 16, hows the province-wise growth of tubewells for extracting groundwater since 1965. Country's tremendous groundwater storage potential available in the form of aquifer system of Indus plain and mountainous valleys of North West Frontier Province and Balochistan (Bhatti, 1999). There is a strong regional diversity in terms of availability of the ground water resources. Most of it exists in the extensive unconfined aquifer in the Indus plain, extending from Himalayan foothills to Arabian Sea, and are stored in alluvial deposits. The plain is about 1600 km in length and covers an area of 21 Mha. This aquifer, with a potential of about 50 MAF compared to 0.9 MAF potential in Balochistan (Kahlown and Majeed, 2002). Climate variability has a strong bearing on the recharge of ground water. Precipitation, river flow and continued seepage from the conveyance-system of canals, distributaries, water courses and application-losses in the irrigated lands contributes to ground water recharge (Kahlown and Majeed, 2002). In a drought year, high temperature causes high evaporation from water bodies and water conveyance systems result low recharge. During 1990-2000, recharge to the ground water was reduced significantly due to prolonged drought in the Indus basin. Recharge in areas outside the Indus basin was reduced considerably because of prolonged drought. Such areas are Balochistan, Barani lands, deserts and coastal areas (Pakistan Country Report, 2003).

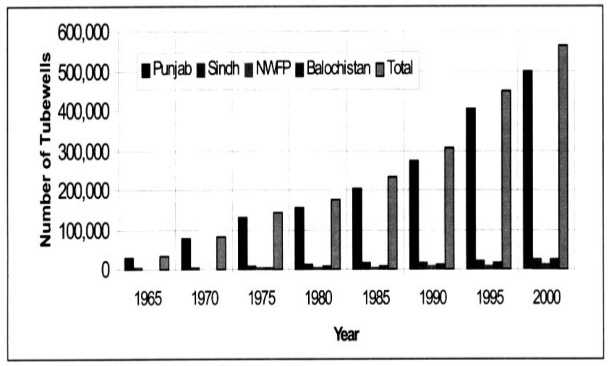

Figure16. Growth of tubewells in Pakistan during 1965-2000

Overexploitation (rate of withdrawal greater than recharge) and mining are twin challenges Pakistan is now facing especially in the areas with high climatic variability and drought vulnerability. Studies conducted in the Kirther range hill-torrent areas indicated that lowering of water table of over 3 m per annum was observed in shallow groundwater aquifers. Due to drought, there were no hill-torrents during the period 1995-2000 and that resulted in reduced recharge and mining of groundwater (Pakistan Country Report, 2002). In Balochistan, in two of the basins (Pishin-lora and Nari) groundwater is being over exploited, beyond its development potential, creating mining conditions and causing a huge overdraft of groundwater that is threatening to dry up the aquifers in the long term (Kahlown and Majeed, 2002). Due to mining in freshwater zones situated close to salt-water zones, groundwater resources in the coastal area face risk of contamination due to lateral and horizontal movement of saline water (Bhatti, 1999). Future rise in sea level may aggravate groundwater contamination.

c. Threatened Mountain Communities: Mountain ecology and the degradation of watershed areas affect nearly half of the world population. About 10% of the Earth's population lives in mountain areas with higher slopes, while about 40% occupies the adjacent medium- and lower-watershed areas. There are serious problems of ecological deterioration in these watershed areas. The mountain and upland areas of the Himalayas are threatened by cultivation of marginal lands due to expanding population. In many areas this is accompanied by excessive livestock grazing, deforestation and loss of biomass cover (UNCED, 1992). Soil erosion is also a growing problem, which can cause a devastating impact on the vast numbers of rural people who depend on rainfed agriculture in the mountain and hillside areas. Poverty, unemployment, poor health and bad sanitation are widespread. A significant number of the population inhibiting in the Himalayas faces a problem of year-round availability of water. This is due mainly to sharp contrast in seasonal availability of water. They receive either abundant water during the monsoon (June-September) or too little for the rest of the year. Despite inter-annual variability and uncertainty and insufficient water, Mountain communities have developed diverse strategies and systems for the management of water to satisfy their needs with the aid of local ingenuity (Chalise, 2001). In the last four decades, mountain areas of the Himalayas experienced a huge influx of people as well as high population growth. Most of the settlements in the mountains usually located at the lower altitudes, which facilitates access to surface and air transport. Usually these settlements are highly prone to flooding and vulnerable to landslides and debris flows (Dixit, 2003; Chalise, 2001). Usually the inhabitants and infrastructure of small watersheds are more vulnerable and due to limited coping capacity, these watersheds are unable to manage the disasters caused by extreme weather events. The frequency of such events is increasing especially in the Hindu Kush Himalayas. For example, the upper watersheds of Bhotekoshi and Sunkosi in Nepal experienced major disasters due to intense rainfall in 1981, 1982, 1987, 1988, 1990, 1995, and 1996.

5. EXTREME CLIMATIC EVENTS: SYNTHESIS OF VULNERABILITY, COPING MECHANISMS AND STAKEHOLDERS' CONCERNS

5.1 Who is Vulnerable in South Asia and Why?

In defining vulnerability the IPCC (2001b) considered character, magnitude and rate of climate change and variation are the main elements to which a system is exposed, its sensitivity, and its adaptive capacity. The definition is broadly limited to natural systems. However, the vulnerability of human system is integrated with natural systems because changes in one system can cause impact on the other. Blaikie *et al.* (1994) defined vulnerability as measure of a person or group's exposure to the effects of natural hazard, including the degree to which they can recover from the impact of that "event". World Commission on Dams (WCD) (2000) suggested to take into account property/infrastructure variables in assessing vulnerability. In South Asia socio-economic conditions of various economic groups, location and living conditions, inequality between rural and urban population (including their intra inequality) and gender broadly defines exposure of these groups to extreme climatic events and coping capacity (Nepal and Pakistan Country Reports, 2003). In absence of information on exposure of socio-economic sectors to extreme climatic events, Nepal Country Report (2003) used socio-economic indicators as an index of coping ability and the sectoral vulnerability. As agriculture is still a significant contributor to the national economies in South Asia, this sector is considered to be most vulnerable. Participation of women in the workforce is one fifth of that of men and income is one-third of their male counterpart. Therefore, women (particularly in the rural areas) are more vulnerable to hazards. Children and senior citizens are also highly vulnerable.

In Nepal, communities such as occupational castes were found to be most hit groups and these groups show very low human development performance reflecting deprivation of opportunities and thus defenseless against natural hazards. **Table 2** synthesizes socio-economic indicators of Nepal, India, Bangladesh and Pakistan and presents arbitrary coping capacity. Among four countries, Nepal has the least coping capacity followed by Bangladesh. India and Pakistan have almost equal magnitude of coping capacity. However, these ranking are certainly inadequate to draw a general conclusion for the whole country. Hazards created by extreme climatic events are highly endemic and micro-level research is required to reveal the magnitude of impact, vulnerability and coping capacity. Nepal Country Study (2003) used a different method of vulnerability estimation. It used human development index (HDI), natural production potential of the environment and road accessibility for assessing coping ability[1]. The result of the analysis shows that the central hills and the central Terai are the most vulnerable regions, followed by eastern Terai and western hills. The less vulnerable areas are far western Terai, hills and mountains and the mountains of western and mid western regions.

Table 2. Selected socio-economic indicators of Nepal, India, Bangladesh and Pakistan

Country	Nepal	India	Bangladesh	Pakistan
Population density	148 (*1*)	335.5 (*3*)	997 (*4*)	179 (*2*)
National poverty rate (% of population)	42(*4*)	35(*3*)	35.6 (*2*)	34 (*1*)
Malnutrition prevalence (% of children under 5)	46.9 (*3*)	47 (*2*)	61.3 (*4*)	40[1](*1*)
Illiteracy rate, adult male (% of males 15+)	40.4(*2*)	32.3(*1*)	47.7 (*4*)	42.5(*3*)
Illiteracy rate, adult female (% of females 15+)	76 (*4*)	55.6(*1*)	70.1(*3*)	72.1(*2*)
Improved water source (% of total population with	81(*2*)	68[2] (*4*)	97 (*1*)	88 (*3*)
Improved sanitation facilities, urban (% of urban population with access)	75 (*3*)	61[3](*4*)	82 (*2*)	94 (*1*)

[1] For details see Chapter 6 of the Nepal Country Report (2003)

GNI per capita, Atlas method (current US$)	240 (*3*)	440(*1*)	370 (*2*)	440 (*1*)
Agriculture, value added (% of GDP)	40.3 (*4*)	26.2(*2*)	24.6 (*1*)	26.3(*3*)
Industry, value added (% of GDP)	22.4(*4*)	26(*1*)	24.4(*2*)	22.8(*3*)
Services, etc., value added (% of GDP)	37.4(*4*)	47.8(*3*)	51(*1*)	50.9(*2*)
Paved roads (% of total)	30.8(*3*)	45.7(*1*)	9.5(*4*)	43(*2*)
Aid per capita (current US$)	16.9(*4*)	1.5(*1*)	8.9(*3*)	5.1(*2*)
Total Rank	41	27	33	26

Data Source: World Bank Report, 2002
1/ International Food Policy Research Institute (IFPRI) (2002); 2/ Unicef, 2001; 3/ WHO/Unicef, 2001.

5.2 Risk Perceptions: Results from the Field Surveys

Risk perceptions of droughts and floods have a unique similarity among the participating countries. In *Pakistan*, respondents during the field survey in both SHUs (Bawalpur and Mirpurkhas) felt that the intensity of drought was much more than in the past and so was length of drought. The recent drought (1998/1999) had extended up to six years, which was much longer then in the past. The group had clear perception about the cycle of drought. For example, they predicted that since the cycle is about six years thus the drought would soon be ending. The duration of drought in the past 40-50 years was seldom more than 2 years. People have clear understanding about impacts on soil texture. People felt that windstorms play havoc with soil texture.

In the SHUs (Sabarmati, Subarnarekha and Mahanadi) in *India*, people anticipate droughts on the basis of delayed/scanty rain. Recovery from a drought usually takes 2/3 years - almost coinciding with the occurrence of another drought, thereby making the recovery almost impossible. Drought increases economic hardships that eventually lead to migration.

In *Nepal*, people have perceived extreme rainfall events as the main cause of the flood. During the last ten years, the events of 1993 and the 2002 had been the worst types. The event of 1993 was most severe since 1954 event, which had the bigger impact. People also perceived that the landslide and debris flow events in the upper catchments of the Bagmati River has escalated the flood disaster downstream in the form of flash flood, river course change, bank erosion and bank overflow in Terai. The flood events of 2002 and 2003 were also of a large scale, but the scale of loss of human lives, livestock, houses and property was less than 1993 event. Local people felt that the benefit of flood mitigation measures through structural methods in one location often trades off by increasing flood risk on the other location. Injudicious expansion of infrastructures and houses has intervened the natural drainage, which has enhanced the flood risk.

In *Bangladesh*, more than three-fourth of the respondents thought that rise in in-stream flows are the major cause of flood. About 60% reported that flood duration has actually increased while the same number of respondents identified that the timing of flood has advanced, while the rest said it was delayed. About 70% observed that the average duration of flood has increased.

5.3 Adaptation Measures/Coping Mechanisms: Results from Field Surveys

Population is highly concentrated on the river basins of South Asia and the rivers are a lifeline to them although the rivers are a source floods. Agricultural activities are also dependent on seasonal rainfall. Failure of rainfall often causes droughts and destruction to agriculture and leads to economic hardships. Despite recurrence flood and drought events, people try to adjust with the aftermath of the hazards by applying adaptation and coping mechanisms. Although a range of measures is in practice, under this study, a field survey was carried out in 2003 in the selected hydrological units (SHUs) (**Figure 4**) to reveal the measures that are being practiced at the micro-levels. The common measures practiced in the draught and flood prone regions were as follows:

a) **Drought (India and Pakistan)**
- Borrow money from the lenders and banks
- Large scale migration in search of alternative livelihoods
- Buy/save fodder for livestock, Change feeding patterns
- Sale of livestock and sale belongings
- Shifting livestock to other areas
- Cultivate less water intensive crop
- Sell or mortgage property
- Work in government sponsored food/cash for work programs

b) **Flood (Bangladesh, India and Nepal)**
- Store dry food and medicines
- Migrate in search of alternative livelihoods
- Engage in off farm activities
- Protect livestock
- Undertake insurance for local crop variety
- Selling premature fish to avoid their escape
- Construction of houses on elevated foundation
- Borrow from informal sector
- Spend past savings
- Pray

5.4 Stakeholders' Concerns

One of the objectives of this study was to communicate results of the study to the stakeholders and incorporate their views in finalizing final project report. The meetings had four major objectives to: share research findings; validate; get feedback on gaps and test robustness. Stakeholders meetings were organized in Kolkata (India), Dhaka (Bangladesh), Kathmandu (Nepal) and Islamabad (Pakistan). Stakeholders included: agriculture and forestry sectors, grassroots farmers from flood and drought prone areas, policy makers from irrigation, water department, environmentalists, meteorologists, social scientists, NGOs and Media. From the field level experience of four countries three major conclusions can be drawn. They are: coping mechanisms are varying from SHU to SHU; priorities in coping mechanisms are somewhat different; and grassroots people want to get continuous information and need scientific actions. Participants welcomed the dissemination process. They attached high importance to continuing research on climate change and hydrological issues. However, the stakeholders opined that comprehensive studies on climate trends are required at national and regional levels. Unveiling people's coping strategies were welcomed by the stakeholders and called for complete analysis of institutional adaptations. Recommendations from the stakeholders meetings are summarized as follows.

a) Drought (India and Pakistan)
- Innovation to produce more crop per drop
- Ponds and canal digging
- Water budget exercise at micro-level
- Encourage stock of fodders
- Technology dissemination to address local level adaptation
- More dialogue of similar type in different geographical and climatological regions
- Creation of agro-ecological zones based on climate change scenarios

- Undertake research to relate climate change to land uses and expansion of irrigation in the barren lands
- Establishment of more meteorological stations especially in the data scarce mountainous areas
- Establishment of national groundwater authority (Pakistan)
- Concentrate on improving the environmental health of the watersheds for sustainable water resources development
- Systematically study water trading between provinces, regions and farmers

b) Flood (Bangladesh, India and Nepal)

- Emphasis on living with flood concept
- Insurance system is not uniform and lacks awareness
- Afforestation and fodder stock
- Technology dissemination to address local level adaptation
- More dialogue of similar type in different geographical and climatological regions
- Emphasis on modernizing flood forecasting system
- Improvement of real-time flood warning dissemination
- Refurbishing and rationalizing existing flood management embankments
- Facilitating water drainage structures
- Promotion of regional cooperation (basin wide) in flood management under IWRM
- Agricultural rehabilitation needs to be revitalized
- Incorporating results into the National Adaptation Plan of Action (NAPA) process and coastal development and management plan (CDMP).
- Introduction of crop and livestock insurance schemes (India)

6. CONCLUSIONS

The study had three major objectives. *First*, conducting analysis of recent experience in climate variation and extreme events was conducted including impact and vulnerability assessments (Year 1). *Second*, focusing on adaptation analysis and assessment through questionnaire surveys in the selected hydrological units (SHUs) (**Figure 4**) in the participating countries. *Third*, organizing stakeholders' consultation meetings to provide them with information needed to reduce vulnerability of the region's water resources to climate and socio-economic change and to development of national and regional strategies.
It is evident from the climatic trend analysis that climate of the Indian sub-continent has been changing. The general rise in temperature supports the hypothesis of global warming. The increasing rainfall variability in monsoon for the eastern Himalayan region (Nepalese terai, eastern states of India and Bangladesh) and decreasing rainfall distribution for the western Himalayan region (Pakistan and drier parts of north-western India) suggests that the region will be far more susceptible to extreme climate events under climate change regime. Since large majority of world's poor are eking out a living by exploiting climate-governed bio-physical resources, occurrence of extreme events would adverse affect food security of region as a whole; while it may also be anticipated that, despite special measures to address poverty, the overall number of poor people in the region will only rise as a consequence of climate change driven increased incidence of water-related disasters.
Floods and droughts are common in the regional countries. Drought management through irrigation could only be possible if sufficient quantum of water is available. Since the availability of water, particularly the availability of the dry season will remain constrained due to increasing demand for irrigation coupled with decreased available surface-flow, it would be necessary to increase irrigation efficiency in near future. Experiences in other parts of the world would be of extreme use under climate change. Grassroots level motivation, demonstration of improved irrigation practices, and implementation of

improved technologies would be a major challenge for the drought affected areas of the region.
Dealing with excess water would be even greater a challenge under climate change regime. The regional countries would have to assess the effectiveness of embankments in reducing flood vulnerability. Many of the existing embankments and road networks do not have adequate drainage infrastructure, which needs immediate correction. The channels, particularly the distributaries of the major rivers in the downstream areas have been heavily silted up which need excavation and desiltation. Efforts must be made to resuscitate natural drainage system of the flood waters. Flood proofing would allow flood waters to recede quickly. Efforts must be made to enhance flood proofing activities, particularly for settlements and physical infrastructure.
Risk perceptions of droughts and floods of the grassroots people are similar in the participating countries. They have clear understanding of the drought and flood cycles. Recovery from a drought or flood usually takes 2-3 years, coinciding with the onset of these hazards. In all four participating countries, it was concluded from the field survey responses that intensity and duration of droughts and floods have increased. It is realized that, people in the region have been facing such climate variability since time immemorial. There is a wealth of indigenous knowledge regarding local-level adaptation to disasters. Efforts must be made to find out these popular adaptations, assess those in light of increased susceptibility to disasters and implement gradually in anticipation of climate change. It is often found that anticipatory adaptation would be lot less costly compared to reactive adaptation.
Dissemination of field level coping mechanisms and adaptation measures through the stakeholders consultation was found to be an important strategy. Stakeholders concluded that comprehensive national and regional studies were required to reveal the complete picture of climate change impacts on water and associated sectors. It was further stressed to have similar kind of comprehensive dialogue. The stakeholders agreed that modernization of hazards forecasting and warning is utmost necessary for meeting the challenge of future climate change.

7. FUTURE DIRECTIONS

The results of this study have clearly established the trend for climate change, mostly warming, in different parts of the sub-continent. The intensity of the extreme events (drought and flood) has also shown an increasing trend and the recent incidents have been more severe than the previous events. Because of the obvious importance of these events to the overall economy of the countries of the region and the threat to human life and property, it is important to study these phenomena in greater detail to enable projection of the climate scenarios and likelihood of extreme events. Efforts have to be made to collect meteorological data from a larger number of stations located in different parts of the sub-continent to enable delineation of sub-zones that have similar trends on temperature and precipitation change so that the temperature, precipitation and water availability in these sub-zones, in future may be projected. This is important to plan land use especially cropping patterns in different sub-zones which may need a radical change in light of climate changes and water availability. Since planning and implementing land use changes takes a long time, it is important to collect the climate data and prepare the projections as soon as possible to prepare for these changes. Besides changes in the cropping patterns, biological research to adapt different crops to changed climate and water availability regimes will have to be prepared that will need extended research on plant breeding and agronomy. Since climate change will also affect the prevailing pest complex (insects, diseases and weeds), it will be essential to study these parameters as well to adapt to the changed climate.

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LIST OF APPENDICES

Appendix1: OUTLINE OF THE PLANNED BOOK PUBLICATION

- Climate and Water: Vulnerability and Adaptation
  Case Studies from Hotspots of South Asia

Appendix 2: CONFERENCES/SYMPOSIA/WORKSHOPS

- Project Initiation Meeting; *Dhaka, Bangladesh, May 23-26, 2002*
- Improving Farmer Decision-Making Related To Climate Change & Impact On Water And Agriculture; *San Diego, California, May 15-18, 2003*
- First Year-End Meeting ; *Katmandu, Nepal, January 7 – 9, 2003*
- Second Year-End Meeting; *Katmandu – 16-19 December 2003*
- Pakistan Stakeholders Meeting; *Islamabad January 13, 2005*
- Final Project Meeting; *Chiang Mai, February 10-12, 2005*

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  Pakistan, India, Bangladesh

Appendix1

OUTLINE OF THE PLANNED BOOK PUBLICATION

Climate and Water: Vulnerability and Adaptation

Case Studies from Hotspots of South Asia

Chapter 1 Introduction: Background
- 1.1 : Climate system: uniqueness
- 1.2 Anthropogenic drivers-climate forcing gases and particles
- 1.3 : Hydrology: specifics
- 1.4 : Socio-economic realities
- 1.3 : Road map

Chapter 2 Climate and Variability of Water Availability in South Asia

Chapter 3 Climate, water and agriculture interactions and people's livelihood

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Chapter 11 Climate Change Impacts on Agriculture and Water Management

Chapter 12 Climate Change, Water and Adaptation: National Responses to International Actions

Chapter 13 Stakeholders' position and Policy Briefs

Chapter 14 Regional Synthesis

Total 235 pages + indexes (5) +table of contents (5) + Preface (2) = 247pages

CONFERENCES/SYMPOSIA/WORKSHOPS

PROJECT INITIATION MEETING

Dhaka, Bangladesh, May 23-26, 2002

SCHEDULE

Thursday, May 23, 2002

8:30 – 9:00 am	**Registration**
	Joint Session: Water Resources and Mountain Projects
9:00 – 9:30 am	**A Review of the APN Water Resources Proposal** *Amir Muhammed*
9:30 – 10:00 am	**A Review of the APN Mountain Proposal** *K. L. Shrestha*
10:00 – 11:00 am	**Discussion of Common Interests**
11:00 – 11:15 am	Break
	Training and Capacity Building
11:15 – 11:45 am	**Report on AIACC Scenarios Training Workshop** *Ahsan Uddin Ahmed*
	Upcoming AIACC Vulnerability and Adaptation Assessment Methods *Motilal Ghimire and Syed Amjad Hussain*
11:45 – 12:45 pm	**Comments and Guidance from Resource Persons** *M. Mirza*
12:45 – 2:00 pm	Lunch
	Conducting National Scale Case Studies
2:00 - 2:30 pm	**Bangladesh** A. U. Ahmed and D. A. Quadir
2:30 – 3:00 pm	**India** J. Roy, S. Shetye, R. N. Singh, D. Gupta
3:00 – 3:30 pm	**Nepal** *M. Ghimire*
3:30 – 4:00 pm	**Pakistan** S. Ahmed and S. A. Hussain
4:00 – 5:00 pm	**Agreement on Common Methodology for Year 1 Activities**

Friday, May 24, 2002

8:30 – 10:00 am	**Discussion of Research Logistical Arrangements**
10:30 – 12:00 am	**Expected Deliverables for Year 1**
12:00 – 1:30 pm	Lunch
1:30 – 3:00 pm	**Next Steps**
3:00 – 4:30 pm	**Joint Session of Water Resources and Mountain Projects to Discuss Common Strategies**

Saturday, May 25, 2002

8:30 – 12 noon	**Core Group to Prepare:** ▪ **Final Meeting Report** ▪ **Agenda for Year-end Meeting** (see Attachment 1) ▪ **Expanded Program** (see Attachment 6) ▪ **Format for Data Collection**
1:30 – 3:30 pm	**Finalize Format for Data Collection**
3:30 – 4:30 pm	**Distribute to Scientists:** ▪ Final Meeting Report ▪ Agenda for Year-end Meeting ▪ Expanded Program ▪ Format for Data Collection

Sunday, May 26, 2002

Schedule to be determined	**Meeting of Core Group and Facilitator regarding Program Management**

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IMPROVING FARMER DECISION-MAKING RELATED TO CLIMATE CHANGE AND IMPACT ON WATER AND AGRICULTURE

San Diego, California, May 15-18, 2003

MEETING GOALS

- APN: Review Activities for Year Two
- APN: Finalize Questionnaires for Survey
- APN: Finalize Work Schedule and Timeline
- Hansen Institute: Review Extension Program Activities
- Hansen Institute: Finalize Questionnaires for Survey
- Hansen Institute: Finalize Work Schedule and Timeline
- APN/Hansen Institute: Prepare Plan for Linking Hansen Institute and APN Activities with Ongoing Agriculture Extension Programs in each Country
- APN/Hansen Institute: Review Budgets and Budget Distributions
- APN/Hansen Institute: Draft Scopes of Work based on Work Plans
- APN/Hansen Institute: Prepare Strategy for Meeting with Country Political Leaders and USAID Missions to Secure Country Support and USAID Mission Support for Proposed Activities of APN and Hansen Institute Collaborative Programs

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FIRST YEAR-END MEETING

Katmandu, Nepal, January 7 – 9, 2003

SCHEDULE

Tuesday, January 7, 2003

Joint Session: Water Resources and Mountain Projects

0900-1030 hr **Session 1: Inaugural Session**

Welcome
K. Shrestha

Opening Remarks
A. Muhammed, SASCOM Chair
A. Mitra, Director, National Physical Laboratory
L. Stevenson, Program Director, APN

Inaugural Address
K. Shrestha

1045–1300 hr **Session 2: Keynote Papers**

1. Recent and Past Patterns of Climate Variability and Extreme Events and Regional Vulnerabilities of Hydrologic Systems: Mr. U. Qazi (Pakistan)
2. Implications of Projected Climate Change and Variability, including Extreme Events, on Regional Hydrological Fluxes and Water Resources: R.Kolli (India)
3. Implications of Socio-economic Scenarios for Regional Water Resource Needs –confirmed presenter: Q.K. Ahmad (Bangladesh)
4. Recent and Past Adaptation and Coping Mechanisms, including Impacts on Irrigation Systems, Agriculture, and Urban Systems and Strategies for Increasing Community Resilience – confirmed presenter: Monirul Mirza (Bangladesh)
5. El Nina and Floods in South Asia Region: A.M. Choudhury (Bangladesh)

1400 -1530hr **Session 3: Projects Overview**

1400 -1430 **A Review of the APN Water Resources Project Targets and Accomplishments**
A. Muhammed

1430-1500 **A Review of the APN Mountain Project Targets and Accomplishments**
K. L. Shrestha

1500-1530 **Discussion of Common Interests and Themes**

1545 - 1730hr **Session 4: Presentation of the National Scale Case Studies**

1545– 1615 **Bangladesh**
A. U. Ahmed (hydrologic changes) and D. A. Quadir (socio-economic)

1615– 1645 **India**
J. Roy (socio-economic), D.K. Chadha (hydrologic changes)

1645-1715	**Nepal** M. Lal Shrestha (climate change and variability, N. Shakya (hydrological changes), M. Ghimire (socio-economic impacts)

Wednesday, January 8, 2003

0830-1000 hr	**Session 4: National Scale Case Studies - continued**
0830–0900	**Pakistan** S. Ahmed and A. Farooqi
0900-0930	**Synthesis Report for South Asia Region:** Assessments of National and Regional Vulnerability & Successful Coping Strategies to Change and Extreme Events M. Mirza and J. Roy
0930-1030	Discussion of country reports and synthesis paper and Finalize Publication Strategy for all Presentations
1045– 1200	**Develop Work Plans & Schedule for Year 2 Activities**
1200-1315	**Prepare APN Proposal for Year 2 Funding**
1430-1630	**Prepare Final Meeting Report**

Thursday, January 9, 2003

0830–1200 hr **Core Group Meetings**

- Program Management & Expansion Strategy
- USAID Meeting
- Finalize Program Expansion Strategy
- Schedule for Next Steps

Meeting of Core Group and Facilitator regarding Program Management

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SECOND YEAR-END MEETING

Katmandu – 16-19 December 2003

SCHEDULE

Tuesday, December 16, 2003

0930-1015……SESSION 1: **OPENING SESSION**

0930-0940 .... **WELCOME ADDRESS**
Prof. Dr. Kedar Lal Shrestha, Chief Advisor, Ministry of Science and Technology *(MoST)*

0940-1015 .... **OPENING REMARKS**

0940-0950 ... Dr. Amir Muhammed, Chairperson, South Asia START Committee (SASCOM)

950-1000 Dr. A. P. Mitra, Director, South Asia START Regional Centre (SASRC)

10:00-10:10 . Dr. Hassan Virji, Deputy Director, START Secretariat

1010-1020 ... Dr. C Sharma, Programme Officer, Asia Pacific Network (APN)

1020-1030 ... Dr. Bonnie Stewart, Executive Director, Hansen Institute for World Peace (HIWP)

1045-1300 ....SESSION 2: **PROJECTS OVERVIEW**

1045-1115 ... **A Review of the APN Water Resources Project & Meeting Goals**
Dr. Amir Muhammad, Pakistan

1115-1145.1 **A Review of the APN Mountain Project Targets and Accomplishments**
Dr. Kedar Shrestha, Nepal

1145-1215 ... **Discussion of Common Interests and Themes**

1215-1240 ... **The Importance of Water Use Efficiency in Agriculture**
Dr. Donald Slack, University of Arizona

1400-18:00 ....SESSION 3: **PRESENTATION OF THE NATIONAL SCALE CASE STUDIES**

1400-1430 ... **Bangladesh**
Dr. Ahsan Ahmed

1430-1500 ... **India**
Dr. J. Roy and Dr. Chadha (by Dr. Roy)

1500-1530 ... **Nepal**
Dr. Balkrishna Sapkota and Dr. Motilal Ghimire

1530-1600 ... **Pakistan**
Dr. Pervaiz Amir and Mr. Zafar Mahmood

Wednesday, December 17, 2003

0800-1300 ....SESSION 4: **EXTENSION PROGRAM AND MULTI-MEDIA KITS FOR DISSEMINATING BEST MANAGEMENT PRACTICES RELATED TO CLIMATE CHANGE TO FARMERS**

0800-0900 . **BMPs & Multi-media Extension Information Examples**
Dr. Michael Reid (UC, Davis – Cooperative Extension, USA) & Ms. Nancy Ransom

0900-0945 . **Presentation of Country Studies and Extension Materials Synopsis**
Indo-Gangetic Plain
Dr. K.S. Rajan
Bangladesh
Dr. Ahsan Ahmed

1015-1145 .... **Presentation of Country Studies and Extension Materials**
Synopsis *continued*
India
Dr. J. Roy and Dr. C Sharma for Dr. Chadha
Nepal
Dr. Balkrishna Sapkota and Dr. Motilal Ghimire
Pakistan
Dr. Pervaiz Amir and Mr. Zafar Mahmood

1145-1230 .... **Summary of Country Extension Materials**
Dr. Michael Reid, Ms. Nancy Ransom, Dr. Donald Slack and Dr. Pervaiz Amir

1245-1345 ....**Luncheon Meeting: Drs. Bonnie Stewart and Dipak Gupta (HIWP), Mr. Jay Pal Shrestha (US Dept. of State), and Dr. Amir Muhammed, Dr. Kedar Shrestha, Dr. A.P. Mitra**

1400-1600 ....**CORE GROUP MEETINGS**

- **APN Activities and Reports**
- **Extension Multi media kits**

PREPARE WORK PLANS, SCHEDULE & BUDGET FOR YEAR 3 ACTIVITIES: HIWP

PREPARE WORK PLANS, SCHEDULE & BUDGET FOR YEAR 3 ACTIVITIES: APN

PREPARE FINAL MEETING REPORT

0900-1800 **Mountain Project Meeting**

Thursday, December 18, 2003

0900-1600 ....**Core Group Meetings continued**

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PAKISTAN STAKEHOLDERS MEETING

Islamabad, January 13, 2005

SCHEUDLE

09:35-09:50	Introductory Remarks **Dr. Amir Muhammed**
09:50-10:15	Climate Change in Pakistan **Mr. Munir A. Sheikh**,
10:15-10:40	Water Resources of Pakistan **Dr. Shahid Ahmed**
11:00-11:30	Soc-economic aspects of drought Results of Field surveys **Dr. Pervaiz Amir**
11:30-12.30	Measures to mitigate anticipated water shortages. **General Discussion-**
12.30-12.45	Plans to meet the challenge of anticipated water shortage for agriculture sector **Mr. Sikander Hayat Khan Bosan**
12.45-14.0	General discussion and concluding remarks **All Participants**

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FINAL PROJECT MEETING

Chiang Mai, Thailand, February 10-12, 2005

<u>SCHEDULE</u>

I. OPENING SESSION

- Opening Remarks *(Amir Muhammed, A.P. Mitra, Hassan Virji, Linda Stevenson, and Bonnie Stewart)*
- Model Scenarios of Climate Change Impacts for South Asia *(Rupa Kolli)*
- Changing Scenarios of Water Resources in South Asia *(Rupa Kolli/Satesh Shetye)*

II. REPORTS FROM STAKEHOLDER MEETINGS AND SCENARIOS FOR SOUTH ASIA

- Reports from Stakeholder Meetings *(*Pakistan*: Amir Muhammed;* India*: A.P. Mitra;* Nepal*: Kedar Lal Shrestha;* Bangladesh*: Ahsan Ahmed)*
- Socioeconomic Scenarios for South Asia: Drivers for Water Usage and Availability and Strategies for Control (*Joyshree Roy/Pervaiz Amir*)

III. CLIMATE CHANGE AND IMPACTS ON WATER QUALITY AND USE IN SOUTH ASIA

- Climate Change and the Impact on Water Quality and Water Use Efficiency in Agriculture (*Donald Slack*)
- Agriculture Extension Strategies for Improving Water Use Efficiency in Pakistan (*Ahsan Abdullah*)
- Text-less Multi-media Extension Tool for Improving Irrigation Efficiency in South Asia (*Michael Reid and Nancy Ransom*)

IV. COPING STRATEGIES

- Mitigation Strategies: Panel Discussion (*Agriculture, Water Recharging, Water Pricing, Virtual Water Concept, Disaster Management*)
- Data Archiving and Dissemination Strategy (*Mitra*)

V. FUTURE PLANS

- Project Reports (*Project Report, 14 February 2005; Financial Report, 14 March 2005; Final Activity Report and Project Review, 17 July 2005*.)
- Publications (*Science & Culture; and Three Year Project Report*)
- Future Program Options (*Monirul Mirza)*

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APN

21) Dr. Linda Stevenson

START

22) Dr. Hassan Virji*

Invited Guests ; Thailand

23) Dr. Jesse Manuta
24) Dr. Louis Lebel
25) Ms. Supaporn Khrutmuang

**Could not participate*

Appendix 3

FUNDING SOURCES OUTSIDE THE APN

International START Secretariat 2000 Florida Ave NW, Suite 200 Washington, DC 20009 Phone: 202-462-2213 Fax: 202-457-5859 E-mail: hvirji@agu.org	**$15,000**
Fred J. Hansen Institute for World Peace Program Development & Management San Diego State University Research Foundation 5250 Campanile Drive San Diego, California 92182-1933 Phone: 619-594-5644 Fax: 619-582-9164 Email: bstewart@foundation.sdsu.edu	**$132,000**

Appendix 4

GLOSSARY OF TERMS

AIACC	Assessment of Impacts of and Adaptation to Climate Change in Multiple Regions and Sectors
APN	Asia Pacific Network for Global Change Research
BCM	Billion Cubic Meters
GEF	Global Environment Facility
GLOFs	Glacial Lake Outburst Floods
HDI	Human Development Index
HIWP	Fred J. Hansen Institute For World Peace
ICIMOD	International Center For Integrated Mountain Development
IGP	Indo- Gangetic Plains
IITM	Indian Institute of Tropical Meteorology
IPCC	Inter-Governmental Panel on Climate Change
SHU'S	Selected Hydrological Units
SOI	Southern Oscillation Index
START	SysTem For Analysis, Research and Training
TAR	Third Assessment Report
UNCED	United Nations Conference on Environment and Development
UNEP	United Nation Environment Program
WCD	World Commission on Dams

Appendix 5

PROJECT SUMMERY REPORTS

DHAKA, MAY 23-26, 2002

The Program initiation Meeting of the APN-supported project on Water Resources in South Asia was held in La Vinci Best Western Hotel, Dhaka Bangladesh on 23-26 May, 2002. The meeting was originally scheduled to be held in Bangalore during February 2002 but had to be postponed due to the difficult political situation between India and Pakistan. Subsequently the meeting was scheduled to be held in Kathmandu but the venue had to be shifted at the last minute due to internal disorder and worsening law and order situation. The meeting was finally held in Dhaka on the invitation of the Bangladesh National Academy of Sciences kindly organized by the SASCOM member Dr. A.M. Chowdhry.

The meeting was well attended. Besides participants from the region including PIs from India, Pakistan, Nepal, Bangladesh, colleagues from the Hansen Institute for World Peace, and Dr. Monirul Mirza, an expert in the subject, currently in Canada but originally a Bangladesh national, also attended the meeting. Dr. Hassan Virji from START and Dr. K. Sharma APN Liasion Officer also participated.

The meeting started with a review of the Regional Water Resources proposal by the PI. Dr. Amir Muhammed, followed by an update of the APN Mountain Development project by the PI. Dr. K.L. Shrestha. These presentations were followed by general discussion on the two projects and possibilities for collaboration with the related project on Glacial Lakes.

Participants in the AIACC project-sponsored training workshops on Scenarios Training (Norwich, 14-27 April, 2002) and Vulnerability and Adaptation Assessment Methods (Trieste June3-14, 2002) next briefly described the two workshops and their relevance to the water resources project. The resource persons-Drs. Monirul Mirza and Hassan Virji next gave the perspective of this project and its relationship to the other projects with similar objectives especially AIACC. Plans for conduct of national scale studies were next described by the relevant participants followed by general discussion.

A core group of 3 persons was constituted to prepare a draft outline for the case studies, format of the datasets to be collected in the national studies, and plans for the year-end meeting of the project in Kathmandu in December 2002. The proposals were discussed in the final session and approved for distribution to all those associated with the project. It was decided that participants will send their comments to Bonnie Stewart/Amir Muhammed for finalization of the Report Outline, plans for country studies and program of the year-end meeting.

YEAR-END MEETING; KATHMANDU, JANUARY 7-9, 2003

The year-end meeting of the APN-supported project on Water Resources in South Asia was held in Hotel Himalaya, Kathmandu on 7-9 January 2003. The meeting was attended by participating scientists from Bangladesh, India, Nepal and Pakistan besides invited keynote speakers who presented papers on selected topics related to the project. The Hansen Institute for World Peace provided supplementary funding to support this meeting and provided management for implementation of year one activities.

The 3-year project was awarded by APN through a competitive process in March 2002, initially for one year. Continuation of the project to the second year is subject to satisfactory performance during the first year and approval by the APN Inter-Governmental Meeting .

The main objective of the year-end meeting was to discuss the reports prepared by teams of scientists from all the participating countries (Bangladesh, India, Nepal, Pakistan and the US) that were prepared according to an agreed outline developed during the program initiation meeting in Dhaka in May 2002. The workshop was also aimed at preparation of the project progress report for submission to APN as per the requirement of the contract, and preparation of the Project Proposal on APN format to request extension of the project for the second year (2003/04).

The meeting was inaugurated by Dr. Upendra Devkota, Minister of Health and Science & Technology, Government of Nepal who emphasized the need to study global change phenomena in the region especially those affecting the water resources. Dr. Kedar Lal Shrestha, Member SASCOM and local organizer of the meeting welcomed the participants on behalf of the local organizers. Dr. Amir Muhammed, Principal Investigator of the project in his introductory remarks described the main objectives of the project and the objectives of the year-end meeting. Dr. A.P. Mitra, Director South Asia START Regional Research Centre (SAS-RRC) described the main activities of the Regional Research Center and briefly mentioned the on-going global change-related research projects in the region. Dr. C. Sharma, APN Liaison Officer for South Asia briefly described the set up of APN and the mechanism for selection of research projects for award by APN.

The second session was devoted to presentation of keynote papers on selected topics relevant to the project. Mr. Usman Qazi from Pakistan presented a paper on " Recent and Past Patterns of Climate Variability and Extreme Events, and Regional Variability of Hydrologic Systems". Dr. Rupa Kolli from India presented a keynote paper on "Implications of Projected Climate Change and Variability, including Extreme Events, on Regional Hydrological fluxes and Water Resources". The other keynote papers presented were on "Implications of Socio-economic Scenarios for Regional Water Resource Needs "by Dr. Q. K. Ahmad (Bangladesh); "Recent and Past Adaptation and Coping Mechanisms, including Impacts on Irrigation Systems, Agriculture, and Urban System, and strategies for Increasing Community Resilience by Dr. Monirul Mirza (Canada & Bangladesh); and "El Nino and Floods in South Asia Region" by Dr. A. M. Choudhry (Bangladesh). All these papers were followed by extensive discussion of the subjects presented.

Session 3 was devoted to the overview of project and of the related APN project on Mountain Environment. Dr. Amir Muhammed described the "Targets and Achievements of the Water Resources Project" while Dr. Kedar Lal Shrestha. Principal Investigator of the Mountain Environment project presented the Targets and Achievements of the Mountain project.

Session 4 was devoted to the presentation and discussion of the national case studies by the country study teams. Dr. A.U. Ahmed & Dr. D.A. Quadir presented the Bangladesh case study while Dr. J. Roy and Dr. D.K. Chadha presented the Indian case study. The case studies on Nepal and Pakistan were presented by Drs. M. L. Shrestha, N. Shakya & M. Ghimire; and Drs A. Farooqi & Shahid Ahmad, respectively. These presentations were followed by extended discussion on the individual country studies.

The last presentation was of a preliminary draft of the "Synthesis Report for South Asia Region: Assessments of National and Regional Vulnerability and Successful Coping Strategies to Change and Extreme Events" by Dr. M. Mirza & Dr. Ahsan Uddin Ahmed.

The next session was devoted to a discussion of all the presentations in relation to the objectives of the project to ensure that all aspects of the study as given in the approved project for the first year had been covered, and to ensure a uniformity in format and style of all the country presentations for purposes of inter-country comparison of the data and preparation of the synthesis report for the South Asia region.

Finally, the group discussed the format for preparation of the Project Report and the Project Proposal for Year 2 on the basis of guidelines provided by the APN Secretariat. Draft reports were prepared by working groups and approved by workshop participants in the plenary session. Plans for compilation of comprehensive workshop proceedings and its publication were also discussed. It was decided that country reports would be reviewed by the respective team members to ensure conformity to the agreed outline and use of uniform format for presentation of climate, hydrological, agronomic and socio-economic data. It was agreed that revised country reports and keynote papers will be completed by 15th March 2003 to facilitate compilation and publication of the workshop proceedings. The draft outline of the country reports for year two, climate scenarios and other tasks were also discussed and a timeline was established.

REPORT ON STAKEHOLDERS MEETINGS
PAKISTAN, INDIA, BANGLADESH

A meeting of the main stakeholders related to the APN-supported project entitled "Water Resources in South Asia: An Assessment of Climate Change-associated Vulnerabilities and Coping Mechanisms" was held in Islamabad in the auditorium of the Pakistan Academy of Sciences on January 13, 2005. The meeting was attended mainly by the scientists and planners dealing with water resources, climate change and related aspects (program of the meeting and list of participants attached). Federal Minister for Food and Agriculture Mr. Sikander Hayat Khan Bosan inaugurated the meeting.

Dr. Amir Muhammed welcomed the Minister and workshop participants to the meeting and briefly described the objectives of the APN project. He stated that the main purpose of the meeting was to share the results obtained so far concerning the trends in climate change, impact on water resources and field surveys to study the impacts of recent drought especially on agricultural production including livestock and residents reaction to the measures adopted so far to cope with the stress and suggestions for future. He emphasized that the workshop will review the perspective of climate change and its impact on water resources and recommend measures for adoption by the policy makers and at farmer's level to meet the challenge of anticipated major shortages of irrigation supplies especially for agriculture.

In his inaugural address, the Minister described government plans to meet the challenge of anticipated major water shortages for the agriculture sector in the coming years. He stated that the shortage of irrigation supplies this year was projected to be 55% compared to last year which has been reduced to 47% because of recent rains. If this shortage persists during the remaining part of the current rabi season, the country will face a major shortfall of wheat that will create a national crisis. He stated that agriculture sector is currently using 91% of the stored water in the country. With rapid population increase and increasing urbanization trend, the need for agriculture commodities especially food crops will also increase substantially. Since about 90% of the country's agricultural production is from irrigated area, the requirements of irrigation supplies will also increase. However with decreasing river flows and overall reduction in total available water resources, the share of stored water for agriculture will also be reduced. In addition, the increasing urbanization will also require additional water supplies for drinking purposes and other municipal requirements. Current efforts for industrial development to increase GNP and per capita income in order to tackle the problem of widespread poverty will also require additional water supplies thus further reducing the amount of water available for agriculture sector.

To cope with this challenge of major shortfall of irrigation supplies in the coming years, the Minister urged the planners and researchers to review the current cropping patterns and especially recommend the introduction of low delta crops instead of the high delta rice and sugarcane crops. He also emphasized the need for research to develop new methods of irrigation to replace the current flood irrigation system. He urged that technologies like laser land levelling, sprinkler, drip and sub-surface irrigation which increase the water use efficiency may be adapted to the Pakistani conditions so that the prices are within the reach of ordinary farmers. He evinced keen interest in the deliberations of the workshop and requested that he will seriously examine the recommendations of the workshop for implementation in national policies.

In his paper on Climate Change in Pakistan, Mr. Munir Shaikh described the comparison between the meteorological data in 1930-60 and 1960-90 at various stations and the trends for climate change for the coming decades. While there is considerable variation in the trends for change in temperature and precipitation at different locations, overall there is a trend towards warming.

Although the available data is insufficient to make a detailed analysis of climate change and determine the trend through the climate models, a preliminary effort has been made to zone the country according to trends in change in temperature and precipitation.

Dr. Shahid Ahmed described the change in the overall water resources of Pakistan with projections for the coming decades. He stated that while river flows have increased and decreased in the past 100 years, there has been a continuous decreasing trend in the flows of all the Pakistani rivers since 1993. This trend projected over the next two decades shows an alarming reduction in the overall water resources of the country and especially of stored water available for irrigation in th3e dry period.

Dr. Pervaiz Amir discussed the results of field surveys in the selected hydrological units in Bahawalpur and Hyderabad districts where teams of researchers had interviewed residents of the selected village about various parameters of the major drought during 1998-2003. Special emphasis was given on the measures adopted by government and private sector organizations to mitigate the impact of drought and farmers reaction to the effectiveness of these measures. After the background presentations, the participants discussed various aspects of climate change, its anticipated impact on water resources, and measures to cope with the major water shortage to meet the requirements of the agriculture sector in coming decades. The final observations and recommendations of the workshop are given below:

A. Main points from presentations

- Winter temperatures increasing in most parts of country.
- Maximum temperatures increase in April-May in most parts of the country
- Annual river flow levels fluctuating
- While river flows fluctuating earlier, the flows since 1996 have been continuously declining.
- Decreasing trend in water availability.
- Water quality both for drinking and agricultural purposes has been deteriorating.
- Irrigated area continuously on the increase.
- Ground water a precious resource. Water table going down and aquifer being disturbed.
- Recent drought in southern Pakistan was more prolonged and severer than previous droughts.
- The affected communities were generally unhappy with the measures taken by the government and NGOs to mitigate the harsh impacts of drought.
- Livestock which is the main asset of farmers in the arid areas was worst affected by drought causing huge financial losses to the farmers

B. Recommendations

1. Climate Change

- *Zone the country on the basis of anticipated climate change. Incorporate this information into zoning for efficient and sustainable land use based on soil type, topography, water availability, and marketing opportunities.*
- *Undertake research to relate climate change to land use and cover change especially large scale deforestation, irrigation projects resulting in cultivation of barren land*
- *Establish more meteorological stations especially in the mountainous areas and extend climate change analysis to decadal level instead of a 30-year interval.*
- *Emphasize the study of glaciology in academic programs*

__2. Water Resources and Irrigation Management__

Ground water is the most precious resource of fresh water that provides flexibility for timely use in crop production especially in conjunction with canal water. At present there is no mechanism in place to regulate the pumping of underground water resulting in excessive use and disturbance of the aquifer in several areas, especially during the drought period.

- *Establish a National Ground water Authority and regulate the use of groundwater and its re-charging to ensure sustainability of this precious resource.*

Total irrigated area in the country is far in excess compared to the available water resources resulting in poor crop yields and the incidence of Waterlogging and salinity.
This needs to be reviewed and future plans prepared with water availability as the limiting factor.

- *Convert some of the marginal irrigated areas with poor productivity into range lands in an effort to reduce the irrigated area according to water availability. Simultaneously increase the crop yields and cropping intensity in the irrigated area to meet the increasing requirements for agricultural products.*

Watersheds of most of the major rivers are deteriorating jeopardizing the water resources of the country.

- *Concentrate on improving the environmental health of the watersheds for sustainable water resources development.*

WAPDA is a development agency specializing in water and power development and cannot devote the required effort in planning and research about water resources.

- *The responsibility for monitoring and planning the water resources and efficient utilization of the scarce water resources may be entrusted to another agency with a research culture.*

Data about water resources availability and requirement for different parts of the country differs vastly depending on the sources of the data. This creates confusion and results in inefficient planning resulting in economic losses.

- *Entrust the collection and compilation of data on water resources to a single agency who should be the source of all agreed figures relating to water resources in the country including ground water*.

Water pricing is a crucial issue to regulate efficient use of limited water supplies. At present cost of irrigation water to farmers is nominal and that too varies for different crops. This promotes wasteful and inefficient use of this limited resource.

- *Rational water prices may be fixed for domestic, industrial and agricultural users to ensure that water is viewed as a precious limiting resource and used efficiently by the consumers.*

Cropping intensity in high delta canals is much lower than the potential.

- *This aspect may be studied to ensure efficient, sustainable use of water for optimum economic benefits.*

Water use efficiency and economic returns from water input vary vastly across the country. Water being a limiting resource, we can ill afford this luxury.

- *Prepare plans to allocate water for optimum economic returns providing for alternative economic opportunities for regions where water use does not give economic returns. Re-allocate water in canal commands according to the efficiency of water use for crop production and income generation.*

Ecological conditions, climate and soil types vary widely across the length of various main canals. It is impossible to recommend a standard set of management practices for different commodities in various sub-zones even for a single canal command.

- *Delineate crop zones along the length of the main canals for various crops and develop zone-specific crop production practices for each sub-zone*

- *Promote use of essential implements especially land leveling equipment as necessary attachment with costly tractors. Provide incentives for purchase and use of such equipment.*

- *Study the impact of changes in water allocation on environmental aspects.*

- *Study the legal aspects of water rights, sharing of common resources especially in relation to ground water.*

- *Systematically study water trading between provinces, regions and farmers.*

3. Mitigation of Drought Stress and Water Scarcity

Most crop varieties grown in drought prone areas have been evolved for irrigated areas. These suffer heavy losses in case of drought.

- *Evolve new crop varieties with resistance to drought stress and high temperatures.*

Karachi has a huge cattle population which depends on interior Sindh for fodder. However the animal manure is not ploughed back into interior Sindh thus depleting the soil fertility.

- *Arrange to transfer the large quantities of animal manure from metropolitan Karachi to interior Sindh which provides fodder for the animal population.*

Liberal electric connections and subsidy on installation of tubewells, especially in areas where there is no adequate re-charge of ground water are damaging the underground water resources in several areas especially Balochistan.

- *Relate policies for subsidized purchase of tubewells and electric connections with ground water extraction policy.*

Regarding institutional aspects of irrigated agriculture, management of agriculture now decentralized to district level while irrigation management is on canal command basis and the geographical domain of the two is not congruent.

- *Resolve this institutional issue to improve efficiency of irrigated agriculture in different districts and sub eco-zones.*

There is a vast scope for upgrading the production technology of high value crops especially orchards, vegetable farms etc. Modern water management techniques and other agricultural practices to improve the productivity and product quality should be implemented on these farms since these are progressive farmers and can afford the expenses for introduction of improved technology.

- *Develop special policy package for modernization of high value crops like orchards, vegetables and floriculture and link to processing and marketing facilities.*

Pesticide residues in most of our exportable products-cotton, textile, honey, rice, fruits and vegetables are likely to become a major issue after full implementation of the WTO regime adversely affecting our exports.

- *Promote organic farming especially for export-oriented commodities.*

Agriculture statistics data not standardized. Different figures being used for the same parameter.

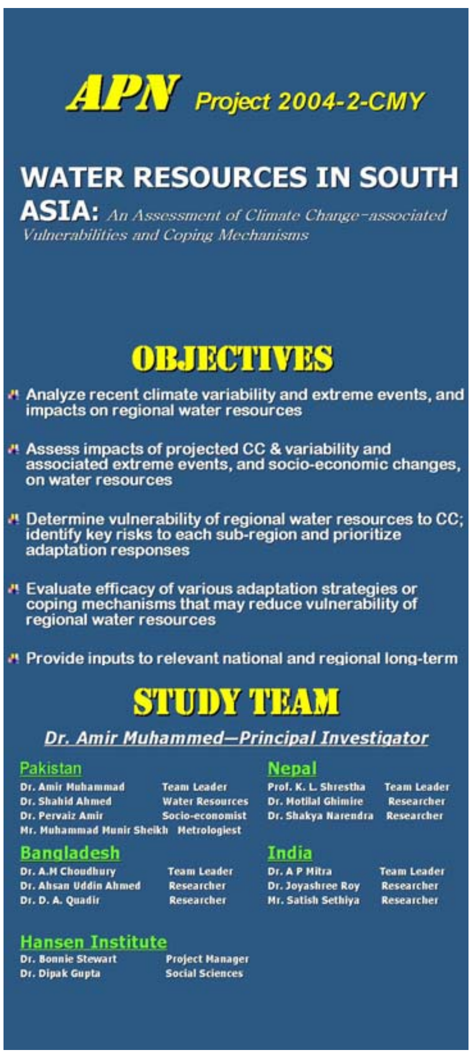
- *Compile all data related to agriculture including climate, river flows and glacier aspects on a standardized format, and put it on a website for wider use.*

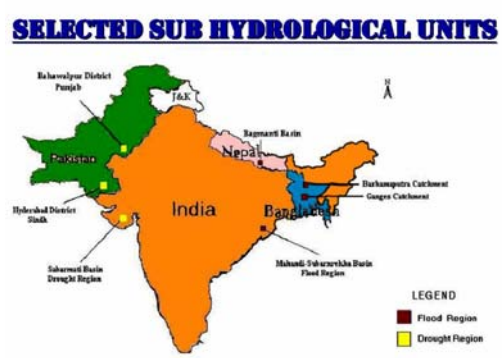
- *Critically review the efficacy of using zero tillage in different zones of the rice-wheat tract with special reference to pest management and likelihood of local waterlogging for wheat crop due to poor percolation.*

- *Emphasize the economic aspect of zero tillage intervention especially on saving of water and labour, and increase in growing days.*

- *On Farm Water Management (OFWM) Deptt is promoting zero-tillage technology while Punjab Extension Deptt is vigorously opposing it. Reconcile the issue on the basis of factual information from field studies.*

- *Review the experience with ridge-furrow cropping as successfully adopted for cotton, for possible extension to other crops. Also review the intermediate technology currently being used by farmers in this respect.*





Indian Stakeholders Meeting

Experience

- Enriching
- Encouraging
- Validated and Robust
- Coping mechanisms are varying
- Priorities in coping mechanisms are different somewhat
- Field level people want to get continuous information and need scientific action

Suggestions

- More Disaster management studies
- Irrigation: more crop per drop, living with the flood
- Insurance system no uniform and lack of awareness
- Afforestation, ponds : local actions
- Water budget exercises at micro level
- Local level support: research, financial, institutional
- More dissemination, Technologies available to address the adaptation
- More dialogue of similar type

Bangladesh Stakeholders Meeting

- Participants well received the dissemination process
- Attached high importance on continuing research on such an issue
- The rising trends needs to be better understood; called for a more rigorous study
- Recognizing that flood was the focus of the study, the participants demanded a full study including other forms of extreme events
- Liked the idea of revealing people's coping strategies; called for complete analysis of institutional adaptations
- Recommended that the findings of the study need to be incorporated into the NAPA process
- Called for wider dissemination, preferably as Bangla publication

Flood Management

- Emphasis on modernizing flood forecasting system
- Improvement in real-time flood warning dissemination
- Refurbishing and rationalizing existing flood management embankments
- Facilitating water drainage infrastructure
- Promotion of regional cooperation in flood management under IWRM
- Promotion of basin-wide approach in flood management
- Social issues need to be taken on board
- Agricultural rehabilitation need to be revitalized
- Incorporating results into the NAPA process and in CDMP Weaknesses
- RCM analysis could not be done
- Watershed modelling could not be done
- Lack of institutional cooperation; lack of resources; methodology
- Very little research is available on adaptation in water-sector