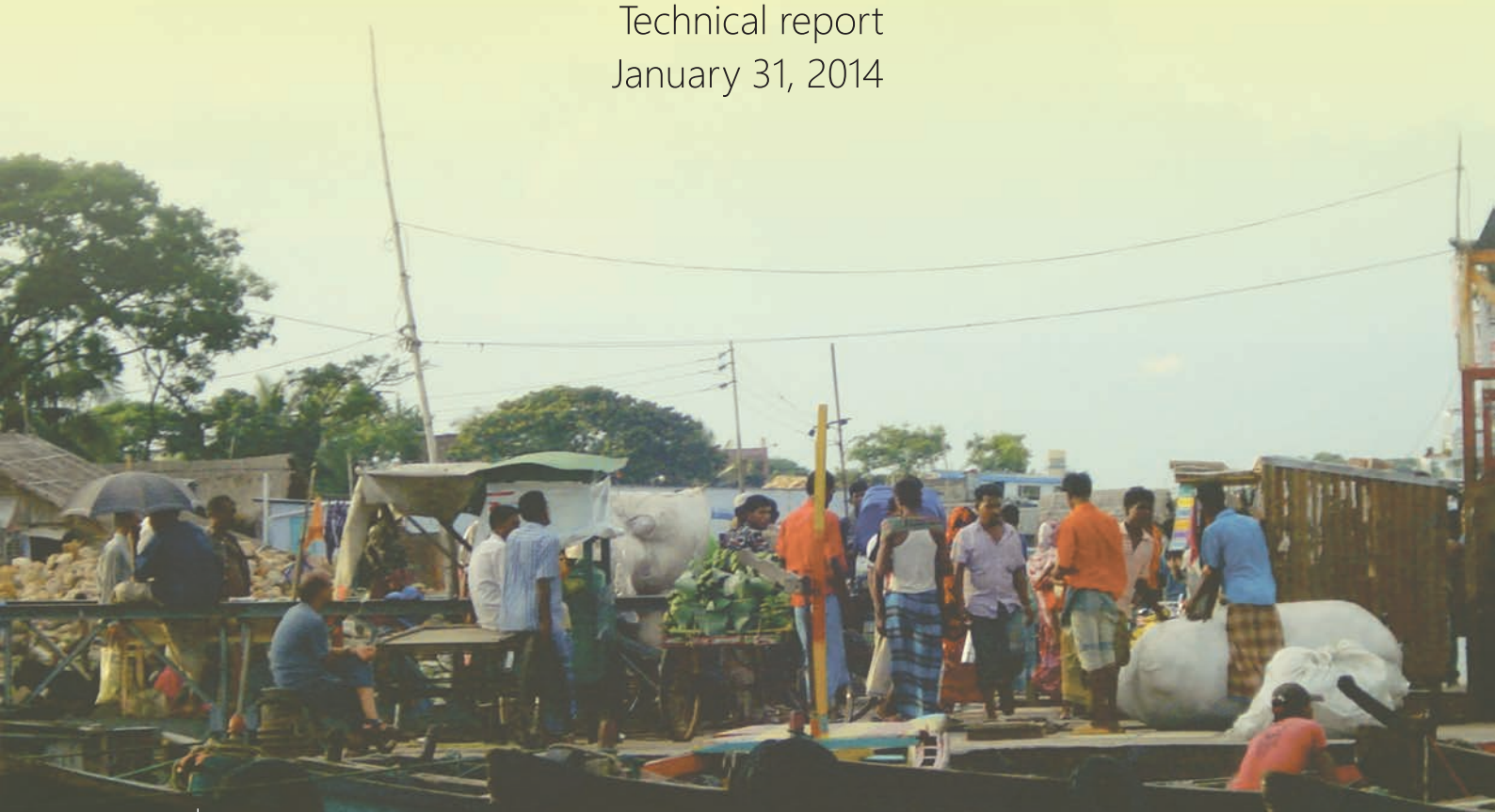
Water Security in Peri-Urban South Asia

Adapting to Climate Change & Urbanization

Water Security in Periurban South Asia
Adapting to Climate Change and Urbanization

Technical report

January 31, 2014



South Asia Consortium for Interdisciplinary Water Resources Studies (SaciWATERs)

Institute of Water and Flood Management (IWFM)

Bangladesh University of Engineering and Technology (BUET)

Nepal Engineering College (nec)

Project Support

IDRC CRDI

International Development Research Centre

Centre de recherches pour le développement international

Canada

Project Partners

SaciWATERs

IDRC Project Number: 106248

IDRC Project Title

Water Security in Periurban South Asia: Adapting to Climate Change and Urbanization

Country/Region:

Khulna, Bangladesh; Gurgaon and Hyderabad, India and Kathmandu, Nepal

Research Institution:

South Asia Consortium for Interdisciplinary Water Resources Studies (SaciWATERs), Hyderabad, India

Dr. Anjal Prakash (Project Coordinator)
Dr. Vishal Narain (Team Leader – Gurgaon and Lead Researcher)
Ms. Sreoshi Singh (Team Leader – Hyderabad and Lead Researcher),

Institute of Water and Flood Management (IWFM), Bangladesh University of Engineering and Technology (BUET), Dhaka, Bangladesh

Prof. M S Khan (Team Leader – Bangladesh and Lead Researcher)
Prof. Rezaur Rahman (Faculty Researcher)
Dr. M Shahjahan Mondal (Faculty Researcher)
Mr. Uthpal Roy (Research Associate)

Nepal Engineering College (nec), Kathmandu, Nepal

Prof. Ashutosh Shukla (Team Leader)
Mr. Mahesh Pathak (Faculty Researcher – GIS)
Rajesh Sada (Researcher- Project Coordinator)
Anushiya Shrestha (Research Assistant)

Table of Contents

Acronyms

BWDB	Bangladesh Water Development Board
CBA	Cost Benefit Analysis
CoCooN	Conflict and Cooperation over Natural resources in Developing Countries
DFID	UK Department for International Development
DHM	Department of Hydrology and Meteorology
DoE	Department of Environment
IRRAD	Institute for Rural Research and Development, Gurgaon
KCC	Khulna City Corporation
KDA	Khulna Development Authority
KVWSMB	Kathmandu Valley Water Supply Management Board
KWASA	Khulna Water Supply and Sewerage Authority
LVI	Livelihood Vulnerability Index
MDI	Management Development Institute
NEC	Nepal Engineering College
NNWW	Nepal National Water Week
NWO	Netherlands Organisation for Scientific Research
PHED	Public Health Engineering Department
PRA	Participatory Rural Appraisal
RS & GIS	Remote sensing and geographic information system
SLD	Shared Learning Dialogue
SOUL	Save our Urban Lakes
VDC	Village Development Committee
WECS	Water and Energy Commission Secretariat

Executive Summary

Massive urbanisation defines South Asia, which is home to over 1.6 billion people in 2010, or a quarter of humanity, of which one-third live in urban areas. Although the rates of urban growth in South Asia are considered to be slower than some other parts of the world, growth is predicted to accelerate in urban areas in next two decades. Further, statistics reveal that most of this urban growth is occurring in the countryside, engulfing the rural landscapes surrounding existing metropolitan cities, that is in the peri-urban areas. These cities grow in numbers and expand physically by acquiring land from the peripheral rural areas. These peripheral areas also receive the waste from the core cities. The peri-urban zones are therefore conceptualized as the transitional areas between the two conceptual extremes of rural and urban in the settlement continuum. These are areas of continuous transformations of the landscape, of flux of people and resources, and of dynamism in their social and economic interactions creating complex and most often contradictory growth patterns. Changes in the usage of the land also involve fundamental transformations in the uses of water, bearing significantly on the environmental health and the well-being of the residents of the peri-urban areas. The acquisition of water from a diverse number of sources, and the pernicious use of water by several users for different purposes, make its supplies unpredictable. At the same time, the reality of climate change, the alteration of rainfall, temperature and other weather phenomena, has observable and adverse effects on water availability. In general, cities are particularly vulnerable to the effects of climate change because of the congestion and the fixed nature of urban infrastructure. The built up surface of cities increase runoff of rainwater and decrease the recharge of the groundwater during the spells of short and intense rainfall periods, and increase evapo-transpiration, and encourage groundwater exploitation. Extensive built up areas contribute to dangerous heat events and increase human vulnerabilities. Therefore, not only the cities but also the peri-urban areas become susceptible to the effects of climate change.

This report covers these dimensions and dynamics of development process in South Asia. It explores the implications of rapid urbanisation and climate change on water availability for vulnerable communities in four South Asian cities - Khulna (in Bangladesh), Gurgaon and Hyderabad (in India) and Kathmandu (in Nepal). This final technical report covers, activities, findings, outputs and outcomes of the project – Water Security in Peri-Urban South Asia: Adapting to Climate Change and Urbanisation. The project was funded by International Development Research Centre (IDRC, Canada and was implemented by South Asia Consortium for Interdisciplinary Water Resources Studies (SaciWATERs), Hyderabad, India in coordination with Institute of Water and Flood Management (IWFM), Bangladesh University of Engineering and Technology (BUET), Dhaka, Bangladesh and Nepal Engineering College (nec), Kathmandu, Nepal.

Methodology, key findings and lessons:

The project developed an understanding on established and emerging water security concerns resulting from urbanization and climate change and thereby developing adaptive capacities of the residents in the

peri-urban areas in four south Asian cities- Khulna in Bangladesh, Hyderabad and Gurgaon in India and Kathmandu in Nepal. In doing this, the project team used a mix of both qualitative and quantitative research tools to capture dimensions of climate change and variability. These were juxtaposed with scientific analyses of secondary meteorological data on key climate parameters across the research locations. The research found that there is evidence of a changing climate due to large scale and unplanned urbanization process across all the four research locations and the poor and marginalized people staying in peri urban locations are hardest hit. They are trying to cope through this process in variety of ways including securing drinking water through commercial ventures, crop changes, migration, diversification of livelihood and feminization of agriculture. The key lessons of this project are:

Climate variability and urbanisation:

The research confirms that urbanisation creates new claimants on water. It was found that all the cities are partially covered by formal water supply systems. New settlements need water. This demand is met by private tanker operators who find it easy to fetch water from peri-urban locations and supply this water in urban areas.

Disaggregating vulnerabilities:

This research finds parallels between the cultural logic of castes/classes and gender discrimination. The gender- and class/caste- disaggregated data collected by this research show entwining of caste\class and gender that defines water allocation and access among users. The evidence of vulnerability and its impact on people lower in socio-economic hierarchy is evident from the present research.

Climate science verses local perception:

The research found that most of the climatic data analysis has been concentrated at the aggregate level (national, regional or state level) and generalized to represent the entire country or region. With extensive variations in topography and microclimate there is need of site-specific climatic data analysis to understand the climate variation at local contexts.

Stakeholders' engagement:

The research shows that local communities are struggling to find ways to prepare for the potential impacts of future climate change. They are dealing with immediate pressures through changing agricultural practices, livelihoods and coping with water stress. Our engagement in this project shows that existing management approaches do not adequately incorporate changing stakeholder preferences. Affected communities are mostly aware of the trade-offs but that is not reflected in the planning process and therefore their engagement is critical for planned adaptation.

The project has achieved considerable outputs in gathering scientific information and knowledge on the issue of peri-urbanisation, water security and climate change impacts. It has engaged with a wide variety of stakeholders including affected communities, policy makers, academicians, researchers and students. In sum, 16 journal articles, 14 discussion papers, 31 internship reports, 27 reports of various workshops, 11 reports of micro activities at the field level, 5 documentaries and 4 policy briefs have been produced by the research teams.

The impact of this project has been two fold – first there is more scientific evidence of the process of peri- urbanization linked with water security and climate change issues.

Many research papers, reports, journal articles and book manuscripts document this process increasing academic and policy level visibility of this topic. Second, rooted advocacy at the community level had helped in increasing awareness of the problem and seeking collaborative solutions.

Keywords: Water Security, Periurban, Climate change, South Asia, Urbanisation

Anjal Prakash

The Research Problem and Objectives

Urbanisation has been an important trend of the 20th century. More than 50 per cent of the world's population currently lives in urban areas, a figure that is expected to increase to 70 per cent by 2050 (UN-HABITAT, 2007). Asian cities are likely to account for more than 60 per cent of this increase. In several South Asian cities, growth and expansion picked up after the 1990s. This growth was led by neo-liberal economic policies, policies favouring the growth of special economic zones and a real estate boom. Both local and global actors have had a role to play in this expansion. Most of these cities in South Asia expand horizontally over space, changing the use of land at the junction between the rural andurban areas, and the transformation of land and water resources at this urban periphery is an integral part of this physical expansion. These peripheral areas serve the urban centre as the sinks of its wastes, while providing the much-needed land and water resources for the urban residents. With changes in land use supporting urban expansion, changes in water use follows suit.

Within a short period, water sources in peri-urban locations succumb to the growing pressures from ever-expanding cities as new and emerging claimants compete for limited amounts of water. At the same time, the disposal of urban and industrial wastes into peri-urban water sources further compromises peri-urban water security. The effects of these are aggravated by climate variability and climate change. Climate change exacerbates the effects of the above through changes in the frequency, timing and intensity of precipitation, incidence of storm surges and extreme events, sea level rise and salinity intrusion.

This project was an attempt to understand the implications of urbanization processes for water access and use of peri-urban residents in four locations across three South Asian countries in the overall context of climate change. This action research project was located in selected sites in India, Nepal and Bangladesh will provide a deeper understanding of the changing access to water for peri urban residents due to development activities and further implications of climate change, especially for the vulnerable social groups differentiated by class, caste and gender. The project also focused on how affected communities responded or adapted to these changes.

Main research objective

To understand the implications of urbanization processes for water access and use in peri-urban locations in 4 select sites in South Asia and to examine water related vulnerability, adaptation and resilience of different social groups in the context of climate change

Specific objectives

- To understand decreased water availability, competition and conflict as a result of urbanisation and to draw out the implications of this for vulnerability and variability in the context of climate change
- To examine how different social groups, women and men, respond and adapt to increased water stress – as shaped by a mix of technology and institutions - and what strategies they employ to cope with or adapt to the situation
- To identify avenues for collaboration with a wide range of stakeholders who are engaged at the peri-urban interface, and find out the institutional gap in adequately addressing the situation

The Theoretical Framework

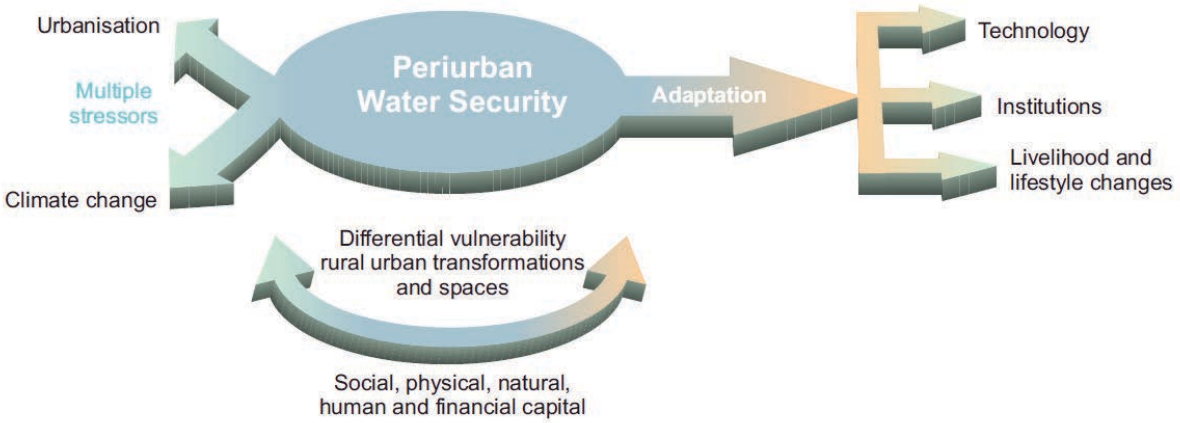
South Asia will have over two billion residents by about late 2050s, with just over a billion people in urban areas (Mukhopadhyay, and Revi, 2009). Increased urbanization will focus on ever increasing demand for water among an ever more concentrated population. Asian cities alone are expected to grow by 1 billion people in the next 20 years. The consumption level of domestic water that each person uses is expected to rise, considering the rate of development of many of the South Asian cities. Moreover this situation is likely to get accentuated by climate change which will result in shrinking of the freshwater resources. The growing population pressure is already creating stresses on water resources and consequent loss of access to water for the peri-urban residents.

The major factors aggravating water scarcity are influenced by climate change. Climate change, as already mentioned, is expected to severely alter the weather patterns, which will have adverse effect on water availability patterns. Global warming phenomena characterized by changes in the seasonal distribution, amount and intensity of precipitation, increased evapotranspiration, accelerated melting of glacial ice, increased coastal inundation and wetland loss from sea level rise would be responsible for increased water-induced hazards like riverine floods, inundations, soil erosion through flash floods, prolonged droughts and spread of alien species and harmful disease, thereby exerting a heavy toll on human life, livelihoods and economic prosperity (Dekens and Eriksson 2009) especially in the South Asian region. The IPCC (2007) has outlined the possible impacts of global warming and climate change in the region indicating that the warming will be quite significant for South Asia. Accelerated melting of glaciers would seriously affect about half a billion people in the Hindu-Kush Himalayas (Stern 2007). Erratic monsoon rains in India and Nepal has been found to be highly correlated with large-scale climatological phenomena such as El Nino. Changes in the intensity and distribution of rainfall are expected to alter the recharge of aquifers, because, the time needed for groundwater to recharge can vary with the amount or intensity of precipitation. Cities are particularly vulnerable because of the complex and fixed nature of urban infrastructure, that is responsible for more runoff and less infiltration during spells of shorter duration but more intense rainfall combined with increased evapotranspiration caused by combined effects of structural interference with thermal radiation, low albedo of impervious surfaces and reduced evapotranspiration leading to a much stronger urban heat island (UHI) effect (Ruth & Gasper in OECD, 2008). Moreover, increased irrigation is expected to lead to groundwater depletion. These will make cities susceptible to dangerous heat events (OECD, 2009), the impact of which will be felt even in the peri urban zones.

Urban sprawl and growth of peri urban areas have been induced by low land prices that have attracted the urban rich to move into the peri urban zone. Although known for the less privileged, the peri urban areas in many South Asian cities are witnessing enormous prospects of residential and commercial development owing to the increasing demand for homes in the city. This process has usurped lands and surface water sources to a large extent, resulting in the poor and marginalized population

suffering the most, because of decreasing access. In many cases, new residential enclaves have taken over the water bodies within their boundaries leaving no source available for the population who earlier relied on these sources for drinking and agricultural purposes. The poor are forced to depend on water provided by tankers, for which they pay a price similar to what is paid by the commercial and residential enclaves using water, not only for drinking but also for recreational purposes like swimming pool, fountains, gardens etc. This is coupled with lack of government regulations to stop the ongoing skewed development. Under such circumstances, instances of conflict over water resources in the peri urban zone is envisaged for the future; competition between multiple water uses, specific environmental challenges, the degree and speed of change, unclear governance frameworks, joint water quantity and quality management (dilution of effluent or bad quality water, management of series of reservoirs) vs. increasing competitive demand, whereby conflicts arise between the different agencies traditionally involved in water management (hydroelectricity, flood control, water supply, sanitation) over responsibility for the management of the reservoir systems. These conflicts between the main agencies tend to remain unresolved due to weak representation of local communities in the participatory bodies, large social inequalities and asymmetry of information and decision-making power which results in an ineffective implementation of land and water policy (Narain, 2010, Prakash and Singh, 2011).

Water infrastructure, usage patterns and institutions have developed in the context of the current conditions. However, they are constrained by the poor development of local institutions and inability to integrate the various agencies that would need to respond, if climate change risks crystallize. Further, any substantial change in the frequency of floods and droughts, or in the quantity and quality or seasonal timing of water availability, will require adjustments that may be costly, not only in monetary terms but also in terms of societal and ecological impacts, including the need to



Urbanization, water scarcity and climate change: challenges for vulnerability and adaptation in South Asia

manage potential conflicts between different interest groups (Miller et al., 1997). Under these circumstances, the immediate and primary concern is to understand the challenges that urbanization poses for water availability in peri urban areas and for residents living therein; how peri urban residents respond/adapt to them and what lessons are learnt about adaptation to climate change that has similar implications for water availability. Climate change can be seen as an opportunity to create an environment that will help in the discovery of a more sustainable urbanization model. Some level of growth, particularly to the extent needed to eradicate poverty and improve human development indicators, however remains non-negotiable (Mukhopadhyay and Revi, 2009).

In this research, peri-urban water security is seen as being shaped by the twin processes of climate change and urbanisation. These processes act as multiple stressors on peri-urban water sources and create a situation of uncertain water supply for peri-urban communities. The effects of urbanisation occur from changing land-use patterns that engender changes in water use through the links between land tenure and water security. The expansion of the city through new building and roads change the water flows. Moreover, the use of these water bodies to dispose of urban wastes further compromises peri-urban water security (Prakash et al. 2011). However, peri-urban residents are not passive recipients of these change processes affecting their water security. They adapt to this situation using a mix of technologies and institutions at both the household and collective levels. Their differential vulnerabilities are shaped by their exposure to these processes as well as their access to resources, technologies and institutions that help mitigate the pernicious effects.

Methodology

This research was carried out over a three year time frame in selected peri-urban locations in South Asia and was designed as a collaborative action research project involving partners from Bangladesh, India and Nepal. A mix of both qualitative and quantitative research techniques were used in the study. Semi-structured household interviews and focus group discussions were used to assess and understand adaptation strategies and responses of the people, the implications of the interface of urbanisation and climate change for water security, factors shaping the differential vulnerabilities and changing gender relations around water. A structured household survey was also conducted to collect gender-disaggregated data on water consumption at the household level as well as to capture inter- household variations in water access. Cost-benefit analyses of adaptation strategies in place were carried out in one of the locations. Apart from this, climate data was collected and analyzed for all the four research locations.

The research tools that were used are listed as follows:

Analysis of hydrologic and hydro-geologic systems:

This method analyzed the interlinked hydrologic and hydro-geologic systems of the peri-urban areas along with their urban components using GIS modeling. The study was based on secondary information available through published documents and relevant agencies. The analysis generated baseline information and understanding for research, and projection of future scenarios. This information was shared with the primary and other stakeholders in the research area through consultation meetings.

Vulnerability assessment tools:

The concept of vulnerability, even at a definitional level, has generated considerable debate among the academic community in south Asia. While the physical scientists and engineers have typically equated it with physical exposure to extreme events and adverse outcomes, on the social scientific side, the emphasis has been on the failure of entitlement to resources, and structural factors making certain groups differentially disadvantaged in the face of disasters (Adger, 2006). Since vulnerability is a dynamic phenomenon, often in a continuous state of flux, measurement of vulnerability must therefore reflect social processes as well as material outcomes within systems that appear complicated and with many linkages that are difficult to pin point. This research has used the Vulnerability and Capacities Index (VCI) method developed by Mustafa, Ahmed and Saroch (2008),that attempted at defining and quantifying appropriate criteria for the three key dimensions of vulnerability, namely material (income, education), institutional (infrastructure, social capital) and attitudinal (sense of empowerment). The data collection tools under VCI were developed and customized to per-urban settings. The report of the same is being finalized.

Assessment of the cost-effectiveness of adaptation strategies:

The study evaluated the cost effectiveness of different interventions that reduces hazard risks or facilitates coping or adapting to increased climate risks and hazards and to the urbanization process. This was done through a mix of qualitative and

participatory methods as well as cost benefit analysis (CBA). CBA research was done for the revival of the Mayur River in Khulna, Bangladesh as a major source of drinking water for the Khulna city. The CBA exercise revealed that net benefits from developing the river for purposes of provision of drinking water are positive, and justify such interventions. The costs that were considered for the exercise include solid-waste management, removal of illegal structures & obstructions, waste-water treatment plant, sanitary landfill costs, river bed dredging and landing facilities, and rehabilitation and resettlement costs.

Engagement with stakeholders and communities:

The research team used a wide range of methods to engage with the community, civil society organisations and state agencies. A wide range of stakeholders were involved in the project from the very beginning to sensitize them to peri-urban water security issues and to garner momentum for change. The intervention strategies involved both the water-users and service-providers. These included stakeholder meetings to promote dialogue between government agencies and water-users, lobbying for the protection of water sources with government agencies and service-providers and mobilizing communities for the formation of water-user groups and committees.

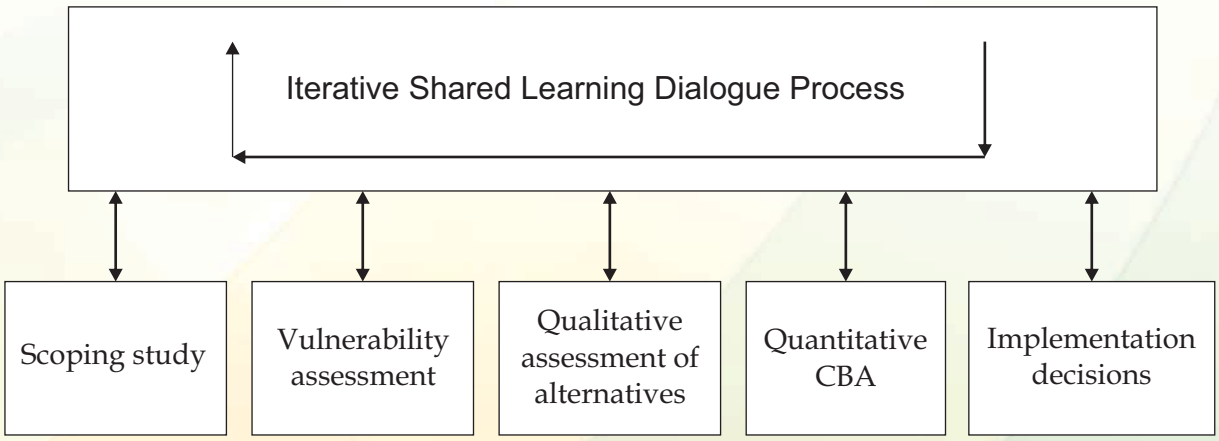
Research Methodology Flow Chart

The flow chart below depicts the process that were followed as research methodology of the project. The process of Shared Learning Dialogues (SLD) as described were iterative as diagramed below.

In sum, a mix of some or all the methods stated above, were used in understanding the extent of vulnerability to water access and climate change for each of the research locations. Different combinations of these methodologies were used by the researchers depending on the country context.

The study locations

Four study sites were chosen - Khulna in Bangladesh, Gurgaon and Hyderabad in India and Kathmandu in Nepal. The figure below shows the location of these cities in South Asia. These cities represent different institutional and agro-ecological contexts in which the combined effects of urbanization and climate change present themselves. Khulna presents the case of a coastal city facing threats of sea level rise and salinity

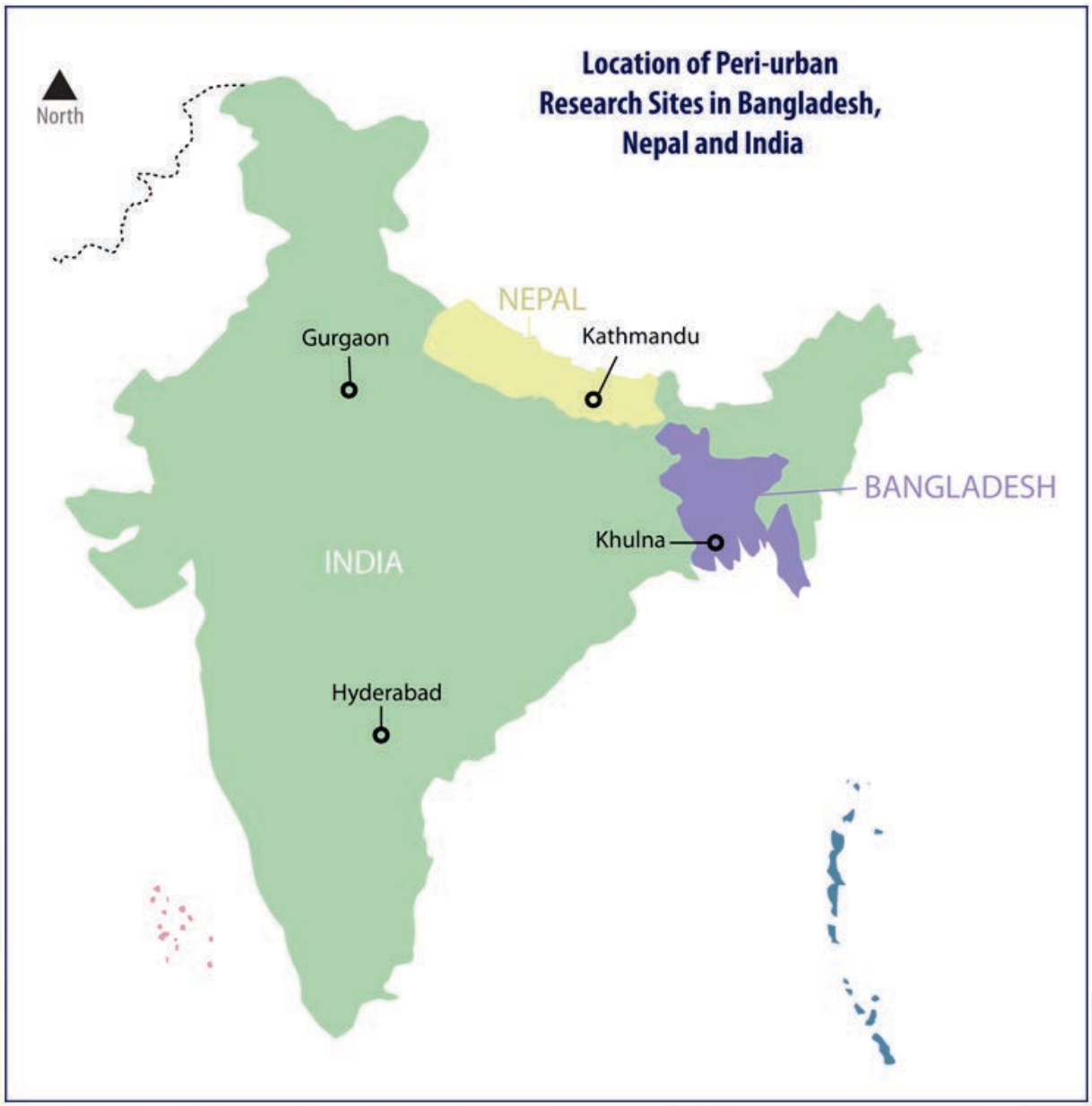


Iterative Shared Learning Dialogue Process

Source: Adapted from ISET, Undated.

intrusion. Kathmandu presents the case of urbanization disrupting the fragile hill environment. Gurgaon and Hyderabad have witnessed urban expansion after the neo-liberal economic policies were adopted in the 1990s. The growth of these two cities was led by information technology and the business process outsourcing sectors.

The location of the project sites in South Asia



Project Activities and Results

The project was carried out in three phases from June 12, 2010 to January 12, 2014. Phase 1 included the inception phase of 6 months duration. During this time, exploratory studies were done to align with the research objectives through preliminary research, individual stakeholder consultations, literature review and field data collection through qualitative means. Phase 2 involved the starting and completion of full-fledged research and was of 24 months duration. Phase 3 was of 6 months duration that was dedicated for writing and consolidating research outputs and dissemination. This project received a six months extension (from June 12, 2013- January 12, 2014) which was spent in consolidating the outputs in terms of publications in referred journals and writing manuscript for the book as an outcome of this research.

The project activities could be grouped into the following:

1. Conducting primary research to
   a. understand the link between urbanization and climate change with special reference to peri urbanization process in south Asia
   b. examine how different social groups, women and men are differentially affected by increased water stress
   c. understand how communities are adapting to climate change
2. Building adaptive capacities of the people and campaign for creating awareness
3. Research uptake through planned dissemination strategy

Urbanisation, climate variability and climate change in study locations

Climatic trends and variability are analyzed in four peri-urban locations in South Asia. These locations represent a diversity in physiographic and climatic patterns as well as similarities in peri-urban issues and processes across South Asia. Long-term climatic data on temperature, rainfall, humidity and evaporation were observed at the weather stations near study locations and were analyzed using standard statistical techniques mostly involving assessment of linear, monotonic trend in a variable at annual, seasonal and monthly time scales. Statistical tools such as t-test and Mann-Kendall test were also employed to assess the significance of the trends. Results of these analyses are interpreted to understand the impacts and implications of these long-term trends and short-term variability in climatic variables.

Khulna, a coastal tide-influenced area, is susceptible to sea level rise, cyclone, storm surge, rainfall flooding, water logging and salinity intrusion, and has a tropical monsoon climate. The annual average temperatures in Khulna range from 12.4 C in winter to 34.3 C in summer. Approximately 80% of the average annual rainfall of 1809 mm occurs during the monsoon months of June-October. Secondary data analysis results indicate that average maximum temperatures in the pre-monsoon and monsoon seasons, and the average minimum temperatures in the pre-monsoon, post-monsoon and winter seasons are increasing at faster rates in recent times (1980-2010) than other projections or model predictions. The monthly data also have similar trends. Heat

Index, representing the combined effect of humidity and temperature on human body, is increasing in March-October. Rainfall in all seasons, and annual number of rainy days and number of consecutive rainy days have generally increasing trends while the monsoon appears to be strengthening towards the end of the season.

Kathmandu Valley has a predominant sub-tropical cool temperate climate where summer and winter temperatures vary from 19 - 27 C and 2 - 20 C, respectively. The relatively large range in altitude in this orographic setting makes the climatic variables more erratic. Approximately 80% of the average annual rainfall of 1400 mm occurs during the monsoon months of June-September. Three different indices were used to analyze the trend and variability in temperature data from seven weather stations at different time scales. Analysis results indicate that both the annual maximum and minimum values of the temperatures have increasing trends. Both the warmest and the coldest days of the year are becoming warmer. There is a decrease in annual number of days with temperature < 0 C and an increase in the number of hot days (>30 C). Analysis results also indicate an urban heat island effect in the peri-urban locations. Trend in total annual rainfall is almost static while there is a non-significant increase in the annual number of rainy days during monsoon.

The semi-arid climate of Gurgaon is characterized by low humidity, hot summer and cold winter. The average temperatures vary from 41 C in summer to 7 C in winter. Approximately 82% of the annual rainfall of 773 mm occurs during the monsoon months of July-September. Analysis results of secondary data indicate that monthly averages of both the minimum and maximum temperatures are increasing although there is a relatively high month-to-month variability in temperature in the recent years (1980-2011). In this recent period, maximum and minimum temperatures are increasing at relatively higher rates. The mean monthly minimum temperature in January also has a slightly positive trend. However, this temperature has a negative trend in the recent years, which implies that the winters are getting colder in the recent years. The month-to-month variability in night-time temperature is found to be reducing while the maximum temperature shows an increasing variability. This implies that the natural fluctuation in daytime temperatures within a year is increasing, most likely due to global warming. The variability in both maximum and minimum temperatures at seasonal and annual scales is decreasing. The variability in rainfall during different seasons is found to be decreasing, indicating that the natural seasonal distribution of rainfall in Gurgaon is gradually changing. The variability in annual rainfall has increased in the post-1980 period at both seasonal and monthly scales.

Hyderabad, situated in the semi-arid Deccan plateau, has a predominantly tropical wet and dry climate. Temperatures in the hottest and coldest months of May and January vary from 26-38.8 C and 14.7-28.6 C, respectively. The average annual rainfall in Hyderabad is 828 mm, 74% of which occurs in the monsoon months of June-September. Analysis results of secondary data indicate an increasing trend in temperature. The monthly mean maximum temperature is increasing in both the overall analysis period (1951-2010 and the recent years (1980-2010). At seasonal scale, pre-monsoon season exhibits the highest temperatures among all the seasons. The intra-year variability in minimum temperature is found to be decreasing at Hyderabad. Long-term maximum data also indicate a

decreasing trend in intra-year variability which is supported by the data since 1991. This means that unlike Gurgaon, the day temperatures in Hyderabad are becoming similar whereas the ranges in night-time temperatures are increasing. It is also evident that variability in mean seasonal and annual maximum and minimum temperatures has decreased in the post-1980 period. The inter-year variability in rainfall has increased in the post-1980 period although the annual rainfall has slightly increasing trend.

It is evident that temperature is rising in all four locations. Rising trends in temperature are observed in general at annual, seasonal and monthly scales, while year-to-year or seasonal variability is also increasing in some locations. May and January are approximately the hottest and coldest months, respectively. Trends in annual rainfall vary widely across the region. Khulna is experiencing increasing rainfall whereas rainfall in Gurgaon has a decreasing trend. Annual rainfall trends in Kathmandu and Hyderabad are almost static. There is, however, an increasing trend in annual number of rainy days in all four locations. For Gurgaon, Hyderabad and Kathmandu, where the annual rainfall is either decreasing or static, this means less rainfall intensity distributed over the year. Variability in short-term rainfall will directly affect water availability and balance in the hydrological cycle.

These climatic changes in the four peri-urban locations of South Asia may have significant impacts on the biophysical systems that have considerable socio-economic implications, which are also perceived by the peri-urban residents. Rising temperature will increase soil evaporation and result in a decrease in the growth and yield of winter crops. Increasing extreme temperatures will cause heat waves, discomfort, reduction in working hours, and increase in pests. Rising temperatures also have direct impacts on human health and well being. Higher temperatures in the monsoon will create an environment favorable to spread of infectious diseases. Decreasing annual and seasonal rainfalls will have direct impact on surface and groundwater availability, soil moisture and groundwater recharge, affecting agricultural production, domestic water supply and irrigation. Increasing rainfalls will be beneficial for aman crop and flushing of soil salinity, but may have adverse impact on soil drainage and rainfall flooding (Khan et al, 2013)

Peri-urban residents perceive climatic trends and variability in timeline and seasonality. Most people can relate these changes with the onset and offset of monsoon, water bodies and springs, groundwater level, crop yield, fog and frost, pest attacks, heat waves, and work stress. These perceptions are in general agreement with the impacts and implications inferred from the secondary data analysis.

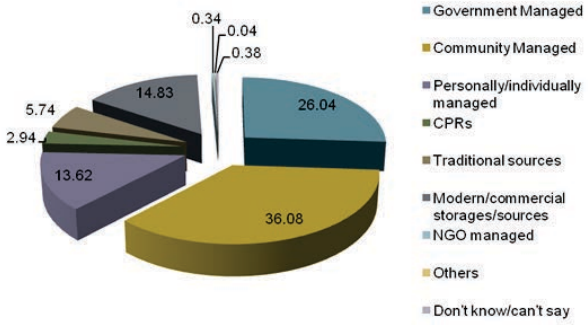
Social differentiation and water in peri urban areas

The research collected qualitative information and conducted a systematic quantitative gender- disaggregated survey in all the project locations. 2650 respondents from 1325 households were interviewed based on a common questionnaire. The research location and gender disaggregated samples are as follows:

Research locations	Males	Females	Total Respondents
Gurgaon	285	285	570
Hyderabad	333	333	666
Kathmandu	582	582	1164
Khulna	125	125	250
Total	**1325**	**1325**	**2650**

Understanding how people in the villages source water is an important step to know how water supply is being managed and has a strong policy linkage for the management of water in the region. A large portion of water is managed by the community themselves (36%) in all the four research locations while about one fourth of the people are served by government managed water supply. About 13 percent people manage water on their own and about 15 percent are dependent on the commercial sources of water supply.

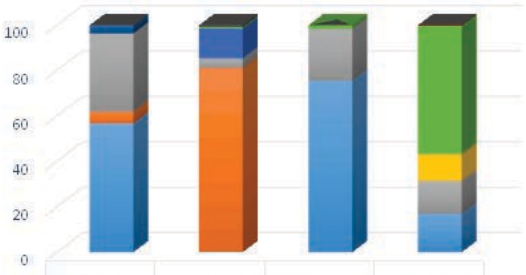
Percentage Distribution of Primary Sources of Water for Drinking in South Asia



Source: IDRC-SaciWATERs Primary Survey, 2012

A research site disaggregated analysis shows that in Khulna (Bangladesh), about half of water supply is managed by the government while about one third of the population manage water on their own through tube-wells and hand-pumps. In Gurgaon (India), people are dependent on government managed water supply system while in Hyderabad (India), there is a shift to obtained water from modern reverse osmosis (RO) plants for a large majority of people .

Primary source of drinking water in four research locations, 2012



	Khulna	Kathmandu	Gurgaon	Hyderabad
Don't know/can't say	0	0.9	0	0
Others	0	0	0	0.2
NGO managed	3.6	0	0	0
Modern/commercial storages/sources	0	0.6	1.6	56.6
Traditional sources	0	13.1	0	0
CPRs	0	0	0	11.7
Personally/individually managed	34.4	4.1	22.8	14.5
Community Managed	5.2	81	0	0
Government Managed	56.8	0.3	75.6	17

Source: IDRC-SaciWATERs Primary Survey, 2012

The research investigated the relationship between the total income of the household and the primary sources of drinking water and whether there are any significant differences between the means (household income) of three or more independent unrelated groups (primary sources of drinking water in this case). This analysis revealed a significant value that shows that income is the defining factor for difference in the primary source of drinking in all the four research locations. Household's whose primary drinking water source is government managed have a significantly lower household income as compared to those who use community managed sources. Further, an analysis was done to check if primary sources of drinking water have gender dimensions. The chi-square value was found to be insignificant which means that the primary source of water for drinking remains the same irrespective of the gender of the respondent. However, the results may vary for other aspects and for the individual sites which is under process. This result may also be due to the fact that while fetching water is largely a woman's responsibility in all the four locations, men

are also involved. This could be attributed to the fact that with increasing water scarcity challenges to access water also increases, hence the involvement of the men folk.

How are communities coping and adapting?

This research explored a wide range of adaptive strategies employed by periurban residents in the four research locations due to water insecurity created by urbanization and climate change. Broadly, in studying these adaptation strategies, it was observed that both planned adaptation (those initiated by the state) and autonomous (those devised by water users themselves) strategies are in place. The autonomous strategies are further distinguished between those that are predominantly technological (involving the use of new technologies to access, store, or distribute water), institutional (involving new forms of water allocation and distribution, the evolution of new norms for water sharing, collective efforts to tap water or access to water markets) and those that involve changes in livelihoods or life-styles (such as changes in water use practices, cropping patterns or choices, settlement patterns or migration).

In **Khulna, Bangladesh,** several biophysical and socio-economic stressors (climate change, sea level rise, salinity intrusion, cyclone and storm surge, coastal flooding water logging, high population pressure, structural intervention, institutional conflicts, urbanization and water pollution) shape the water related vulnerabilities of the coastal communities. The Khulna Water Supply and Sewerage Authority (Khulna-WASA) is responsible for providing water and sanitation facilities in Khulna city. However, at present Khulna-WASA provides only 30 percent household coverage through pipe networks and rest of them are managing their water supply through personal or community based deep tubewells. Khulna city also suffers from urban flooding and water logging which is exacerbated by increased rainfall and rising sea levels. To adapt to this situation, Khulna City Corporation (KCC) and WASA have been working for developing climate resilient infrastructures such as climate resilient urban drainage facilities, implementation of building code, protection of the surface water bodies (rivers, khals and canals). Khulna-WASA took initiative to transport water from the peri-urban areas through pipe network to increase supply but this plan did not succeed due to protest from the peri-urban people. To meet the city's demand, Khulna WASA is implementing a big water project (US$ 361 million) to transport water from the Modhumoti River which is approximate 40 km away from the KCC. However, this project may not be successful, as salinity level of the Modhumoti river water is already increasing than the expected level. Due to acute problem of water supply people are installing deep tube-wells. Local people are in favour of using pond water both for drinking, household needs and for other uses, but finding a suitable pond in a peri-urban area is very difficult.

BUET, Bangladesh


Rohan Dhawan

In **Gurgaon, India,** the research has demonstrated that water resources are under stress from climate variability as well as growing and competing pressures from urban uses in the peri-urban locations. As water tables have fallen, a wide range of adaptive responses are noted in response to local agro-ecological and institutional contexts. Technological responses include a switch in water extraction technologies to dig deeper and the adoption of sprinklers to economise on the use of scarce water. Water extraction technologies have changed from manually or animal operated rainths and lao chedas to tubewells and submersible pump-sets to dig deeper into the aquifers. In villages like Sadhraana, farmers have switched to submersible pump-sets over the last 7-8 years. 7hp pump-sets are common. Another technological response is the use of sprinkler irrigation sets, seen very commonly in Sultanpur as well as in Sadhraana. Sprinklers are found to be an adaptive strategy especially when the land is undulating and soils are sandy making flood irrigation difficult to pursue. The use of sprinklers enables farmers to apply water closer to the crops; besides, it also economizes the use of scarce labour; with occupational diversification, farmers spend lesser time on the fields and to that effect automated irrigation technologies are a superior alternative to manual irrigation. In Jhanjhrola Khera, on the other hand, where there is greater salinity, sprinklers are not used as providing water that close to the crops can prove harmful. Thus, it has been noticed how the choice of adaptive strategies is shaped by local agro-ecological contexts. For the elite, acquiring a private submersible on their own plot of land is a way of improving water security.

In **Hyderabad, India,** the nature of water insecurity arises from urbanisation coupled with erratic rains as experienced by the communities living in the peri-urban areas. The adaptive strategies for farmers have been shifting their cropping patterns from rice to vegetables and fruits. Instead of three

Anjal Prakash

rice crops, the farmers now restrict themselves to growing only two crops of rice and during the other seasons, they grow vegetables. Many have shifted largely towards growing of fruits like papayas and guavas, which are grown using sprinkler irrigation, which uses less water, as has been adopted by several farmers in peri-urban Hyderabad. Those farmers, who are not able to afford a separate bore for themselves, usually grow rice only during the monsoons and during the remaining months, grow vegetables using wastewater from the urban areas,. Some also leave their lands fallow and work in the factories or in the city to adapt to a loss of livelihood for a certain period of the year. Another adaptation strategy has been to dig deeper bore-wells to satisfy the need for water in agriculture. At the household level, water insecurity largely arises from technical issues in the public water supply system and certain malpractices like water thefts or excessive use by certain households, location of households in an elevated terrain or a rear part of the village, which leads to a good number of households, irrespective of caste to remain water insecure as compared to the remaining village. In such situations, people actually move to a secondary source of water, purchase water from tankers and local shops and RO plants, depend on neighbours, travel longer distances to fetch water. Those who can afford, install personal pump-sets to draw water from the ground or a few households may pool in their resources to install a bore to draw water, which when used by other households often result in conflict, over who owns the pump and therefore the water.

In **Kathmandu, Nepal,** several interesting adaptive responses were observed, especially among women who have devised innovative ways of allocating water in the face of scarcity. Institutional responses vary from devising systems of water rationing , collectively deciding on number and size of buckets for collecting water to commuting together to fetch water – a task in which men share in the domestic responsibilities of water collection. Women have evolved institutional systems of rationing water. In order to avoid conflict, they have started a system of rotational water collection - of sequencing the households as they collect water. This is based on mutual understanding and consent. There are taps with a sequencing system practiced for over 30 years. There are stand posts conducting rotations in daily, weekly, monthly or even annual basis. This system has helped maintain local social bonds and prevent water conflicts. With the new Dovan Water Supply scheme


Rajesh Sada

however, the load on the stand-posts has reduced and the sequencing system has discontinued in many stand-posts. Dugwells are a major source of water but where groundwater is poor in quality; the households rely on water sources of their neighbors. Fetching water from spring sources at neighboring VDCs is common. Several households unite to reserve a vehicle and carry many water vessels filled with water for days or even weeks in a single trip. Tankers supplying water from neighboring VDCs are common during dry season and in the monsoons when water supply pipes are destroyed by land-slides. Households buy water at the rate of NPR 5 per gagri (approximately 15 litres). An important observation is that on account of proximity to the city, there are a large number of tenants who face discrimination in accessing water, as they get a chance to collect water only after the owners have collected it. They must wait for a long time before they get a chance to fill a bucket or arrange water from water tankers.

Building adaptive capacities of the people and awareness campaigns

The question is that why do some community-based adaptive strategies perform better than others? The answer may lie in developing institutional design principles to address collective choice situations. The research team's effort to enhance community-based management performance also requires an analysis of exogenous and endogenous variables that influence how social actors not only act collectively but do so in ways that respond to changing circumstances, foster learning, and build capacity for management adaptation. In this section outlines some of the initiatives that have been taken under the project to build adaptive capacities of the communities towards addressing the continuum of urbanization, water insecurity and climate variability.

In **Khulna, Bangladesh,** the focus was to see adaptive capacity from a socio-technical perspective. On technical side, advocacy is being done for management of water so that


BUET Bangladesh

Students participating in a rally for creating awareness for source conservation of River Moyur which is the source of drinking water supply in Khulna City Bangladesh

salinity ingress is less in the areas where agriculture is prevalent. Development of strong public forum to raise public voice regarding the water related vulnerabilities of the peri-urban communities is need of the hour which the present project is trying to do. Development of multi-stakeholders' platform for conservation of natural water bodies such as rivers, canals, khals, ponds and wetlands are important and these issues are discussed in the stakeholders meetings. Capacity building of local people through community based adaptation technique and innovation in agriculture is the need of the hour. The project has taken up a campaign called – Save Moyur River which is trying to create a citizen's platform for raising concerns over the process in which development is affecting the poor and the urbanisation and consequent environmental problems are creating externalities for people living in peri-urban areas.

Dialogue with PHED officials

Sreoshi Singh

In **Gurgaon, India,** the research team focussed mainly on two components of coping capacity. First, developing human capital in terms of enhancing livelihood skills. This has been accomplished by imparting the peri-urban residents' livelihood skills to facilitate occupational diversification in the face of land acquisition and climate variability. Uncertain rainfall patterns on one hand and land acquisition on the other, erodes the bases of a livelihood. Thus alternative livelihood skills can build resilience. This has been accomplished through vocational training with the GMR group. The second component has been targeting building and strengthening local social capital in terms of providing voice to peri-urban residents by getting them into direct dialogue with service providers. Climate change or no climate change, getting service providers responsive to water users, breaking the distrust between the two and providing a forum especially to the underprivileged to express their concerns about service delivery is essential. This has been accomplished through a series of stakeholders meetings between water users and service providers and follow-up with the latter by the members of the team.

In **Hyderabad, India,** the strategy has been to work with both the communities as well as relevant government departments. Intense community meetings were organised in two intervening peri-urban villages. In one location, the water and sanitation committee was successfully formed which has taken a pledge to work on the water inequity in the village. Capacity building activities in the project has attempted to orient government officials of the relevant government departments towards identifying the peri-urban as a critical zone. Apart from this how climatic variability would further lead to water insecurities and degradation of natural resources, is also something that is being

attempted, through training and orientation. For the communities, awareness programmes on climatic variability and the need to manage groundwater for secured agriculture were taken up. Apart from this, training of the communities on cost effective methods to increase productivity and uptake the right choice of crops to improve soil moisture, ways of constructing rainwater harvesting systems, simple sand filters etc has been undertaken. This will help to recharge groundwater and build resilience of the communities against climatic variability.

In **Kathmandu, Nepal,** the team has been continuously facilitating, building the resilience and enhancing the adaptive capacity of the people in the intervention village. Regular stakeholders' meetings, capacity building programmes and engagements with the government are being undertaken to improve the existing situation. Apart from this, number of training workshops were taken up for imparting information on roof top rain water harvesting that created awareness and its application. This has drawn interest of the local people to practice household level rain water harvesting. Several campaigns were organised in coordination with local communities. to create awareness among the local people of upstream reach for not polluting the Godawari river. This is because river is the main source of drinking water to the downstream residents. This campaign has also been able to successfully sensitize the local people to act towards the conservation of the Godawari river.

Campaign for river source conservation in peri urban Kathmandu

Project Outputs and Outcomes

The project had achieved considerable outputs that borders on gathering scientific information and knowledge on the issue of peri-urbanisation, water security and climate change impacts. It has engaged with a wide variety of stakeholders including affected community, policy makers, academicians, researchers and students. Some of the outputs are written below:

a. 16 Journal articles

b. 14 Discussion papers

c. 31 internship reports

d. 27 reports of various workshops

e. 11 reports of micro activities done at field level

f. 5 documentaries and extensive photo documentation of the project activities

g. 7 media reports in major newspapers

h. 4 policy briefs published and disseminated

i. 8 Representations of research consortium members in major workshops

The details of these outputs are submitted separately and can be sourced at the website www.saciwaters.org/periurban.

The outcome of the three year long project was envisaged in terms of influencing the institutional and policy processes through scientific research and innovations, building capacities of network members in water and climate research, enhancing the adaptive capacities of the affected community and their institutions, especially of the disadvantaged and marginalized.

This research has been path breaking in more than one way. It has established the evidence of the peri urbanisation process affecting desired development outcomes due to unplanned development and at the cost of precious environmental resources in south Asia. 14 key research papers in referred journal (out of this 4 papers have already been published in journal with high impact factor) is a key outcome that shows that the scientific knowledge generated from this project has been accepted widely in the academic and policy circles. A book manuscript has been submitted as an outcome of this project to Oxford University Press. There has been more than 5000 people who have visited and downloaded our research discussion papers from the website www.saciwaters.org/periurban different parts of the world. This project therefore scientifically linked, peri-urbanisation, water security and climate issues which is rather rare in academic and policy circles.

This project also mobilised vast pool of young researchers, academicians, policy makers and affected communities to understand the trajectory of development better. 31 young students did internship in 3 years of the project. Three research associates got through PhD positions abroad which shows how their research capacities were built during the project. This research group won two new research projects funded by DFID and Netherlands Organisation for Scientific Research on periurban process in south Asia which is a mark to show more acceptability of the topic of research amongst international community.

At the community level, this project has tried to address water insecurity issues. It started with systematic understanding of

the factors and processes leading to water insecurities and integrating them into awareness and capacity building and advocacy at the local and policy levels. In Khulna, the campaign around saving Moyur River picked up momentum. The Moyur is the only freshwater river in Khulna. However, this river has been dying due to encroachment and solid waste disposal. The campaign has created a platform where all stakeholders are able to meet and discuss various options to ensure water security for the people of the city of Khulna. Based on certain hard scientific facts, the group is taking the shape of a large campaign for building awareness around water and climate issues. In Gurgaon, a major impact of the project has been an improved communication between water users and service providers. It was very satisfying to see how representatives could raise water issues from their respective villages, listen patiently to what the PHED officials had to say, reach a level of mutual trust and understanding and then move on to discussing the next issue. This was the rationale behind improving the communication between water users and service providers, so that with time, they develop a relationship beyond that of a blame game, and move towards solutions. In Hyderabad, the team has been able to align with a city based platform called "Save Our Urban Lakes" (SOUL-www.soulhyd.org) for saving water bodies of Hyderabad. The degradation of all varieties of water bodies in the city of Hyderabad has been going on at an accelerated pace since sharp growth of the city in recent decades. The project has been able to align with SOUL network through research and advocacy support which has helped in revitalizing the urban water spaces in Hyderabad. In Kathmandu, there is an increased appreciation and motivation on part of the people to seek local solution to the problems emerging from water insecurity. This motivation is demonstrated by active participation of the people in the stakeholders' meeting and workshops organized under the project and conviction among them in approaching appropriate solution.

Overall assessment and recommendations

Overall the research team associated with this project feels satisfied with the outputs and outcomes of this project. The team has stretched itself to achieve results that were beyond its imagination. It has also strengthened the south Asian team and their capabilities to do development research especially in the area of climate analysis. There has been lots of influence between researchers of this consortia that had individual capacities for social research as well as climate related research. After the project completion, the group feels that the natural scientists have learnt social acumen while the social scientists have started appreciating the need for hard core scientific research for developmental outcomes. This has resulted in appreciation and pooling of disciplines for a better developmental understanding and outcomes. The project team was actively engaged in local level policy influencing work which has been an added skill and helped the team to understand the context in which development researches needed to be placed. The different approaches for collecting data and analysis has also built the internal capacities of each of the team members.

In this project, the team has placed emphasis for action in all the four locations. The action programmes are confined to capacity building, stakeholders' dialogue, community initiatives and campaigns. These processes are slower than direct implementation projects. It has been observed that the community wants quick results without much of action and expects the team working to solve their problems through large scale interventions. Though the team has been constantly informing the communities about the objectives of the project, there seems to be a dilemma of matching community's expectation with limited resource and time allocation in the present project. The team feels that this project could be extended to test the adaptation response that has come out of each of the four study locations. This would go a long way in institutionalising this at a community level which will help communities in building up a planned adaptation program and build resilience to cope with the externalities of climate change and water insecurities.

References

Adger Neil W. 2006. 'Vulnerability' Global Environmental Change, 6: 268-281.

Dekens, J and Eriksson, M 2009. Adapting to Climate-induced hazards in the Hindu Kush-Himalayas In Water Storage: a strategy for climate change adaptation in the Himalayas. Sustainable Mountain Development. No. 56 Winter 2009, pp. 34-37.

Intergovernmental Panel on Climate Change (IPCC). 2007. Climate Change 2007: The physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press.

Khan, Shah Alam M, M Shahjahan Mondal, Rajesh Sada, Shaili Gummadilli. 2013. Climatic trends and variability in South Asia: A case of four peri-urban locations. Hyderabad. SaciWATERs and IDRC.

Miller, A Kathleen, Steven L. Rhodes and Lawrence J. Macdonnell. 1997. Water Allocation in a Changing Climate: Institutions And Adaptation. Climate Change. Volume 35, Issue 2, pp 157-177

Mukhopadhyay, Partha and Aromar Revi. 2009 Keeping India's Economic Engine Going: Climate Change and the Urbanisation Question. Economic and Political Weekly. vol xliv no 31. August 1. Pp- 59-70.

Mustafa, A, Ahmed, S Saroch E, and the Risk to Resilience Study Team, 2008. Pinning down Vulnerability: From narratives to numbers, From Risk to Resilience Working Paper No 2, eds. Moench, M Caspari , E and A. Pokhrel, ISET, ISET-Nepal and ProVention, Kathmandu, Nepal, 28 pp.

Narain, V. 2010. 'Peri-urban water security in a context of urbanization and climate change: A review of concepts and relationships', Peri Urban Water Security Discussion Paper Series, Paper No. 1, SaciWATERs.

OECD 2009. Cities, Climate Change and Multilevel Governance. Environment Working Papers, OECD, Paris.

OECD 2008. Competitive Cities and Climate Change: OECD Conference Proceedings, Milan, Italy, October 9-10, 2008, OECD, Paris.

Prakash, A., Singh, S., 2012. 'Gendered and Caste Spaces in Household Water Use: A Case of Aliabad Village in Peri-urban Hyderabad, India', Peri Urban Water Security Discussion Paper Series, Paper No. 5, SaciWATERs.

Stern, Nicholas. 2007.The Economics of Climate Change- The Stern Review. Cambridge: Cambridge University Press, p 692.

ISET. Undated. Moving from Concepts to Practice: A process and methodology summary for identifying effective avenues for risk management under changing climatic conditions. CBA study team. Institute of Social and Economic Transition. Colorado. USA. Unpublished document.

Appendix: Questions for CCW-supported project teams

Water quality/availability, adaptive capacity, and risk

1. Within the scope of your project activities, have there been improvements in the quality and/or availability of water, especially for vulnerable communities? Have risks or the awareness of the risks associated with climate change (e.g. flooding, drought, sea-level rise, storms, etc.) been understood or reduced? If so, please describe how.

This project has been making an effort to bring changes on the ground, at least in a small way, whereby the resilience of communities could be improved. This would enable them to adapt to changing climate in the long run apart from the impact of urbanization, which has affected their water access.

In Hyderabad, an intervention during the latter part of the project action phase (in the yadav basti of the Raviryala village) were to undertake organized disposal of garbage and segregate waste and protect individual household water storage areas from getting contaminated. These are examples of how the Village Water Sanitation Committee has been effective in improving the quality and quantity of water received by the peri-urban households through improved management. Their interest to take this forward in other colonies and involving women in this effort will be very effective for improving the water security of the larger community.

In Gurgaon, this was done through a long process of engagement and capacity-building in which water users were brought face to face into dialogue with service providers. This led to some effort at improving both the quality and quantity of water supply in villages Jhanjhrola Khera and Sultanpur. The cement pipes were replaced by the D.I. (ductile iron) pipes; this reduced the possibility of pilferage and leakage and improved access to water for those at the tail-end of the system. What is perhaps a more important accomplishment of the action research in Gurgaon is that the team has built a capacity of the water users to ask for better service delivery and so the change is much beyond the physical augmentation.

In Kathmandu, evolution of an institutional effort at the local level for planning and management of water resources has been a major achievement towards improving access to water for peri-urban residents. Lubhu Drinking Water Supply and Sanitation Committee constituted during the project have been instrumental in exploring technological and financial assistance for the development of filtration system for the Dovan River. This is the most reliable water source in the VDC both for domestic and irrigation uses at Lubhu. Following the Dovan River source conservation campaign organized in coordination with Lubhu Drinking Water and Sanitation Users Committee the local people have been sensitized on the negative impacts of river degradation and to maintain the river ecology. Through the committee, water access to around 400 households of the VDC has been improved.

In Khulna, it was evident from that water security (presently highly dependent on groundwater) would largely improve if water pollution in the Mayur river could be mitigated. Several ways and means to improve surface water quality, identified through community consultations and

supported by short-term scientific studies, and embedded in the interdisciplinary research framework, appeared to be feasible. The short-term studies, conducted to facilitate stakeholder engagement in improving water security, ranged from clarification of the problems (e.g. characterisation of wastewater, pollution load in the Mayur river, peri-urban water use conflict, ground water quality for drinking, impact of development projects on water security, farmers' attitude towards compost generated from solid waste, etc.) to the possible solutions (e.g. requirement of effluent treatment plants (ETPs), performance of duckweed-based wastewater treatment system, etc.). Studies were also conducted to explore the scope for revival of the Mayur River in ensuring water security (e.g. geomorphic changes of the Mayur; water, sediment and soil quality of the Mayur; regulatory protection of the river; valuation of the costs and benefits of Mayur river revival, etc.).

Overall, the teams also had better clarity on impact of climate change and how it affects lives and livelihoods of people. Within the team, there is greater awareness of the impact of climate change, especially as one of the stressors on peri-urban water security. This has been made possible through a three-pronged approach: analysis and review of the secondary literature on climate change, analysis of the climatological data and engagement with the communities to understand their lived experience of climate change. An important learning is that both positivist and interpretive approaches have a role in understanding climate change. There is immense value in using multiple sources of data as a means of triangulation to understand aspects of climate change and variability. The major challenges faced were in accessing secondary data for Gurgaon and Hyderabad, because of the lack of data in a form that could bring out the accurate understanding. For Kathmandu and Khulna, analysis if hydrological and meteorological data has been done in greater details, with elaborate interpretations.

2. Has the project put in place strategies for building adaptive capacity of people and institutions? Have you observed a measurable change in the adaptive capacity of the communities or institutions associated with your project? Please describe.(Note: Building adaptive capacity implies that the project has improved the ability of people, through access to resources, such as financial, human, social and natural capital, to modify practices to cope with and manage the negative impacts of climate change.)

A conscious effort was made to build the capacity of both water users and service providers through a wide range of capacity-building workshops, training programmes and stakeholder dialogues. In this project, a series of capacity-building workshops were organised. The general strategy adopted and followed throughout the project was awareness building through generation and dissemination of knowledge with mobilisation of necessary action and advocacy inputs at appropriate levels. The programs included several short-term training programs, rally, dissemination workshops, stakeholder consultations, etc., targeting a wide range of stakeholders.

The purpose of capacity building workshops in Gurgaon was to build the water users' ability to reflect collectively on water management problems, encourage them to ask for change and secure better responsiveness of service providers. Separate capacity-building workshops were targeted towards the officials of the PHED and state agencies, with an intention to sensitize them to water management challenges and to seek their support and

involvement in our work. Apart from this, visual media was another approach that was taken in the project involving water users and communities in the preparation of videos and films. Three videos were shot during the project, interviewing different stakeholders and capturing their perspectives. One of these was a participatory video exercise. This was directed, scripted and filmed by the women of Jhanjhrola Khera. Six village youth were trained by the GMR Varalakshmi Center for Livelihood and Empowerment. In Nepal, such workshops involved training in roof catchment rainwater harvesting system at nec for the local community of Lubhu. The training reflected upon the possibilities of rainwater harvesting as potential household level solution to water scarcity. Training on preparation and application of compost fertilizer at household level was organized to reduce the vulnerability of farming communities to the combined implications of climate change and increasing urbanization at peri-urban interface of Kathmandu. Exposure visits were organised in Hyderabad and Kathmandu, wherein communities in the former location were exposed to the watershed management systems and how it could help in rejuvenating the water table, while in the latter, the communities were exposed to the technology of water treatment plants aimed to strengthen the institutional capacity of the communities in Lubhu VDC. Training in Hyderabad has also involved women from self help groups to be trained on health issues related to water and how to protect the water storage systems within the home from contamination. The yadav households in Raviryala village have also been trained on methods to segregate their wastes in a systematic manner, without contaminating other water sources and keeping the colony clean. In Bangladesh, the engagement of the city Mayor in the research and action was planned right from the beginning of the research. The research objectives were fine-tuned to match with the current priorities of the city government so that the Mayor could be involved in the process without any conflict of interest. This strategy proved to be very successful at the later stages of the research when a campaign called 'Save the Mayur' was mobilised based on a general consensus of the urban and peri-urban stakeholders and also vetted by the city Mayor. The project extended its support to Environmental Science department of Khulna University by providing equipment (i.e. computer and laboratory instruments), academic research support to undergraduate and graduate students (12 students completed their BSc/MSc thesis based on our research support), and faculty members for conducting different short-term studies. Support was also provided to Khulna University for local level seminar, research presentation, rally on 'Environment Day', etc. Such assistance had improved the in-house research capacity of the department in conducting independent research. Moreover, support was extended in providing field research exposure to several undergraduate students of Asa University. Researchers, specially the research fellow and research assistants, had exposures in writing for peer reviewed journals and conferences, online blogs, etc. They also attended several national and international training programmes and the research fellow presented at the World Water Week in Sweden under the project support.

3. Has the project identified barriers that are impeding the uptake of existing technologies and strategies for improving water resources management? If so, please describe these barriers.

Executing the project activities was challenging initially in absence of locally

elected representatives and the logistics demanded by the local people. These have been successfully solved through regular interactions on project objectives, scopes and limitations and involvement of local water resource committee. Increasing appreciation of the project among the people has been demonstrated by active participation of the people in the programs organized under the project. In certain cases, like in Hyderabad, Gurgaon and Kathmandu, there was expectation from the communities from this project that some form of direct intervention through technological means would be available, but through continuous engagement and discussions, the basic premise in the intervention strategy towards building capacities of individuals/communities was conveyed. The idea was also to steer away from technical or social engineering quick fixes. In Gurgaon, for example, a forum for dialogue between water users and service providers paved the way for technical interventions (replacing the cement pipes by the DI pipes). The learning is that institutional change may be needed prior to technical improvements in water supply. In Kathmandu, executing the project activities was challenging initially in absence of locally elected representatives due to the logistics demanded by the local people. These have been successfully solved through regular interactions on project objectives, scopes and limitations and involvement of local water resource committee. Increasing appreciation of the project among the people has been demonstrated by active participation of the people in the programs organized under the project. In Bangladesh, the major challenge faced by the researchers was to facilitate formation of a multi-stakeholder platform to bring together the peri-urban communities, urban/peri-urban actors, service providers, policy makers and all parties concerned in one common stand for improved water security. Diverse interests of the stakeholders, overlapping and conflicting jurisdictions of service providers, etc., often created barrier in accomplishing project goals. However, these obstacles were overcome, at least partly, by conveying the common good for all through ensuring water security. Political instability was another obstacle causing delay in completing several project activities, specially the end-project activities, in time.

Climate change adaptation research methods

1. Did researchers involved in the project apply relevant research methods (e.g. economic analysis, social vulnerability assessment, gender analysis, hydrological and climate modeling, etc.) to improve water management in the context of climate change? Which methods were particularly valuable or innovative?

Based on the project objectives and the varied capacities of the different teams, different methodologies have been used, but in most cases, a mixed use of qualitative and quantitative techniques were used, with special emphasis on certain economic methods and modelling exercises depending on special capacities and field context. In Gurgaon, qualitative analysis of the factors shaping the differential vulnerabilities of communities was undertaken. We found it useful to take an ethnographic approach to assessing vulnerability, as it brings out the social embeddedness of vulnerability. Understanding vulnerability requires an appreciation of the intersection of the multiple roles and identities of gender, caste and class that shape vulnerability. Thus the approach to vulnerability assessment adopted in Gurgaon was, through an ethnographic approach, to understand the intersection of different factors that shape

water users differential vulnerabilities.

Although the other teams have also used these qualitative methods through PRAs, modelling on hydro-meteorological data has also been used, apart from developing other indices like the LVI by the Nepal team. Livelihood Vulnerability Index (LVI) was assessed based sustainable livelihood framework developed by DFID and compared using an alternative method of calculating vulnerability index for the confirmation. LVI was calculated using forty one different indicators developed from eleven different components derived from five capitals of DFID sustainable livelihood framework. These were developed based on the literature reviewed and availability of the data collected during household survey. Similarly, the Hyderabad team has done a Vulnerability and Capacity index to understand vulnerability of specific communities in the four peri-urban sites. In Nepal hydro-meteorological data (daily temperature and rainfall data) for seven stations within the valley selected considering their proximity to research sites were collected from Department of Hydrology and Meteorology (DHM) and analyzed for understanding the long term trend, extreme events and anomalies. The analysis has been carried out in greater details for the peri-urban sites in Nepal unlike Gurgaon and Hyderabad, due to lack of sufficient data for the latter.

This research employed a mixed methods approach, utilising both qualitative and quantitative methods. In analysing the aspects of climate change and variability, linear trends in hydro-climatic variables were assessed using secondary data and following standard statistical techniques. Such analysis revealed evidences of climate change in the meteorological variables in the Khulna region. Perceptions of local people in peri-urban Khulna on climatic trends and variability, and their impacts were investigated through conducting a gender segregated semi-structured household survey and employing a number of participatory research tools. This baseline household survey also covered a wide range of issues including demography, socio-economic condition, water related vulnerabilities, urbanisation impacts and climate change implications, in the three selected peri-urban sites of Khulna. A semi-structured interviewing approach was followed so that answers could be analysed by means of statistics in order to identify significant patterns among people and places. In order to explore the difference in responses between male and female, a gender segregated household survey was administered through interviewing a male and a female from the same household. Qualitative information collected by employing participatory research techniques served as the initial step in identifying the relevant issues requiring further investigation and devising the final questionnaire. The study was important in depicting the differential impacts of urbanisation and climate change on water use and access at household level distinguished by socio-economic and other factors.

The short-term studies conducted under the support of this project utilised a wide range of tools and techniques using both primary and secondary data. Standard guidelines were followed in collecting and assessing the samples for water quality analysis. For spatial analysis needed in several studies remote sensing and geographic information system (RS & GIS) techniques were of great use. Physical modeling was exercised and economic evaluation was made in demonstrating efficacy of certain adaptation measures. Projections of future population, water demand, land use categories, etc.,

were made following standard procedures. These studies, conducted by the students of Khulna University, provided hands on training and real life exposures of water and environmental issues not only to the students but also to the faculty members supervising the student researches.

In addition, a number of participatory research techniques and tools were used. A series of consultation meetings were held with the local service providers, NGOs and civil society groups to understand the existing environmental problems in the peri-urban areas and to contextualise those with the climate change issues. These were followed by a series of focus group discussions with the peri-urban communities. A number of interviews were held with different key informants. Several case studies were also conducted with the climate migrants in the urban and peri-urban areas. In general, the participatory research orientation helped the researchers to identify the opportunities and constraints to improved water access for the vulnerable groups. This approach effectively resulted in a value beyond the research insights and helped the team in strong rapport building with the stakeholders, and was of a great support in the action and advocacy components.

In all the research sites, both positivist and interpretive approaches were used to understand gender. To overcome the lack of gender segregated data, a structured household survey was administered to men and women separately in each household. At the same time, direct observation and ethnographic work helped understand the transformation of gender relations around water with the onset of the processes of urbanization. Thus the innovativeness and usefulness lay in combining both qualitative and quantitative approaches to understand gender relations.

2. Were researchers involved in the project (including students) trained to use relevant methods (such as those mentioned in question #4) to conduct their research? How did they apply these methods?

The young researchers on the team acquired a wide range of exposure and training in research methods including PRAs, ethnographic research, SPSS and analysis of climatological data. This served on the one hand to enhance their capacity and research skills and on the other was a big support to the project in terms of the analysis and synthesis of the data. Some of the team members also attended other training programmes organised by Cap-Net. In Hyderabad, several students from Universities in India and abroad were engaged in studying the private water tanker market and its implication for water security. Since most of them were from varied backgrounds, they were introduced to the basics of ethnographic research, snowball sampling etc. These helped them in the field to bring out the relevant information about the politics of the water market in a specific location of peri-urban Hyderabad and how the qualitative data could be interpreted to explain water security/insecurity.

Engagement of research users and policy influence

1. How did researchers work with policy makers in the project? What worked well, and what challenges did the team encounter?

The engagement with policy makers were undertaken in this project at different levels through different means depending on the context. The levels at which this was undertaken was either at the administrative levels functioning on the ground, or at the level of relevant government departments. The different ways in which these were done

included discussions in forums, bringing them for local level meetings to illustrated the problems and its implications, and through documents, like policy briefs (from all four sites, highlighting on some of the key issues around water insecurity and adaptation). In India, a consultation paper was contributed by the Hyderabad and Gurgaon teams for development of the 12th Five year Plan. In Gurgaon, a visit of 24 mid-career civil servants was organized to Sultanpur Village, to expose them to what peri-urban was all about. They also attended a meeting in which local residents were present and voiced their grievances, giving them a forum to express their anger and resentment. The Public Policy Programme participants came back with a good exposure to public policy challenges in dealing with peri-urban issues.

In Hyderabad, presentations on the issues at the peri-urban research sites, generated concern in the minds of the Urban Development Minister, who promised to save the water bodies in the peri-urban areas. While policy makers at one point of time, hardly managed to recognise the peri-urban, our efforts at various forums to express the uniqueness and therefore the complexity of this terrain has made them think deeper while planning any form of development activities in such zone. In Kathmandu, day long dialogue with people from different backgrounds has been successful to draw attention of Government of Nepal (GoN), water sector agencies and water professionals to regulate groundwater use and improving the institutional arrangements for implementation of Groundwater Management Policy 2011. In Khulna, Stakeholders' active engagement was an essential element of this research. Periodic sharing of the research findings with stakeholders generated a knowledge base regarding water management issues in Khulna. Stakeholders included policy makers, civil society and community representatives. Knowledge sharing meetings were also organized separately with government organizations like Bangladesh Water Development Board (BWDB), Khulna Water Supply and Sewerage Authority (KWASA), Khulna Development Authority (KDA), Department of Environment (DoE), and local government bodies like Khulna City Corporation (KCC). Particularly, participation and support of the KCC Mayor throughout the process was pivotal for implementation of this action research. Throughout the project, the research objectives, and the relevance and importance of improving water security for the peri-urban communities were discussed with the City Mayor and other policy makers. Information gathered through these interactions was considered seriously while designing and conducting this action research and advocacy to understand the scope, limitations and opportunities of generating relevant and effective options towards 'Khulna Water security'. Through these processes of sharing the research findings with all levels of stakeholders, generation of mass opinion was facilitated towards putting the research findings into action to address water insecurity issues. Subsequently, our scientific work and sharing of research findings as well as discussions and dialogues with stakeholders at all levels generated different feasible options for revival of the Mayur River as a resource shared by the urban and peri-urban communities.

The participatory approaches used in the engagement with the state agencies, which were generally insensitive to peri-urban problems, was successful in building their ownership of our action research, and in

including peri-urban issues in urban planning. The approach was also successful because the action design was congruent with the present interests and priorities of state agencies. For example, in Khulna, the City Mayor convened an exclusive meeting of all 52 Councillors and Corporation officials in which the research team presented the research findings along with recommendations to address water crises of Khulna City and its periphery. The Mayor and Councillors appreciated the research findings including the options for revival of the Mayur river as a potential source of fresh water for Khulna city and its peri-urban areas.

2. Did project team members improve their ability to communicate research results to diverse audiences? How?

The project team has devised various ways to communicate their research to a diverse audience. First of all, a combined website for all the project partners were hosted by SaciWATERs with regular update and communication within and outside the groups. The research findings have been communicated through academic reports, discussion papers, journal papers (contributed by all researchers from the project locations), policy briefs, press reports in national dailies, media interviews, radio programmes, documentaries etc. In all the sites, documentary films have been made based on the specific sites and the related issues. Three press-reporting unrevealing the implications of climate change and urbanization on peri-urban water security have been published in national dailies. In Nepal, Interview with Ms. Anushiya Shrestha from the peri-urban research team, on the research objectives and outcomes was broadcasted by Radio Sagarmatha FM 102.4 M.Hz. on a weekly program based on Environment and Climate Change that was aired in collaboration with Kathmandu Municipality. This program was re-broadcasted several times and has been effective in communicating the impact of urbanization and climate change on peri-urban water security; adaptive practices and resulting vulnerability to wide range of stakeholders. At the Nepal National Water Week (NNWW) and World Water Day, the team presented its research results to a larger audience which included Kathmandu Valley Water Supply Management Board (KVWSMB), Water and Energy Commission Secretariat (WECS) and Ministry of Urban Development. The growing exploitation of peri-urban groundwater resources received special space during discussion organized in the second half of the programme. Learning through sharing was instrumental in attaining the overall goal of this action research. A wide range of mediums was used in facilitating a sustained engagement of the project team members with the diverse audiences. Project flyers, policy briefs and study reports were widely disseminated among the local, regional and national stakeholders. Several articles were published or are in the process of publication in peer reviewed journals. Presentations were made at international conferences and feedbacks were incorporated in the course of actions. Other important means of communicating research findings was the newspaper reporting and online blog highlighting the updated project activities. Eventually through the processes of such communication the research team facilitated a dialogue with the leading actors of Khulna to mobilise a multi-stakeholder 'Think Tank' with a notion of advocacy and lobbying for putting the research findings into action, especially to 'Save the Mayur' for water security of the Khulna city area. Such activities resulted in improved capacity of the team to conduct 'research with impacts'.

3. Were any policy options identified through the research? Have any of the policy options developed through the project influenced policy change at the local/regional or national level?

Through the various means that research has been communicated to policy makers, has itself been a means to achieve policy change at the local/regional and National level. In India, a state level project recently undertaken by the Ministry for Rural Development in Andhra Pradesh took into account the delicate nature of the peri-urban landscape during the planning phase, as expressed by a senior bureaucrat in a workshop organised by SaciWATERs in Hyderabad. She emphasized that her exposure at the different forums have given her sufficient means to understand what peri-urban is, a word unknown to her and the larger fraternity of policy makers, even till a few months back. In case of Hyderabad, the research that has fed into the advocacy work uptaken by Save our Urban Lakes (SOUL) has essentially changed the way the legal system now looks at water bodies, allowing for complaints at local police stations, if any signs of encroachments are noticed. This is also a major policy change, which can have longrun implications for legally protecting water bodies from encroachment.

In Nepal, for example, though the Groundwater Management Policy 2011 has been prepared as integrated policy for effective groundwater management, control on the over-extraction of groundwater still remains a question with acute shortage of water and failure of water supply. But the project has been able to set the ball rolling in this direction, through constant engagement with the government agencies. In Bangladesh, the major policy option identified by this research was the recognition of the Mayur river as a potential source of fresh water. It was evident that collective initiatives with relevant institutions such as the KCC, KDA, KWASA, BWDB, DoE, and the district administration were needed for immediate action to revive the river and protect it from any polluting activity. The research activities successfully convinced all concerned parties to arrive at a consensus to bring the research findings into action, especially to 'Save the Mayur'. Realizing the potential of the Mayur in ensuring water security, KCC was convinced to revise its 'Linear Park' project around the Mayur River by conceiving a more integrated one incorporating the water security issues in the project, which was primarily focused only on addressing the encroachment of the river. Together with the City Mayor, the process of formulating a comprehensive plan to save the Mayur is on the way. DoE had expressed its scope of involvement by implementing small scale wastewater treatment plants around the river to reduce pollutant load. BWDB agreed to handover the regulator on Mayur River to the KCC for proper operation and maintenance.

Future research plans

4. Have you or your partners been able to secure additional resources to carry out further research related to adaptation to climate change and/or water resources?

As a result of the engagement with the project, all the junior researchers who joined the Gurgaon project moved on to positions that would allow them to stay engaged with research on the subject. Pranay Ranjan moved on to do a PhD at Ohio State University, the USA. Sumit Vij accepted a position with IRRAD, Institute for Rural Research and Development, Gurgaon and is engaged in a project on Living With Climate Change. Aman Dewan accepted a position with a Ford Foundation Project at MDI, Gurgaon on rural livelihoods. At the time of

writing this report Afke Van der Woude is in the final stages of preparing her Phd proposal on peri-urban water security at Wageningen University, the Netherlands.

The lead researcher of the team continues to stay engaged with SaciWATERs on two new projects around climate change and peri-urban water security (CoCooN research funded by DFID and NWO) and another one on urbanizing deltas (funded again by NWO). In general, the consortium members will continue working together on related subjects. In Hyderabad, several new projects to build a database of the status of water bodies has been undertaken in one of the projects, funded by Earthwatch. The research and action undertaken in the project has generated interest among funders, to undertake further action and implementation work. The US consulate in Hyderabad has provided this platform, which enabled, awareness programmes about saving the lake through a campaign called the "Adopt a Lake". Also, feasibility studies on rejuvenating the lake through specific technologies have also been undertaken and shared with communities for their feedback. Among the students pursuing M.Sc. at nec in Nepal, there has been progressive increase in undertaking of research focussing on different aspects of adaptation to climate change in rural, peri-urban and urban areas of the country. These studies can be supportive to understand the wide array of adaptive practices. In Bangladesh, the research initiated many activities in the urban and peri-urban areas of Khulna. The 'Save the Mayur' campaign has generated interests and impetus for collective actions for reviving the river. There is a need for continued advocacy and awareness-building drives so that the peri-urban interests and water security concerns are included in urban policy making, planning and programme development. This study investigated the feasibility of several collective actions such as community based solid waste management and compost preparation, biological wastewater treatment using duckweed pond, wastewater agriculture, and more adaptive cropping and pest management. There is a need for piloting these community based actions and other peri-urban adaptation options facilitated through this research so that those can be effectively scaled up later on.


TATA
STOP
AP28 TV 1042
OK
PLEASE HORN

SaciWATERs

B- 87, 3rd Avenue, Sainikpuri, Secunderabad - 500 094, Andhra Pradesh, India
Tele Fax: +91 40 27116721, 27117728; Website: www.saciwaters.org