Moving from Water Problems to Water Solutions: Research Needs Assessment for the Eastern Gangetic Plains

Proceedings of the International Workshop held at the National Agricultural Science Complex (NASC), Indian Council of Agricultural Research (ICAR), New Delhi, India, May 7-8, 2013

IWMI International Water Management Institute

CGIAR RESEARCH PROGRAM ON Water, Land and Ecosystems

CGIAR RESEARCH PROGRAM ON Climate Change, Agriculture and Food Security CCAFS

Australian Government Australian Centre for International Agricultural Research

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Executive Summary

Poverty is acute in Eastern Uttar Pradesh, Bihar, West Bengal and Assam in India, the Nepal Terai and the Bangladesh part of the Eastern Gangetic Basin. Household incomes are low, food security is not assured and devastating floods (and also water shortages) occur too often, which have severe impacts on the poor. The floods occur primarily due to excessive rainfall in the steep hilly transboundary catchments. The impacts of such floods can be reduced through better groundwater management that enhances the regulating services of the basin's natural and agricultural ecosystems. The Eastern Gangetic Plains (EGP) is underlain by one of the most prolific aquifers in the world; yet, farmers struggle to cope with dry spells and droughts because of their inability to access groundwater.

The CGIAR Research Program on Water, Land and Ecosystems (WLE), led by the International Water Management Institute (IWMI), and partners organized a two-day international workshop which was held on May 7-8, 2013. The workshop titled **"Moving from Water Problems to Water Solutions: Research Needs Assessment for the Eastern Gangetic Plains"** focused on reviewing the state of knowledge, institutions and successful practices to enhance productivity of land and water resources within the region. A range of knowledge gaps that exist within the Eastern Gangetic Plains were identified.

The workshop organizers had previously identified three pillars that directly influence land and water resources, its policies and institutions at a regional scale. These were: (1) **Availability** of the resources; (2) **Access** to the resources; and (3) **Achievements** that can be obtained through the use of the resources (yields, productivity and income enhancement from these land and water resources). The two-day workshop focused on identifying appropriate research questions that would help improve the livelihoods of the rural poor in these three areas to cope with spatial and temporal variability, and scarcity, of available land and water resources, improve farmers' access to these resources and ensure their distribution in an equitable manner, and achieve optimal productivity.

Over the duration of the workshop, participants openly shared their knowledge and experiences within the region and contributed towards developing concept notes that would address the key challenges and areas that were identified throughout the various sessions. The process included a total of 30 overview presentations, some of which were generic in nature while others addressed specific issues in each country. This was followed by two working sessions, one addressing thematic challenges and the second addressing regional challenges.

The key challenges identified include (1) inefficient rural institutions to manage water availability in a reliable manner, especially during dry seasons; (2) inadequate adaptation of successful institutions at a larger scale; (3) inequity in access to water for disadvantaged groups such as female and poor farmers; (4) change in farming practices due to migration of male labor from rural areas; (5) lack of comprehensive knowledge of spatial and temporal variability of water resources at local and regional scale; (6) coping mechanisms for rising energy costs for pumping groundwater; (7) coping with extreme climatic conditions in the coastal zones of EGP; and (8) coping mechanisms to minimize the damage to rural properties as a result of floods.

Regional working groups identified a total of 10 concepts, and a degree of duplication among concepts was noted. Hence, some concepts were merged to provide a regional view of such issues. Finally, seven concepts were identified and selected for development into future projects.

CN 1: Role of institutions in agricultural water management.

CN 2: Gender and labor migration in the EGP.

CN 3: Water resources assessment and information systems for the EGP.

CN 4: Water-energy nexus in the EGP.

CN 5: Utilization of land and water resources in the coastal region to improve livelihoods.

CN 6: The 'Ganges Water Machine' – ensuring adequate, equitable and reliable irrigation, and sustainable ecosystems in the Ganges Basin.

CN 7: Flood forecasting management systems.

This report presents an account of the workshop proceedings, including highlights from the breakout group discussions as well as the opportunities identified for collaborative research projects with both internal and external partners.

The workshop organizers would like to thank the CGIAR Research Programs on Water, Land and Ecosystems (WLE), and Climate Change, Agriculture and Food Security (CCAFS), and the Australian Centre for International Agricultural Research (ACIAR) for co-sponsoring the workshop.

Our sincere appreciation is also extended to Ms. Shalika Vyas and Ms. Martina Mascarenhas for painstakingly compiling information and opinions expressed by over 65 participants during the two-day workshop.

Bharat R. Sharma, Principal Researcher and Coordinator – IWMI India

S. A. Prathapar, Theme Leader – Productive Water Use, IWMI

Organizers

IWMI

The International Water Management Institute (IWMI) is an international, non-profit research organization dedicated to improving the management of land and water resources for food, livelihoods and the environment. IWMI is a member of CGIAR, an international consortium of agricultural research centers. IWMI's mission is to improve the management of land and water resources for food, livelihoods and the environment. IWMI's vision, as reflected in the Institute's Strategic Plan, is water for a food-secure world. IWMI targets land and water management challenges faced by poor communities in the developing world. Research for development (R4D) is the core activity of IWMI. The Institute's research agenda is organized around four priority themes: Water Availability and Access; Productive Water Use; Water Quality, Health and Environment; and Water and Society. IWMI works through collaborative research with many partners in the North and South and targets policymakers, development agencies, individual farmers and private sector organizations. For more information, please visit http://www.iwmi.cgiar.org/index.aspx

WLE

The CGIAR Research Program on Water, Land and Ecosystems (WLE) is an ambitious twelve-year program that brings together innovative thinking on agriculture, natural resource management and poverty alleviation to deliver effective solutions for food security and environmental protection. Unmatched in CGIAR, both in terms of its scope and range of partners, the Program brings together specialists in CGIAR subject matter to solve pressing problems in specific focal regions. The vision of WLE is "a world in which agriculture thrives within vibrant ecosystems, and where communities have higher incomes, improved food security and the ability to continually improve their lives." For more information, please visit http://wle.cgiar.org/

CCAFS

The CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) addresses the increasing challenges of global warming and declining food security on agricultural practices, policies and measures through a strategic collaboration between CGIAR and 'Future Earth'. Led by the International Center for Tropical Agriculture (CIAT), CCAFS collaborates with all 15 CGIAR research Centers as well as with the other CGIAR thematic research programs. CCAFS will, thus, define and implement a uniquely innovative and transformative research program that addresses agriculture in the context of climate variability, climate change and uncertainty about future climate conditions. For more information, please visit http://ccafs.cgiar.org/

ACIAR

The Australian Centre for International Agricultural Research (ACIAR) is a statutory authority that operates as part of the Australian Government's development cooperation programs. The Centre encourages Australia's agricultural scientists to use their skills for the benefit of developing countries and Australia. ACIAR funds research projects that are developed within a framework reflecting the priorities of Australia's aid program and national research strengths, together with the agricultural research and development priorities of partner countries. For more information, please visit http://aciar.gov.au/

Participants

Workshop participants included representatives from government, research and nongovernmental organizations (NGOs) from India, Nepal and Bangladesh as well as the donor community and private sector. Experts from these areas made presentations on past research and current problems that exist within the EGP. The structure of the two-day workshop focused on identifying appropriate research questions that would help improve the livelihoods of the rural poor in these areas by improving their access to, and the sustainable use of, land and water resources. The workshop provided a forum for participants to share their current experiences given their expertise, and to contribute to further refining existing methodologies together with a better understanding of the complexities and opportunities that this region presents. The workshop witnessed an overwhelming participation of around 65 participants, from different countries and backgrounds, including donors, researchers, academicians, policymakers and think tanks. Figure 1 shows the representation of the various groups as a percentage of the participants.

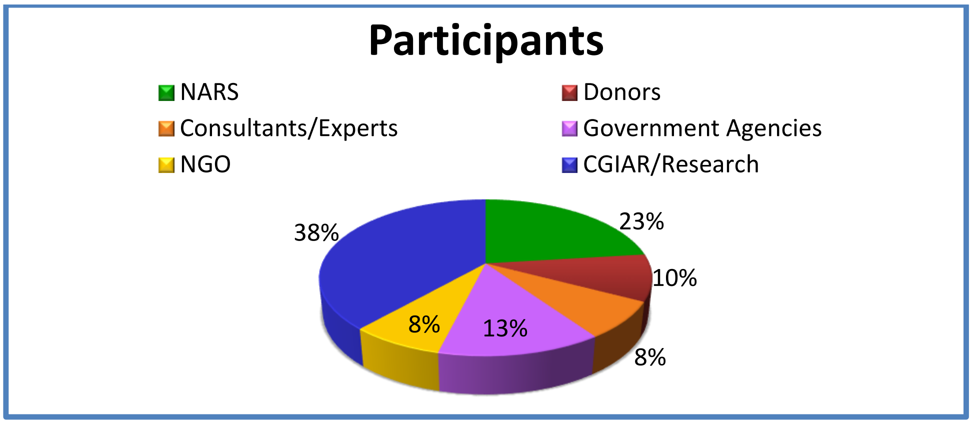

Figure 1. Participant details.

The information in Figure 1 shows that the participants were an egalitarian mix of representatives from different sections and were adequately represented, which is reflected in the enriching discussions and holistic outcomes of the workshop as detailed below.

Session 1: Welcome and Introductions (WLE, SRPs and EGP)

Inaugural address: Bharat Sharma, Principal Researcher and Coordinator – IWMI India

The workshop started with the welcome speech by Dr. Bharat Sharma. Outlining the importance and the need for this workshop, Dr. Sharma highlighted that the EGP has lagged behind in agricultural growth, with the Green Revolution essentially bypassing this region altogether. He explained the unique socio-ecological and hydrological characteristics of this region, and the major constraints to, and opportunities for, agricultural growth. In this light, recognizing signs of past failure and ways to address those issues gains paramount importance. Dr. Sharma urged the participants to think about various research needs specific to this region, and stated that a multi-disciplinary approach was needed to address the complex concerns of the region.

Introduction to IWMI: Peter McCornick, Deputy Director General – Research, IWMI

A brief overview of IWMI as an institution was elucidated by Dr. Peter McCornick. He then went on to explain the organizational evolution and reforms in the research programs. Different CGIAR Research Programs, including WLE, led by IWMI, and CCAFS, were also explained. He described how different "patchwork" of research had to be woven together through a single coherent story encompassing the entire basin/region. He also emphasized the need for an extensive feedback mechanism from various stakeholders about IWMI's research.

ACIAR's interest in the EGP: Evan Christen, Research Program Manager, Land and Water Resources, ACIAR

Dr. Evan Christen emphasized the need for greater impact from research investments to farmers and end users. He also advised the stakeholders to extensively test the inherent assumptions and new innovative research projects. Dr. Christen highlighted some of the projects funded by ACIAR in the eastern region and opportunities for the future. He expressed ACIAR's appreciation to be a sponsor for this workshop.

Country overviews and expectations

India: Alok Sikka, Indian Council of Agricultural Research (ICAR), New Delhi

Dr. Ashwani Kumar provided a bird's-eye view of the water challenges currently being faced by India, and its implications in terms of ecological, economic and developmental losses. He presented details of the research being conducted by ICAR Institutions for efficient agricultural water management, and the roadmap for tackling the issues of low productivity and growing scarcity of water resources.

Bangladesh: Sattar Mandal, Member (Agriculture, Water Resources and Rural Institutions), Bangladesh Planning Commission

Dr. Sattar Mandal explained the Bangladesh story of water, with interrelated issues as varied as political and economic. He highlighted the achievements of Bangladesh's agriculture sector in increasing food production by threefold since the 1970s, despite a decline in cropped area. He also mentioned the groundwater markets of the country and the stronghold of private tube wells over Bangladesh's irrigation scenario. Being a distinguished policymaker, he provided some insights into the future plans of the government that included a focus on agricultural development in the southern delta areas. He expected that the workshop would result in various important research topics, broadened partnerships and transboundary cooperation.

Nepal: S. K. Sharma, Department of Irrigation, Nepal

Mr. Sharma highlighted the complexity of transboundary issues and the increasing need for regional cooperation in research and policy making. He mentioned that although there were various water treaties, no such agreement was made for hydroelectric projects. He also expressed his views on the need to create a basin-wide analytical framework. Giving the example of the Kosi River flood of 2008, Mr. Sharma emphasized the need for supplementary irrigation systems, as well as the information and cooperation required to mitigate such natural calamities.

Research to lead development in the EGP - Lessons from the IWMI-Tata Water Policy Research Program: Tushaar Shah, Senior Fellow, IWMI

Dr. Tushaar Shah started the discussion by explaining the creative tension that usually emerges between different partners, and how the IWMI-Tata Water Policy Research Program mitigated such tension by leading various high-value and high-impact research projects. He also provided some useful insights for creating research impact for the eastern region.

Introduction to WLE: Andrew Noble, Acting Program Director, WLE

Dr. Andrew Noble emphasized some critical issues facing the water sector, globally, and highlighted the approach taken by WLE that builds on the outcomes from the CGIAR Challenge Program on Water and Food (CPWF). He emphasized the need for a comprehensive research framework that includes the fundamental elements of water, land and ecosystems, which are the basis of our food production systems. The management of these resources in a sustainable and integrated manner will be critical in meeting future global food demand, and ensuring that we remain within the planetary boundaries which define the safe 'operating space' for humanity. The role of WLE was to provide the fundamental basis for sustainable agricultural intensification.

Introduction to different Strategic Research Portfolios (SRPs): Priyanie Amerasinghe, Head, IWMI-Hyderabad and Senior Researcher - Bio-Medical Sciences; Vladimir Smakhtin, Theme Leader – Water Availability and Access, IWMI; and S. A. Prathapar, Theme Leader – Productive Water Use, IWMI

A brief outline of different SRPs that are part of WLE were explained to workshop participants: Resource Recovery and Reuse (by Priyanie Amerasinghe); River Basins (by Vladimir Smakhtin) and Irrigated Systems (S. A. Prathapar).

Overview of the Activity Cluster Water Management in the EGP: Bharat Sharma

Dr. Bharat Sharma provided an overview of the EGP. He briefly explained the underlying issues affecting agriculture and the water sector, with a short historical background. He emphasized the unique characteristics of the region and the associated issues that need to be resolved. He also outlined an analytical framework which could be used to develop research assessments in the EGP, through Availability, Access and Achievements.

Session summary

The session concluded on the note that continuous feedback from various stakeholders is extremely important. The rural-urban continuum (linkage) has been a major driver of change that needs to be understood and characterized further through more research and empirical understanding. In such a scenario, research has to be conducted in diverse environments and should be cohesive.

There was general agreement that cooperation at different scales is highly desirable for conducting research that leads to impact. Lack of available data and information (especially about water resources in the Upper Himalayan and transboundary data availability) was identified as being a major hurdle. This issue is vital as it was not only voiced by stakeholders but has been identified as the main issue in the media as well (http://www.bbc.co.uk/news/science-environment-23358255). Stakeholders agreed that they will look into developing data sharing policies, in which institutions such as IWMI can play a pivotal role.

Session 2: Theme - Availability of the Resources

This session delved into the issue of availability of resources, especially land and water, in the EGP, and its potential impact on productivity and livelihoods of the people. The session comprised of five presentations and interactive discussions:

i. The 'Ganges Water Machine' - Surface water resources of the EGP: A. K. Gosain, Professor, Water Resource Management, Indian Institute of Technology, New Delhi

The big picture: Water quality issues in the Ganges

The presentation focused on water quality issues in the Ganges - contaminants and sediment loads. The issue of biological oxygen demand (BOD) was discussed at length. The selected study showed positive results in the ability of dams to control sediment loads.

Future of the Ganges

Different modeling techniques were used to ascertain future analysis of water quality and quantity in the Ganges River, using different scenarios based on predetermined factors.

Possible research issues

- Carrying capacity of the Ganges in terms of pollution.
- Equity of resources.
- Pollution and water quality issues – with a specific focus on industrial pollution and sewage treatment.

ii. The 'Ganges Water Machine' - Groundwater resources of the EGP: D. Saha, Regional Director, Central Ground Water Board, India

The dynamics of groundwater resources in the EGP were presented. Technical issues, which included soil composition and its effect on the availability of water resources as well as hydrogeology of the Ganges, were explained at length. The importance of understanding aquifer systems of the EGP is essential for any groundwater-related interventions. The presentation also focused on the spatial and temporal variation of resources. The study reinforced the understanding that ample groundwater was available for development in the EGP.

iii. Water resources of Nepal: L. Bharati, Senior Researcher - Hydrology and Water Resources and Head of Office, IWMI, Nepal

The presentation started with an interesting glimpse of water resources in Nepal.

Water resources

- Mean annual runoff: 224 billion cubic meters (Bm^3).
- Per capita water availability: 9,000 cubic meters (m^3).
- Large spatial and temporal variability.
- Only 689 megawatts (MW) of a potential 45,610 MW of hydropower have been developed.

Water use

- 42% of the cultivated area is under irrigation
- 72% of the population has access to basic water supplies
- Only 25% of the population has sanitation facilities

Climate change and its implications

The presentation then focused on climate change and its perceivable impact in the coming future. Results of some simulation models were presented which foretold the incumbent challenges associated with climate change. Therefore, it was argued that adapting to existing climate variability is crucial in this regard. Lack of data was identified as being a significant obstacle in research activities.

Possible research issues

- Resource assessment.
- Climate change adaptability.
- Enhancing water productivity.
- Peri-urban solutions and gender issues.

iv. Water resources of Bangladesh: L. Muthuwatta, Hydrologist/Mathematical Modeler, IWMI

Streamflow analysis of the Ganges using different modelling techniques was presented. Various land-use and population projections were used, along with hydrological modeling. The Soil and Water Assessment Tool (SWAT) was presented and discussed. Future modeling requires incorporating climate change and altering land-use patterns.

v. Cascading Ganges: Floods and their impact on the EGP: Giriraj Amarnath, Researcher – Remote Sensing and GIS, IWMI

Floods were described as being one of the primary natural disasters, causing global economic losses to the tune of USD 165 billion per annum.

Historical and regional contexts

An analysis of major floods over the past decade was presented. The study aimed at identifying and characterizing flood hot spots in the EGP. Flood mapping of the entire region was carried out using remote sensing images and modelling techniques.

Mitigating floods: Modelling techniques

Flood inundation mapping was identified as an important tool. The study showcased the HEC-HMS modelling technique. Temporal variability in inundation was mapped in the study.

Possible research issues

- Continuous monitoring of flood inundation dynamics.
- Monitoring of waterlogged areas using multispectral and multi-temporal techniques.
- Studying remote sensing data products and their use in flood mitigation.
- Specific analysis on flood dynamics and the ecosystem coherent with climate change.
- Formulation of regional water management plans based on flood mapping.

Discussions

The participants were fascinated with different issues that were presented to them. The main topics discussed were as follows:

- Floods and their impacts: Economic analysis.
- Climate Change: Glacial erosion, snow melting, conservation and aquifer mapping of Nepal.
- Development of comprehensive data on water resources across the EGP.

Session 3: Theme - Access to the Resources

This session involved discussions about the constraints and access to water resources in the EGP.

i. Improving rural livelihoods in the EGP: Palanisami Kuppannan, Principal Researcher, IWMI

Dr. Palanisami focused on irrigation, specifically tank irrigation, and how it can supplement livelihoods in the EGP. The presentation showcased an ACIAR scoping study for tank irrigation in the EGP and its impact in augmenting livelihoods. The study noted a general reduction in the area under tank irrigation in the EGP, with farmers opting for tube wells/bore wells instead. The main causes for this were attributed to ownership, maintenance and investment issues. The main advantages of tank irrigation were its ability to supply water for multiple purposes, including fisheries, supplementary irrigation and household water needs. The study Identified major intervention areas such as tank rehabilitation, bund strengthening, fisheries development and storage structures, etc. It also focused on access to such resources, exploring new models of public-private partnerships, farmer groups and other institutional arrangements.

ii. Water-energy nexus: Tushaar Shah

The perplexing paradox of the EGP — Abundance in groundwater resources, yet poverty is widespread — was discussed in length. The presentation urged that lessons should be learned from the unsustainable groundwater boom in southern and western India. Alternate energy models which are sustainable are urgently required. A comparative analysis of the electric pump, diesel pump, biogas and solar energy was attempted for the EGP.

iii. Institutions and policies: Sattar Mandal

A brief overview of the agriculture sector of Bangladesh was provided. Despite the rapid increase in food production, food security is still a distant dream. Bangladesh is abundant in water resources, yet access to these resources is the main problem. Therefore, the need for alternate water management institutions was put forward. The presentation focused on the prevalence of groundwater markets and rising energy costs. These issues, coupled with groundwater contamination, act as major constraints to farmers’ access to water resources. Thorough analysis of the Barind Multipurpose Development Authority (BMDA) as an effective management solution was identified as a plausible research need.

Possible research issues

- Polder management.
- Soil and water conservation - effective solutions for salinity and drainage problems.
- Policy interventions for better cost recovery in irrigation projects.
- Alternate governance and management models for water users.

iv. Agrarian stagnation in Bihar: A. Kishore, Postdoctoral Fellow, International Food Policy Research Institute (IFPRI)

The presentation started off with some startling facts about agrarian Bihar. Bihar has the highest rural poverty density. Agricultural growth has stagnated through the decades despite policy interventions and the increased use of farm inputs. Agricultural output was found to be volatile. The water-energy nexus was found to be the main reason for this, as expensive irrigation negates the natural abundance of water. The diesel pump subsidy was found to be ineffective and unproductive. Various land issues such as tenancy and declining landholdings were also attributed to stagnated growth. Lack of reliable data was described as being a hindrance to drawing conclusions about the region.

Possible research issues

- Program evaluation - diesel subsidy, price support mechanism of the government and farm mechanization.
- In-depth analysis of production relations - tenancy and lease arrangements.
- Alternate energy mechanisms.
- Improvement in data quality and consistency, and collection of livestock data.
- Research design for effective data collection – Living Standards Measurement Study (LSMS).

v. Access to land and its effect on water management: F. Sugden, Researcher – Social Science, IWMI

Access to land and irrigation was found to be a critical issue in the EGP. The role of land tenure in mediating irrigation expansion was studied. It was found that part-time laborers and tenants dominate agricultural space in the region. The study also found that tenancy insecurity hampers investment in irrigation. Policy interventions were unable to reach all, the cause of which was attributed to lack of documentation of tenancy arrangements which would give legal rights to smallholders to avail the benefits of government schemes. All this has led to a boom in pump and tube well rental markets in the region and monopolistic pricing by agencies providing water.

Possible research issues

- Collective ownership of tube wells/pump sets.
- Low-cost energy pump models for irrigation.
- Studying possible revitalization of community resources: ponds, canals, etc.

Discussions

An interesting discussion followed these presentations focussing mainly on the following issues:

- Potential use of solar energy for groundwater pumping.
- Feminization of agriculture in the EGP.
- Definite factors for agricultural stagnation.
- Role of ponds and tanks in improving water access.

Session 4: Theme - Achievements that can be obtained through the Use of the Resources

This session was dedicated to exploring the achievements that can be obtained through the use of the resources, including production, productivity, poverty levels, etc. It also deliberated on the issues of knowledge gaps and obstacles in realizing potential yield levels.

i. Overview of the EGP: A. Sikka, ICAR, New Delhi/B. P. Bhatt, Director, ICAR-Research Complex for Eastern Region (RCER), Patna, India

The presentation provided a detailed analysis of yield, production and productivity levels, and the social characteristics of the region. The following main knowledge gaps were found:

- Price control mechanisms of the government.
- Productivity maximization and low water-use efficiency.
- Alternate energy systems.
- Groundwater contamination.
- Skewed input use: lack of micronutrient applications.
- Land and tenancy issues.
- Climate change and its socioeconomic impacts.

ii. Agrarian straitjacket: Constraints to achieving potential yield in rice production: M. Mondal, Collaborative Research Scientist, International Rice Research Institute (IRRI)

The presentation focused on the key challenges to rice production, including flooding, salinity, tidal surges and declining groundwater levels. Drainage/waterlogging was identified as a major problem in the coastal regions, suppressing rice yields. The study showed that terminal drainage between different crop seasons can considerably improve production levels. It also demonstrated the effectiveness of drainage through a field experiment. Alternate production systems of rice-shrimp and rice-fish-shrimp were found to be economical.

iii. Participatory approach for efficient water use: A. Zaman, Bidhan Chandra Krishi Viswavidyalaya (BCKV), Orissa, India

Water-saving irrigation technologies were showcased in this study. It was shown that diversified crop farming increases production. Management techniques such as irrigation scheduling, crop pattern management, agronomic measures, etc., were shown to have quite an impact in increasing the efficiency of water use and thereby increasing yields.

iv. Replication of Barind Groundwater Management model to Muhuri irrigation project: A. Zaman, Consultant, Asian Development Bank

A case study of the Bangladesh Agricultural Development Corporation (BADC) was showcased in this presentation. It was an institutional intervention which also included some technological innovations such as the development of an inverted deep tube well design, pre-paid meter with SIM card for irrigation, irrigation coupons, incentives to stakeholders, etc. The results were found to be quite overwhelming, and the financial independence of the beneficiaries and sustainability of the project were the key highlights. It was shown that this participatory model had yielded good results when replicated in other regions as well.

Possible research issues

Study of replication of the Barind Groundwater Management model for different irrigation systems, especially to the Indian states of Bihar and West Bengal.

v. Constraints to achieving potential in fisheries: P. Katiha, Indian Agricultural Research Institute, New Delhi

The presentation showed that the significance of fisheries to food and nutritional security is enormous and well documented. The EGP has tremendous potential for inland fisheries. The study tried to showcase different constraints to fisheries that include lack of reliable data and non-availability of timely inputs. Development of fisheries in community structures is difficult as there are issues of ownership and management. Leasing arrangements also act as a major hindrance. The study noted that there are very few policy interventions in this area.

Possible research issues

- Possible interventions in community fisheries management.
- Need for capacity building and policy interventions.
- Research on reliable data collection techniques and building a database.

vi. Innovative land and water management practices for enhancing agricultural productivity and incomes in the EGP: A. Kumar, Directorate of Water Management, Orissa, India

The presentation noted that the scientific management of water resources is a prerequisite for development. Various innovative techniques were presented which could be implemented in the EGP:

- Crop diversification with short duration, low water-consuming species.
- Water harvesting structures: rubber dam.
- Farm pond-based agricultural diversification and integrated farming systems.
- Water distribution systems such as tank well systems.
- Management of canal commands.
- Water use-efficiency enhancement through different interventions.

Session 5: Theory of Change and Impact Pathways

This session delved into the science of management of research. The session helped many participants in identifying higher goals and how research should be streamlined to achieve these goals over a period of time. The concept of theory of change and impact pathways was introduced.

i. Theory of change and impact pathways: E. Weight, Global Science Uptake Coordinator, IWMI

The presentation started with an explanation of the framework of impact pathways and highlighting its relevance in research, especially in the context of the EGP. CGIAR's strong focus on these concepts was emphasized. Use of impact pathways in creating impactful research, monitoring and evaluation, developing a shared vision and establishing partnerships was highlighted. Various components of the impact pathway were discussed using an example for the EGP.

ii. Gender and the EGP: N. de Haan, Coordinator – Gender, Poverty and Institutions, CGIAR Research Program on Water, Land and Ecosystems (WLE)

The presentation aimed at emphasizing the importance of studying gender balance in research. The increasing feminization of agriculture was witnessed and is expected to increase due to the migration of male farmers in search of alternate livelihoods. It was noted that women often have less access to resources than men, leading to decreased productivity. Therefore, there is a need to study gender equity in terms of promoting sustainable intensification in vibrant ecosystems.

Session 6: Research Needs Assessment: Think Tank Activity I

The preceding sessions provided deep insights into some of the issues constraining productivity in the EGP, with possible solutions to mitigate these issues. The next sessions were designed to apply the deliberations and discussions into tenable outputs in the form of concept notes.

This session was aimed at dividing the participants into think tank groups, which would help to delve more deeply into the issues and suggest possible research outcomes. Each group had about 15 to 20 expert participants with a designated resource person to keep the discussions on track and capture the results of the discussions.

The participants were divided into the following thematic groups:

- Availability
- Access
- Achievements

i. Think Tank Activity: Availability of the Resources

Water quantity: The 'Ganges Water Machine'

The group recognized that the concept of the 'Ganges Water Machine' (GWM) has been articulated for many years to enhance surface water-groundwater interactions and benefit irrigated agriculture in the Ganges Basin. The discussions focused on the implications of GWM on ecosystems and its related trade-offs. Since fluctuations in water levels based on wet and dry seasons were identified as the main issue plaguing the region, the simplest solution is proper management of water resources and storing the excess water for lean seasons.

Two levels of modelling were deemed essential for studying feasibility of such a transfer:

- (Mathematical) - How much water might recharge the aquifer?
- Larger water accounting.

Changes in land-use patterns have a major impact in such water accounting initiatives. Since the entire region is mostly irrigated with the use of pumps, and most of such pumping activity is unaccounted for, it was concluded that it is difficult to ascertain the exact volume of groundwater abstraction. The system was found to be even more complex for the coastal regions because of tidal surges and wide spatial and temporal variability.

Water quality

Focusing on water quality was also considered to be important in having availability and access to clean water. With increased incidences of fluoride and arsenic contamination in the eastern region, it was clear that these issues need research focus.

Basin approach

It was also felt that a basin approach was essential in future research of the EGP, since the entire region is a cohesive geological unit. Lack of basin-wide data was cited as a major problem. A cohesive water balance was considered important in understanding the hydrology of the region. Use of remote sensing for estimation of evapotranspiration was considered as being important.

Flood management

Various flood mitigation measures were discussed for the region. A technical feasibility analysis of such measures was considered an important activity for future research. Complex environmental problems associated with floodwater harvesting structures, such as dams and reservoirs, should be studied more deeply. A real-time flood mapping system was considered as being most essential for the coastal regions of the EGP. Policy interventions, such as flood insurance, was also mooted during the course of discussions. Better drainage and waterlogging solutions were also thought to play a critical role in augmenting coastal agricultural systems.

ii. Think Tank Activity: Access to the Resources

This resource group comprised of 14 participants representing regional experts and diverse institutions which included research, academic institutions, government representatives and private consultants. The initial discussions deliberated on various issues. However, eventually, the following four issues (as shown in Figure 2) were widely recognized as having the biggest impact on access to resources. Thus, these four issues were discussed in detail.

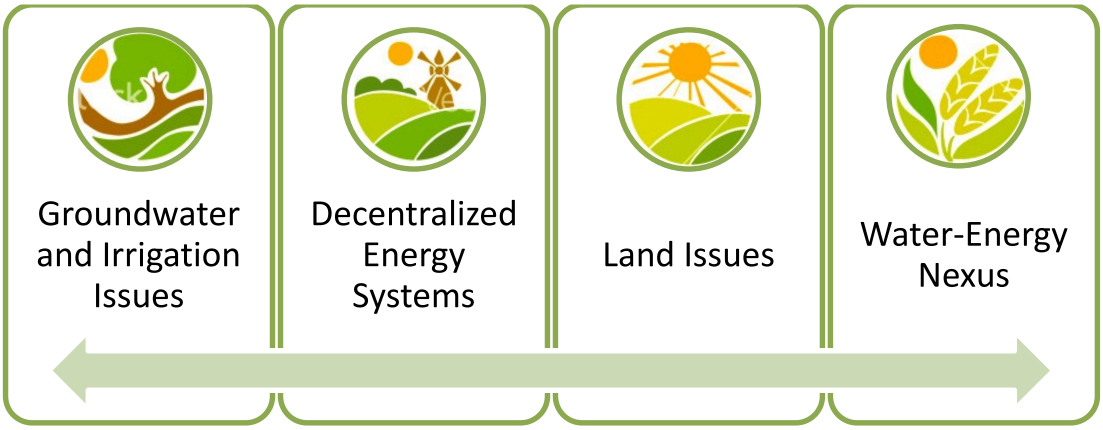

Figure 2. Issues in access to resources.

Groundwater and irrigation issues

Management of aquifers was recognized as an important activity. Participants called for scientific analysis of aquifers in the eastern region, especially for their protection from contamination, and understanding the hydrogeology of the region. Institutional frameworks were recognized as being a backbone of irrigation systems and a franchise model of private irrigation systems in Gujarat, the Barind model in Bangladesh, were discussed at length. Surface irrigation and managing public irrigation systems also deemed important for improving access to water by various stakeholders. The 'groundwater markets' were recognized as paying a pivotal role in the region.

Decentralized energy systems

Renewable energy is to play a major role in the coming years. Solar power and biogas were identified as key areas.

- Solar power: This energy source was discussed at length. In the wake of the recently launched Solar Mission and heavy government subsidies, participants agreed that it can be a reliable solution for power woes in the EGP. Power subsidies were recognized as being a major hurdle to attract adequate investments in low carbon energy systems. Issues of equity bore a special reference as initial capital investments were high and the payback period was long, seriously undermining it's suitability for smallholders. A detailed economic analysis and feasibility study for solar power in the EGP was identified as a plausible research subject.

- Biogas energy: This is one of the cleanest fuels, with a high degree of suitability for the region and was identified as yet another priority area. Linking animal husbandry with biogas could be an effective energy solution. It was also agreed that a thorough institutional analysis of community biogas plants, better targeting and robust service provider models were essential to developing this energy resource.

- Linking different agricultural systems with energy: The case was made of the need to link diverse agricultural systems, such as dairy and fisheries, to energy. Both of the mixed farming models (agri-dairy and agri-fisheries) are considered robust and an important way of enhancing livelihoods and mitigating poverty. The participants also called for the creation of an enabling environment for energy systems in the EGP, including the better targeting of government policies, better service delivery mechanisms and appropriate institutional support.

Land issues

Lack of data, specifically the extent of tenure and lease, was recognized as a major obstacle in ascertaining comprehensive research issues for the region. Survey of different institutions, tenancy, and land and migration patterns was considered as important. Participants also concluded that certain sociological studies are vital for delving deeper into agrarian issues constraining the region. Labor migration, caste dynamics, agrarian structure and pattern mapping were considered as being some of the vital issues which should be researched by various sociologists, as critical social relations often frame agrarian economy and indirectly affect access to various resources. Risk-spreading strategies, such as optimum utilization of land through mixed farming practices, were considered a viable option by many.

Water-energy nexus

The participants identified this as being one of the major hurdles in access to energy for water. It emerged from the discussions that the cost of irrigation using diesel pumps play a major detriment for small and marginal farmers causing poor returns and the poor returns instead, disincentivized farmers to invest in their fields. This has created a vicious cycle, due to which farmers often have to depend on rental pumps for irrigation.

It also emerged that there was wide variation in pump charges, both spatial and temporal in nature, which should be studied in detail. The group came to the conclusion that the following points (as shown in Figure 3) should be researched thoroughly, and their importance is immense in increasing access to water in the EGP.

Volatility and variation in pump charges	•Reasons for such wide variations •Egalitarian distribution of rental pumps, and how access for smallholders is impeded
Institutional arrangements for collective ownership	•Study the scope of various institutional models which can be replicated - a case in point - Barind model •Franchise model for different irrigation systems
Access to technology and its implications on smallholders	•Reasons for absence of trickle down of technology, especially to lower strata - smallholders •Cost barriers for adoption: Alternative models

Figure 3. Issues in water-energy nexus

iii. Think Tank Activity: Achievements that can be Obtained through the Use of the Resources

The session dealt with impediments which hinder the productivity of the resources and limit the achievements which could be obtained through their use. The group identified the following main issues:

Determinants of low productivity

The issues which were identified included preexisting natural conditions and production management issues. The main issues identified were erratic rainfall and its implications, poor–quality farm inputs and their timely availability, degrading soil conditions such as salinity, waterlogging, water management practices, high cost of energy, small landholding size, access to technologies, access to credit and increasing vulnerability of smallholders, to name a few. In Nepal, factors such as market access and prices, access to technology and social factors which drive people's interest in achievement were considered important.

Migration and feminization of agriculture

The need for studying migration patterns was exemplified. Detailed study of sociology of the region was deemed important. Aspects such as decision making, family structure and its contribution to farm labor are important in developing a cohesive understanding of the region. The issue of diversification of farm activities into non-farm livelihoods was also found to be important. Increasing male out-migration has resulted in the increasing feminization of agriculture and this is corroborated by rising farm rates of women labor. Hence, it was felt that there was the increasing need for capacity building of female labor and the need for drudgery reducing machinery in the farm.

Market linkages

Aggregation of farm outputs is necessary for realizing optimum prices for farmers. Post-harvest practices such as proper handling, grading, packaging, storage, certification, etc., considerably increase the farm prices. Strengthening market systems is important, and marketing arrangements such as contract farming need to be intensively studied to gauge their impact on farmers' income.

Diversification

Diversification of agriculture assumes a greater importance to balance the increasing vulnerability of farmers. Identifying suitable areas for diversification such as urban/peri-urban agriculture, use of wastewater, etc., is important. Diversification was also deemed necessary to eliminate wide nutritional deficiencies plaguing the region. Some diversification activities that were discussed are (i) *boro* paddy in Bangladesh; (ii) winter maize in Bihar; and (iii) integrated farming systems by ICAR.

Smallholder agriculture

It was generally agreed that model farmers are highly diverse, location-specific and cannot be a prescriptive solution for a wider region. A major constraint identified was the lack of access to technologies and markets, which impede smallholders to successfully apply such models in their local context.

Fisheries/animal husbandry

Nepal and Bangladesh has showcased important lessons in its development of inland fisheries. The need for better management practices were identified as the single most important factor impeding achievements in this sector. Larger support mechanisms through policy intervention and market support are essential in tapping the full potential of these activities. Lack of proper processing and packaging facilities also act as constraints.

Specific recommendations given by participants of the Think Tank Activity I:

- Strengthening of infrastructure including the markets.
- Strengthening of institutional systems.
- Capacity building, especially of women farmers.
- Transfer of proven technologies for sustainable agriculture.
- Focus on the farm as a system, and the technological/social/economic impacts of proposed changes.
- Enhanced and affordable energy on the farm.
- Water management is the key to improving productivity, so research should be focussed on rainwater utilization, supplemental irrigation and drainage to ensure potential yield of rice and timely establishment of crops in the *Rabi* season.

Session 7: Research Needs Assessment: Think Tank Activity II

This penultimate session of the workshop aimed at capturing and producing tangible outputs from the workshop in the form of 'concept notes'. The participants were divided into four groups (Nepal, Bangladesh, India and Transboundary issues) and each group was asked to conceptualize two to three concept notes based on national research priorities, discussions and learning from the workshop. The following concept notes were formulated by each of the four groups in this session (see Annexure 3 for detailed concept notes).

Concept notes: Nepal

1) Role of institutions in water management.
2) Gender and migration of rural workforce.
3) Water Resources Information System for Nepal.

Concept notes: Bangladesh

4) Water resources assessment of the potential of groundwater and surface water for sustainable use (groundwater recharge).
5) Water management adaptation towards intensification and diversification of agriculture.
6) Migration, livelihoods and gender in the rural landscape.
7) Utilization of land and water resources in the coastal region to improve livelihoods.

Concept notes: India

8) Replication of the Barind model in the EGP: Feasibility analysis.
9) Assessment of cost–effective alternate energy sources.
10) Real–time flood forecasting and management system.

Concept notes: Transboundary issues

11) The 'Ganges Water Machine' – ensuring adequate, equitable and reliable irrigation, and sustainable ecosystems in the Ganges Basin.

Some of the concept notes, which are addressing similar issues, were merged to develop transboundary/basin–wide research proposals.

Session analysis

After detailed discussions, analysis and brainstorming by participants, 11 concept notes emerged from the workshop. These concept notes were formulated after careful planning and discussions, and have immense potential for augmenting impactful research in the EGP; hence, they merit detailed analysis for their successful implementation. Table 1 shows the outline of the main framework used to develop different concept notes.

Content	Description
Context	Problem to be researched is explained, along with its context in the regional priorities.
Outcome	Development changes which are aimed are elucidated in detail, along with description of change agents/stakeholders.
Objective	Objective of the proposed study, with requirements of the enabling environment are described.
Knowledge gaps	Existing knowledge gaps and measures to address them are listed.
Resources	Financial, human and technological resources required for the study are described in detail.
Partners	Institutions that provided support to the program are listed here.

Table 1. Framework for concept notes.

Geographical scope

The EGP is a cohesive hydrological unit and many of its peculiarities are found in the entire region. Most of the associated problems are ubiquitous, across the basin. This was evident in the presentations, when participants observed many of the issues as being common, across the three countries. Hence, quite a number of the concept notes address similar issues. It shows that there is a greater potential to develop regional, transboundary research projects to address those specific needs. Table 2 shows some of the common issues spanning across different concept notes.

<table>
<tr><th>Nepal</th><th>Bangladesh</th><th>India</th></tr>
<tr><td></td><td colspan="2">Water management in coastal regions</td></tr>
<tr><td colspan="2">Social issues: Gender and migration</td><td></td></tr>
<tr><td colspan="3">Water resources management: Assessment, information systems and adaptation strategies</td></tr>
<tr><td></td><td colspan="2">Alternate institutional models, Water-energy nexus</td></tr>
</table>

Table 2. Common issues in concept notes.

As shown in the above figure, a wide range of issues have regional convergence and hence the research should not be limited to national boundaries. These issues of convergence have a wide bearing on resource management, overall productivity of water resources, and can have a profound impact in augmenting agricultural production and livelihoods in the region.

Nepal

The concept notes developed for Nepal focused on the following main topics:

- Institutional arrangements (CN 1)
- Social issues: Gender and migration (CN 2)
- Information system for water resources (CN 3)

These issues have their genesis in presentations and discussions where majority of the participants agreed that lack of data acts as a serious hurdle in Nepal. Weak institutional arrangements often mar the public irrigation systems and hence render weak access to water resources for the ultra-poor. Similarly, issues of gender and migration are increasingly becoming pertinent for the landscape of Nepal, as men often migrate to cities causing increasing feminization of agriculture (a phenomenon also noticed in India). The objective analysis of the concept notes based on the needs assessment framework, which attempts to capture the essence of these concept notes and their relevance for research, is shown in Table 3. This analysis primarily evaluates different concept notes in terms of their relevance, accurate identification and comprehensive analysis of research needs, clarity in outcomes and project design, along with adequate organizational capability required to undertake such research.

Indicator	CN 1	CN 2	CN 3
Complementarity - larger goals - regional priorities	Poverty alleviation/inclusive growth	Gender equity	Indirect impact: Efficient water management
	Many policies focus on strengthening institutional arrangements	Increased focus on gender issues by the government and NGOs	Increasing focus on data management, the government is keen to collaborate
Justification/relevance	Well documented, weak institutional arrangements mar pro-development efforts	Well documented, need for research on social aspects as cited by many	Highly mooted by workshop participants, lack of data cited by various stakeholders
Clarity of outcomes	Outcomes are clearly indicated and well defined	Focus on capacity building; more strategic and likely to support broader goals - Sustainable Development Goals (SDGs)	Database management, will impact outcomes of other projects
Design and approach	Will include developmental interventions that have wide applicability	Study would help in designing development interventions which address gender issues	Aims of creating a comprehensive database
Organizational capability	Crosscutting team of different specialists required	Social scientists of IWMI can collaborate with other agencies for project implementation	Team of data analysts and hydrologists to create a framework for achieving an inclusive database
Pro-gender and pro-poor focus	Will lead to empowerment of poor/gender responsive	Directly address these issues	Indirect impact
Economic validity	Budget: USD 1.5-2 million Intangible outcomes having great potential for inclusive growth	Increasing feminization of agriculture supported by economic studies, hence valid	Budget – USD 3 million Quantifiable outputs such as creation of the database, potential for partnership with the government
Partnership arrangements	NGOs, policymakers, farmers, private sector	Policymakers, NGOs, farmer groups	Various government agencies, database service providers

Table 3. Concept notes developed for Nepal.

Bangladesh

The concept notes developed for Bangladesh focused on the following main topics:

- Social issues: Migration, livelihoods and gender (CN 1)
- Water resources assessment of the potential of groundwater and surface water resources (CN 2)
- Water management adaptation towards intensification and diversification (CN 3)
- Utilization of land and water resources in the coastal region to improve livelihoods (CN 4)

These issues are directly linked with the major problems perceived in Bangladesh. The objective analysis of the concept notes based on the needs assessment framework, which attempts to capture the essence of these concept notes and their relevance for research, is shown in Table 4.

Indicator	CN 1	CN 2	CN 3	CN 4
Complementarity - larger goals - regional priorities	Gender equity, sustainable livelihoods	Indirect impact: Efficient water management	Increasing productivity, poverty alleviation	Poverty alleviation, sustainability
	Government emphasis on migration and labor issues	Relevant: Resource quantification aim of various government policies	Relevant: increasing efficiency is focus of many govt. agencies	Endemic poverty in the region is the focus of the government.
Justification/relevance	Well documented need for research on social issues	Well documented, need for quality data for future research	Well documented need for increased adaptation	Endemic poverty, vulnerability concerns, solutions needed
Clarity of outcomes	Direct outcomes in gender equity, livelihoods, etc.	Strategic and likely to support different future projects	Strategic, will help in policy planning	Direct help in poverty reduction, climate change adaptation
Design and approach	Lead to better interventions which address gender and social issues	Study would help in quantifying water resources of the region for better management	Will help in suggesting relevant adaptation strategies, increase efficiency	Will help in better coastal management, improved livelihoods
Organizational capability	Social scientists to collaborate with other agencies for project implementation	Team of data analysts and hydrologists to collaborate with other agencies	Crosscutting team of different specialists required	Crosscutting team of different specialists required
Pro-gender and pro-poor focus	Will lead to empowerment of poor/gender	Indirect impact, increased income	Indirect impact, cost reductions	Directly address these issues
Economic validity	Increased feminization, labor scenarios to be focused	Quality data essential for policy planning, research, etc.	Essential for improving existing systems, adaptation strategies	Empowerment of highly vulnerable groups

Indicator	CN 1	CN 2	CN 3	CN 4
Partnerships	Researchers, policymakers, NGOs, contracting labor groups	Policymakers, NGOs, farmer groups, industry	NGOs, policymakers, farmer groups, National Agricultural Research Systems (NARS)	National agricultural research and extension systems (NARES), policymakers, coastal communities

Table 4. Concept notes developed for Bangladesh.

India

The concept notes developed for India focused on the following main topics:

- Institutional Issues: Replication of the Barind model for groundwater development and management (CN 1)
- Cost-effective energy sources (CN 2)
- Real-time flood management system (CN 3)

These issues were already discussed during the presentations and Think Tank activities. The Barind model of Bangladesh was seen by many as a potential answer to participatory irrigation management (especially for cooperative groundwater development), which, if replicated well, can help in increasing access to water resources. The water-energy nexus was widely cited as a major problem which causes decreased yield and a higher cost burden on smallholders. Clean energy systems, if made cost-effective, can go a long way in addressing these problems. Recent natural disasters have only emphasized the need for robust flood-mitigating measures. The objective analysis of the concept notes based on the needs assessment framework, which attempts to capture the essence of these concept notes and their relevance for research, is shown in Table 5.

Indicator	CN 1	CN 2	CN 3
Complementarity - larger goals - regional priorities	Inclusive growth, poverty alleviation	Ecological sustainability, energy security	Better ecosystem management
	Robust institutional mechanisms are highly needed in the region	Highly relevant, the government is keen on developing clean energy mechanisms	Highly relevant, disaster management agencies express interest
Justification/relevance	Participatory interventions have failed, a successful model is required	Well documented, imminent energy crisis warrants creating new and clean energy systems	Flood management capacity building system required by many agencies, direct uptake
Clarity of outcomes	Focus on capacity building; creating a robust institutional framework	More strategic in nature, will help in identifying future energy sources	Clear: Flood management system for the basin

Indicator	CN 1	CN 2	CN 3
Design and approach	Detailed study of the Barind model and its replicability for India	Cost-benefit analysis of different energy systems and their fit within the region	Aims at creation of comprehensive database and forecast system
Organizational capability	Crosscutting team of different specialists required, collaboration with Barind agencies	Economists, ecologists and social scientists to carry comprehensive Cost-Benefit Analysis	Team of data analysts, modellers, remote sensing (RS)-geographic information system (GIS) specialists and hydrologists needed
Pro-gender and pro-poor focus	Directly address these issues	Indirect impact on water access and use	Direct impact on decreasing vulnerability
Economic validity	Better management results in various economic gains for the poor	Study essential to understand economics of different energy systems in local conditions	Budget – USD 1.5 million Tangible product, potential for partnership with the government.
Partnerships	Policymakers, NGOs, farmer groups, Barind management agencies	NGOs, policymakers, farmer groups, private sector, National Agricultural Research Systems (NARS)	Various government agencies, disaster management authorities

Table 5. Concept notes developed for India.

Transboundary issues

The following concept note was developed for this region:

- The 'Ganges Water Machine' - ensuring adequate, equitable and reliable irrigation, and sustainable ecosystems in the Ganges Basin (CN 1).

The idea of the 'Ganges Water Machine' has been debated for a long time. The aim of this study would be to have basin focus on the region and assess suitable strategies for the entire region, taken as a single but complex hydrological unit. The objective analysis of the concept notes based on the needs assessment framework, which attempts to capture the essence of these concept notes and their relevance for research, is shown in Table 6.

Indicator	CN 1
Complementarity - larger goals	Poverty alleviation, sustainable ecosystem, reduced vulnerability and improved efficiency
- regional priorities	Renewed focus on the basin approach
Justification/relevance	Despite abundant water resources, temporal variability causes poor yields and endemic poverty in the region; the study will aim to address these issues

Indicator	CN 1
Clarity of outcomes	Focus on strengthening the basin and water resources management by efficient storage, mitigating floods and increasing efficiencies
Design and approach	Detailed study of the basin, its hydrological processes, sediment loads and spatial/temporal variability
Organizational capability	Crosscutting team of different specialists required, cross-country collaboration to understand the hydrology of the basin
Pro-gender and pro-poor focus	Neutral concept, but has potential to have indirect impact on these aspects
Economic validity	Better management results in various economic gains for the poor
Partnerships	Central Ground Water Board, Central Water Commission, South Asia Water Initiative (SAWI), irrigation departments in Nepal and Bangladesh, groundwater departments in Nepal and Bangladesh.

Table 6. Concept notes developed for the Transboundary region.

Session 8: Way Forward and Closing Remarks

Feedback from various participants

Participants expressed their gratitude and satisfaction in the organization of the workshops. Most of the participants found the presentations quite insightful. Many iterated that the idea of coming together as a partnership and retaining these relationships is really important at all levels, and emphasized the need for collaboration.

Conclusion

The workshop was able to produce tangible outputs in the form of a set of research concept notes, by means of a pull approach. The research needs were derived after assessing and discussing the ground realities, hence the concept notes were need-based in approach. A continuous refinement of these concept notes through stakeholder consultation will result in developing project proposals, which will help in addressing key issues of the EGP. These can be presented as shown in Figure 4.

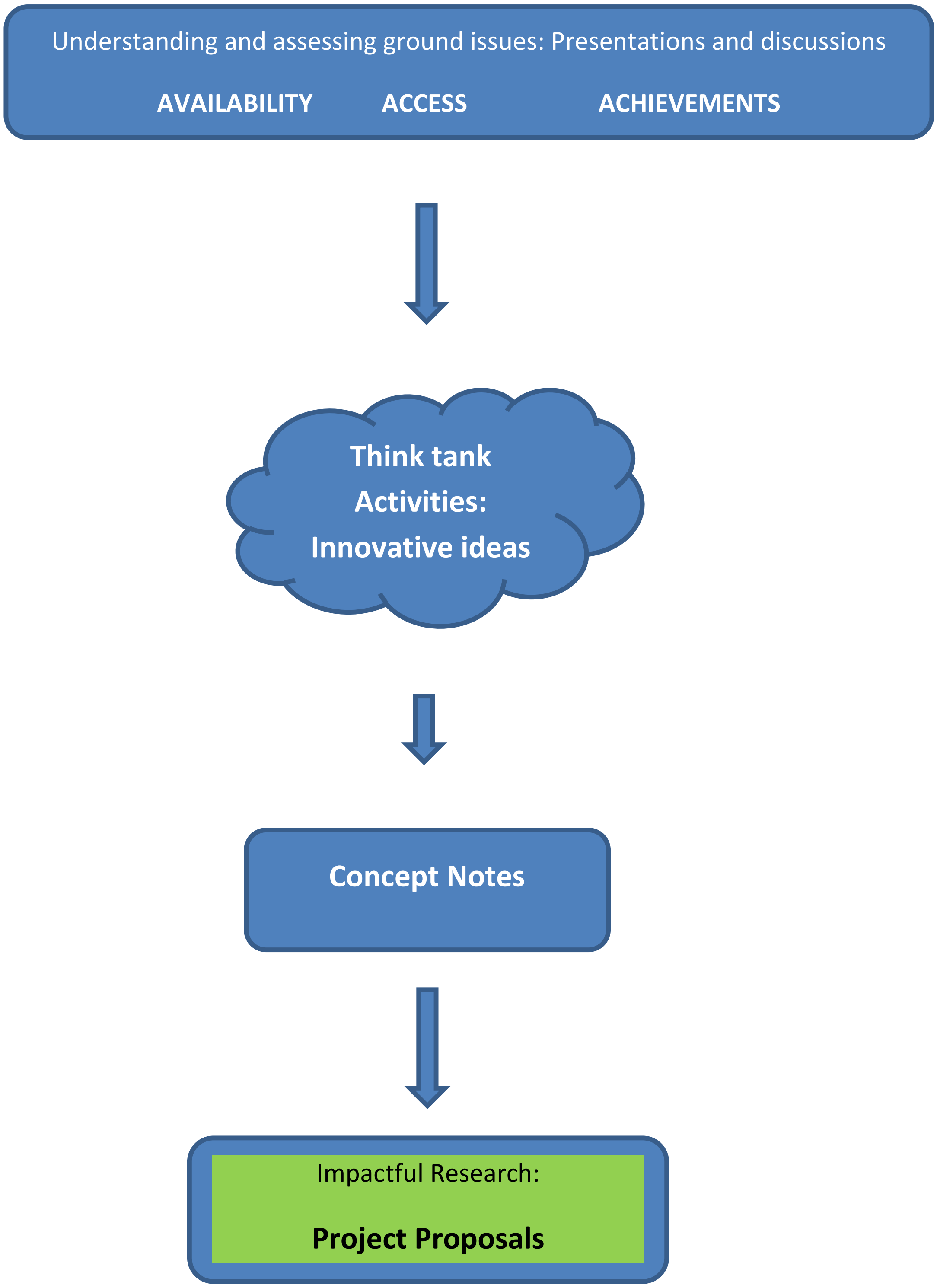

Figure 4. Schematic flowchart of the EGP workshop design, implementation and outcomes.

Annexure 1. Concept Notes - EGP Workshop

CN 1: Role of institutions in agricultural water management

Country/subregion/region: Nepal-India

Institutions at different scales respond differently to natural resource management (NRM), in general, and water resources, in particular, for inclusive livelihood improvement. Often successful rural institutions are not involved in NRM and the occasional attempts at forming new NRM institutions have failed when external support is withdrawn. Therefore, it is essential to study the role of existing successful institutions such as the Barind model and, where necessary, the need for new institutions to better manage NRM to ensure sustainable management of natural resources. For example, the Barind model is characterized by incorporating innovative water management techniques for a more efficient water resources management. Innovations include the following:

- Adopting appropriate localized policies to meet the needs of the project.
- Development of innovative "inverted well" and surface water supply.
- Underground plastic pipe water distribution system for surface channels.
- Replacement of cash transaction "pre-paid meter with SIM card."
- Provide the best possible services at reasonable and affordable rates.
- Introduction of crop credit.

This study will aim to analyze the feasibility of replicating the Barind institutional model and any other successful institutions, and replicate them in the regions of India and Nepal. Table 6 summarizes the concept note developed.

Context	Robust Institutional mechanisms, such as the Barind model, can have a profound impact on the success of irrigation projects. This study will aim at looking into the feasibility of the Barind model of Bangladesh and any other successful institutions, for their replication in irrigated areas of India and Nepal.
Fit with regional focus	Focus on institutional arrangements fit in with the government's vision of enhancing the well-being of the rural population; national planning.
Outcome	Improved governance and inclusive access to resources, especially for the poor and marginalized; equitable and sustainable groundwater development.
Benefits	Equitable and reliable access to water resources.
Beneficiaries	Marginalized and the poor people engaged in decision making.
Main target	Farmers, local social mobilizers, irrigation management agencies, community based organizations (CBOs)/NGOs, local administrations, policymakers and decision makers.
Pro-poor/gender issues	The study aims at providing inclusive access to water resources, especially to smallholders. Hence, it is pro-poor and gender responsive.
Impact on ecosystems	Help in maintaining robust ecosystems and improving degraded ecosystems through equitable and sustainable sharing of natural resources.
Objectives	• To identify the specific role of each institution at different spatial scales or administrative levels in ensuring NRM. • To study the feasibility of replication of the Barind model and the modifications required.
Novelty	Bottom-up analysis of the problems; reviving existing institutions to enable inclusive decision making; different institutional mechanisms will be studied.
Knowledge gaps	Lack of understanding of the reasons for institutional failures in NRM; diffusion of technology; policy implications of the change process; capacity development needs; and a detailed study of successful models such as Barind.
Partners	Farmers, CBOs/NGOs, private suppliers, government departments, local administrations, local political actors, policymakers, think tanks and decision makers.
Design	a) A comprehensive Barind model modified to suit the conditions in the EGP. b) A detailed regional analysis. c) Start with a sub-basin of the EGP as a pilot, and then replicate the model to other areas in the next 3-4 years.
Resources required	Tentative budget required ranges from USD 1.5 to 2 million.

Table 6. Concept note 1.

CN 2: Gender and labor migration in the EGP

Country/subregion/region: Nepal-India (Bihar) - Bangladesh

Male migration has led to feminization of agriculture, exacerbated inequity in access to water resources, and changed gender relationships and farming patterns. There is an urgent need to understand the sociological contexts of migration and its effect on agrarian structure, food production, household food security and gender issues. Also, it becomes imperative to understand what kind of support women farmers need to improve their livelihoods. Table 7 summarizes the concept note developed.

Context	Male migration has exacerbated inequity in access to water and changed cropping patterns, altering food security and implications on the labor market.
Fit with regional focus	Regional focus on the issue of male migration. The need to understand what kind of support women farmers need to improve their livelihoods.
Outcome	• A woman's enhanced capability to improve their livelihoods. Rural families also have improved livelihoods, not only through farming. • Social change in beliefs on the capacity and role of women. • Improved understanding of migration issues and its effects.
Benefits	Livelihoods of rural families have improved; gender-responsive policies.
Beneficiaries	Women empowered, less stress, greater well-being, higher confidence and skills. Others - farm families, policy planners.
Main target	Communities and youth; policymakers, NGOs, government agencies
Pro-poor/gender issues	Creates an enabling environment for community development, and women's empowerment and social change with more equitable gender relationships; less discriminatory in nature. Detailed study of feminization of labor.
Impact on ecosystems	Stress on the ecosystem will be constrained to their extent of resilience and, where possible, degraded ecosystems will be rehabilitated.
Objectives	Understanding new farming dynamics, gender relationships in regions – context-specific and identify mechanisms to improve equity in access to water.
Novelty	Women's attitude to water and relationship to land; sustainable rural mechanization to replace technology; sustainable livelihoods; new service providers and new entrepreneurs.
Knowledge gaps	Women-farm-water relationship and its impact on household food security and livelihoods is not well understood.
Partners	Policymakers, NGOs, development organizations, farmer groups
Design	Research findings will inform the design of development interventions; review of past studies will also be undertaken
Resources required	Time, money, labor and collaboration with partners.

Table 7. Concept note 2.

CN 3: Water resources assessment and information systems for the EGP

Country/subregion/region: Nepal-Bangladesh

Lack of information on the availability of water resources and resource endowment is one of the major hurdles in creating informed developmental interventions. There is insufficient information/decision support system to assess the spatial and temporal variability of surface water and groundwater availability and use at multiple scales. Such information is needed to allocate water resources (to all sectors). Therefore, basin-wide water resource availability, use, and possible future changes and its analysis would be good to support developmental interventions in the various sectors. Table 8 summarizes the concept note developed.

Context	Insufficient information/decision support system on spatial and temporal variability and use of both surface water and groundwater resources.
Fit with regional focus	Main national priority – in Nepal and Bangladesh – is for water resources development for irrigation, hydropower, and domestic and industrial uses. Therefore, information on basin-wide water resource availability, use and possible future changes is essential.
Outcome	Well informed and designed water policies; database creation.
Benefits	Reliable, equitable and sustainable development of water infrastructure will ultimately lead to: Productivity increase, gender-focused income growth, diversify work opportunities and improve access to water for the poor.
Beneficiaries	Policy planners, research agencies and ultimately farmers.
Main target	Farmers, communities, industry, planners/policymakers.
Pro-poor/gender issues	Improved information for water resources development and planning will benefit all sectors and stakeholders; incorporating gender-responsive and equitable resource endowment plans.
Impact on ecosystems	Detailed land and water resources mapping is an integral part of the ecosystem services management plan. Underutilized and vulnerable components of the ecosystem will be identified.
Objectives	To develop a cohesive water resources assessment plan; participation and commitment of relevant agencies to use the decision support system that has been developed; knowledge requirement.
Novelty	New and comprehensive database of water resources; reliable data and information about water management adaptation towards intensification and diversification.
Knowledge gaps	Lack of data for comprehensive analysis leading to water scarcity.
Partners	Water and Energy Commission Secretariat (WECS), Nepal; Department of Irrigation, Nepal; Groundwater Resources Development Board (GWRDB); Ministry of Environment; Ministry of Physical Planning; National Planning Commission; Ministry of Local Development.
Design	Integrated resources assessment framework will be developed followed by creation of database framework and data collection.
Resources required	USD 3 million

Table 8. Concept note 3.

CN 4: Water-energy nexus in the EGP

Country/subregion/region: Bangladesh-India-Nepal Terai

The water-energy nexus is a major player in the EGP. Ecologically sustainable energy mechanisms are the need of the hour, in the wake of the energy crunch faced by the region. The cost of irrigation in the region has significantly increased in recent years due to a myriad of factors, resulting in marginalization of vulnerable communities. This study aims to assess the factors responsible for this, as well as suggest adaptable strategies to mitigate such issues. Therefore, in this project, the scope of renewable, clean energy sources for groundwater access will be studied, which will help in devising appropriate energy policies for agriculture. Table 9 summarizes the concept note developed.

Context	The increasing cost of energy is making irrigation more expensive. Scope of renewable, clean energy sources for groundwater access needs to be studied.
Fit with regional focus	Renewed national and international focus on clean energy for irrigation.
Outcome	Access to irrigation water increased; irrigation value chain is strengthened because water will no longer be a constraint for agricultural production; equitable and sustainable groundwater development.
Benefits	Improved livelihoods, ecosystem services improved, better resource management, efficient energy systems.
Beneficiaries	Farmers, policy planners, research agencies, energy service providers.
Main target	Policymakers, researchers, farmers, service providers
Pro-poor/gender issues	Improved irrigation that is more cost-effective and pro-poor. This also creates new markets; it aims at providing clean energy solutions and has a direct impact on increasing access to water.
Impact on ecosystems	Will be environmentally responsive and help in sustaining robust ecosystems.
Objectives	To create environmentally responsive adaptation strategies for farming. Detailed cost-benefit analysis of different energy systems.
Novelty	Lower energy cost, more efficient irrigation systems, energy-efficient water use.
Knowledge gaps	Lack of cost-effective energy alternatives; demand for energy in all sectors including agriculture; comprehensive analysis of adaptation measures; study of different energy systems and their feasibility vis-à-vis local agrarian conditions and social structure.
Partners	NARES, policymakers, entrepreneurs and farmers.
Design	Review of existing adaptation strategies and their feasibility analysis.
Resources required	5 years. USD 2 million and two years to carry out a detailed scoping study.

Table 9. Concept note 4.

CN 5: Utilization of land and water resources in the coastal region to improve livelihoods

Country/subregion/region: Bangladesh

Coastal regions of Bangladesh witness abject poverty which is coupled with increased vulnerability of their livelihoods. The region also faces ecological unsustainability, frequent flooding, salinity and land deterioration problems.

These factors significantly decrease utilization of the resources, due to lack of investments, capacity and priority being given to the survival needs of these coastal communities. Prevalence of such endemic poverty is one of the major concerns of the policymakers. Better utilization of resources to better manage aquaculture and agriculture simultaneously will go a long way in addressing these issues, and in providing secure livelihood options to the poor. The study will also help in maintaining the ecological stability of this vulnerable region. Table 10 summarizes the concept note developed.

Context	Endemic poverty of the region and increased vulnerability to floods and cyclones, reduces the capacity of coastal communities to fully utilize the resources.
Fit with regional focus	Coastal region management, especially issues of chronic poverty is a national priority for Bangladesh.
Outcome	Improved livelihoods in the coastal region; better management of saline/flooded regions - ecological stability.
Benefits	Better resource management in coastal regions; increased income; land improvement.
Beneficiaries	Farmers, smallholders, coastal dwellers, policy planners.
Main target	Poor coastal inhabitants; vulnerable groups such as farmers and the landless.
Pro-poor/gender issues	This will help reduce poverty, improve livelihoods and target the most vulnerable (poor/women) communities. Gender-responsive strategies will be incorporated in the study.
Impact on ecosystems	Ensure protection of the ecosystems; stability in the environment; and will check the land deterioration of the region.
Objectives	To develop improved strategies for coastal regions aimed at the following: • Salinity/flooding issues. • Adaptation of agricultural and aquatic systems to salinity, waterlogging and flooding strategies. • Reduced vulnerability.
Novelty	New knowledge generated by coastal resource management.
Knowledge gaps	Lack of strategies to deal with annual flooding, consequences of poldering, and complementary management interventions for aquaculture and agricultural development.
Partners	NARES, policymakers, communities
Design	Comprehensive study of coastal management and devise appropriate strategies.
Resources	Five-year time frame.

Table 10. Concept note 5.

CN 6: The 'Ganges Water Machine' - ensuring adequate, equitable and reliable irrigation, and sustainable ecosystems in the Ganges Basin

Region: Transboundary

Despite there being plenty of water resources in the region (Ganges Basin), not enough water is available to meet crop evaporation demand for up to eight months a year. To increase its access for irrigation, it is essential to develop groundwater resources and manage floods within the basin. Possibilities of underground storage of monsoon waters, is cited by many as a useful proposition for water management in the region. Table 11 summarizes the concept note developed.

Context	Not enough water is available to meet crop evaporation demand in the region. Therefore, it is essential to develop groundwater resources and manage floods within the basin.
Fit with regional focus	Implementation of the 'Ganges Water Machine' is seen as a potential benefit for better water resources management and sustainable development.
Outcome	a) Increase access to water, food security and increased productivity. b) Improve flood management by capturing the floodwater and storing it for use during the dry seasons for irrigation. c) Equitable and sustainable groundwater development.
Benefits	Livelihoods will be improved by minimizing the severity of floods displacing societies, and by increasing agricultural productivity.
Beneficiaries	Farmers, policy planners.
Main target	The government bodies at national, state and local level; farmers.
Pro-poor/gender issues	It is a neutral concept; it is neither pro- nor anti-poor. It will entirely depend on the implementation of the project.
Impact on ecosystems	Ecosystem services will be improved by a lower magnitude of floods. It will minimize flood volumes and ferocity, and sediment loads.
Objectives	Create a consensus among policymakers to trigger groundwater management.
Novelty	The study aims to address not just the improvement of flood management and groundwater utilization but to also provide the benefits of the 'Machine' for the maintenance of ecosystems and food security.
Knowledge gaps	Knowledge of spatial and temporal consequences of groundwater development within the basin. Better understanding of recharge and discharge mechanisms, behavior and frequency of floods, the extent of shallow and deep aquifers, the occurrence of arsenic in groundwater. Quantifying flood damage, socio-environmental impact.
Partners	Central Ground Water Board, Central Water Commission, South Asia Water Initiative (SAWI), irrigation departments, groundwater departments
Resources required	Approximately USD 0.5 million, and two years to carry out a detailed scoping study.

Table 11. Concept note 6.

CN 7: Flood forecasting management systems

Region: India (extension to all three riparian countries)

Despite repeated flood events in the region, a robust forecasting system which can help in mitigating it is still not being utilized. This project will aim at developing a comprehensive, real-time flood forecasting system, which can help in giving timely inputs to disaster management agencies and state officials. The study will also aim at developing an appropriate capacity building system, which will be required to utilize such a modelling system. Table 12 summarizes the concept note developed.

Context and regional focus	In the wake of recent flood disasters in the region (Bihar-Kosi floods, Uttarakhand floods), a real-time flood management system becomes highly relevant and vital for sustainability of the region.
Outcome	Output will be integrated flood management and capacity building systems. Outcomes will be preventing natural calamities and better management of the resources.
Benefits	Better forecasting systems.
Beneficiaries	Farmers, local inhabitants, disaster management agencies.
Main target	Government agencies.
Pro-poor/gender issues	It will have direct impact on pro-poor and gender issues of the region.
Impact on ecosystems	It will improve the ecosystem and better resource management.
Objectives	To develop a real-time flood forecasting management system.
Novelty	An improved real-time flood forecasting management system.
Knowledge gaps	Technical knowledge, real-time database of entire region.
Partners	Government agencies, Farmers, NGOs and National Agricultural Research Systems.
Resources required	Approximately USD 1.5 million.

Table 12. Concept note 7.

Annexure 2. Concept Notes Framework

1. What is **the context/problem**? How does this fit in with national or regional priorities?

   Research Questions

2. **Outcome**: What are the main types of development changes that we want to support?

   Who has to change?

   What is required to facilitate the change?

   What will be the benefits? Who will be the beneficiaries?

   Who will be the main target?

   How does this address pro-poor or gender issues?

   Will this sustain or improve existing ecosystems?

   How will this reach beneficiaries?

3. **Objectives**: What needs to be in place for these outcomes to be possible?

4. **Knowledge requirement**: What knowledge is required/necessary to support the envisioned change?

   What's new?

   What are the knowledge gaps (technological/institutional/policy/others)?

5. **Partners** in research?

6. What **resources** will be required?

Annexure 3: Background Papers and Presentations

Listed below are some of the abstracts selected highlighting the concomitant water management issues, and their implications on the availability, access and achievements that can be obtained through the use of natural resources.

Research to Lead Development in the Eastern Gangetic Plains

Groundwater in the Eastern Gangetic Plains: Research Needs for Better Management of the Resources

The Aquifer Systems and Groundwater Resource Availability in the Eastern Gangetic Plains

Water Resources in Nepal and IWMI-Nepal Strategy

Water Management in the Ganges Coastal Zone of Bangladesh

Cascading Ganges: Floods and their Impact in the Eastern Gangetic Plains

Improving the Rural Livelihoods through the Development and Management of Small-scale Water Resources of East India and Nepal

Water-Energy Nexus in the Eastern Gangetic Plains: Old Issues and New Options

Water Management Institutions and Policies in Bangladesh

Putting Bihar Agriculture on Take-off Trajectory: Nurturing the Seeds of Growth

Land Tenure and Its Effect on Water Management in Bihar and Nepal

Agrarian Straightjacket: Constraints to Achieving Potential Yields in Rice Production

Replication of the Barind Model to Muhuri Irrigation Project

Participatory Approach for the Efficient Use of Water to Enhance Water Productivity and Livelihood Improvement of Small Farmers in the Eastern Region

Constraints to Exploiting Fisheries Potential in the Indian Indo-Gangetic Basin

Research to Lead Development in the Eastern Gangetic Plains

Tushaar Shah, Senior Fellow, International Water Management Institute (IWMI)

As the CGIAR system has increasingly begun to emphasize outcome-oriented research, there has been a growing interest in understanding how to redirect research for policy and development impact. In an institution like IWMI, the impetus for policy and development impact has to come from creative tension between demands for quality science, on the one hand, and for real-time outcomes and development impacts, on the other. In responding and adapting to these conflicting pressures and expectations, we need to constantly work on three aspects of research: what to research, how to manage research for development, and what to do with research products.

What to research:

This has to do with how we conceptualize and design our research projects. If the aim is 'research for development', the closer our research questions are to issues important to powerful policymakers then the greater the chances of success. Issues important to top societal leaders vary across societies. There is some equivalent of Maslow's hierarchy in operation. In the EGP countries today, this hierarchy would be different, for example, from say the European Community (EC) countries. The schematic diagram (Figure 1) attempts to develop a research framework for development issues in the EGP.

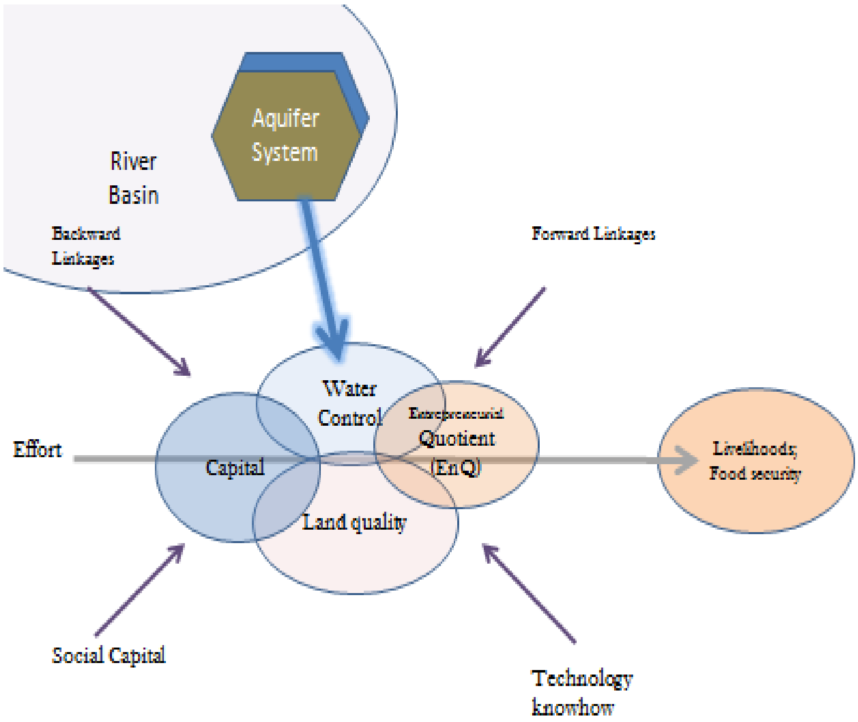

Figure 1. Framework for Research.

In the former, livelihoods, food security and poverty alleviation are at the top; in the latter, household food security may not be on policymakers' mental map at all and reducing emissions may top the list. To the extent that it is aligned with the concerns of policymakers who have the power to make/change policies, research would have greater potential to deliver development impact. Policymakers generally look for change propositions that co-deliver 'political dividend' and 'development dividend' (and sometimes 'pecuniary dividend'). Policymakers also take propositions seriously only when they can carry them through using their own 'bandwidth' in the time frame available to them. In the context of the EGP, our research will have high potential for development impact if it generates practical, doable solutions to agrarian livelihoods for the region's small farmers. What we often overlook is that while water control is a necessary part of such solutions, it is seldom sufficient as shown in Figure 2. Therefore, a 'research-for-development' project cannot operate just in a 'water' space; it needs to encompass a bigger playing field in a 'water-energy-agriculture-livelihoods' space.

How to manage research for development (R4D):

Research leadership: Since R4D cannot take a water-centric view of the world, its leadership needs to promote a disciplinary, problem-solving research ethos to operate on a larger water-energy-agriculture-livelihoods canvas. This often clashes with the requirements of high science.

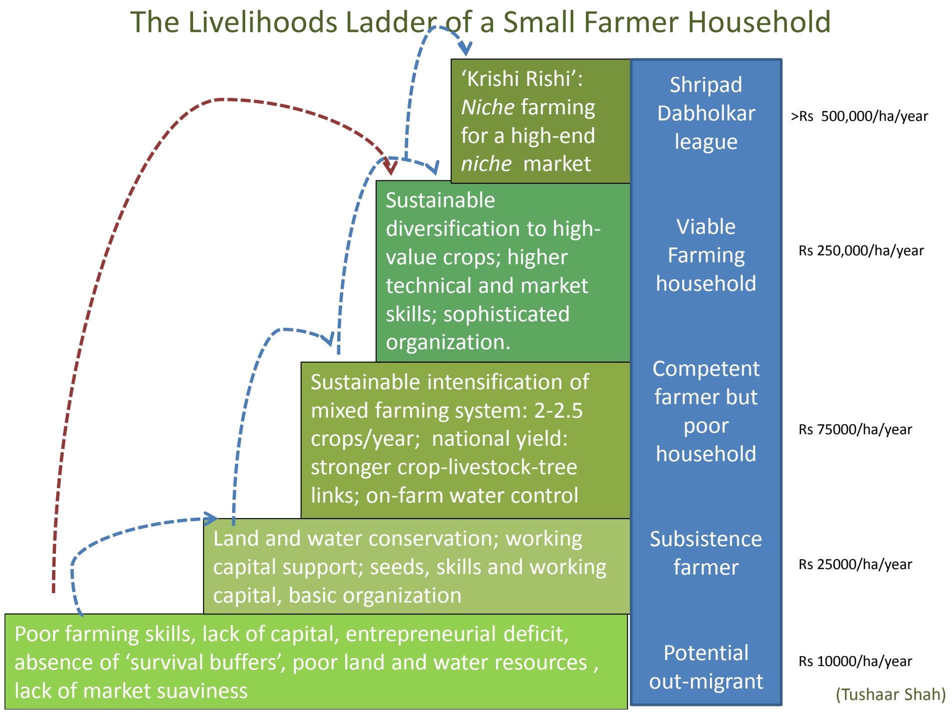

Figure 2. Livelihood ladder for a small farmer household.

Research culture: Outcome orientation is central to R4D's distinctive work culture. Senior scientists often look for problems that fit into their own area of specialization. Often, providing a flexible and nurturing workplace for young interns, who have not yet found their niche, is effective in exploring new, blue sky ideas.

Research protocol: Participatory agenda building and frequent discussions of evolving research need to be a critical part of the protocol which may involve: (a) scanning the research world to identify knowledgeable people who can contribute; (b) commissioning thought pieces; (c) commissioning small quick studies; and (d) undertaking their own field research. In the IWMI-Tata Water Policy Research Program, weekly seminars were held and everyone presented their work—at whatever stage or in whatever shape, the entire group participated and brainstormed along with the presenter. The hours spent every week were thus considered an important investment. Outside experts with relevant knowledge or those with bold, innovative ideas were often invited for interaction in these weekly meetings (IWMI-Tata Water Policy Research Program 2012).

Research anchor event: In the IWMI-Tata Water Policy Research Program, the Annual Partners' Meet has emerged as the 'finishing line' that anchors all work during a given year. The Annual Partners' Meet provides the test of each team member's performance and success in delivering policy-relevant research. It also reinforces the problem-solving emphasis. The Annual Partners' Meet itself—and the run up to it—are the key vehicles for the uptake of ideas and their impact. New ideas/propositions emerging from research carried out by the IWMI-Tata Water Policy Research Program get into circulation at this stage, and some go viral.

Research ecosystem: Finally, an innovative R4D program can thrive only in an institutional ecosystem that is nurturant, supportive, flexible and quick-acting. Innovation, by definition, means taking risks; some ideas will succeed and some will fail. If the ecosystem penalizes failure and ignores to recognize and reward success, innovation will come aground.

What to do with research products:

Aggressive communication of research products is critical for converting research into development outcomes. Effective R4D will always be in search of 'convening power' and 'reference power'. 'Convening power' gives you the ability to get an audience with people who have the power to make change. 'Reference power' means that change-makers struggling with a certain set of problems, in which you have accumulated R4D expertise, will seek you out to get advice. For both these factors, effective communication of the research is the key.

While we should use the best professional communication resources we can command for research outreach, there is also the need to recognize the chancy and serendipitous route that often transforms research results to policy change. The most critical step in achieving effective communication is to get a powerful message that has a practical, doable change proposition with the twin dividends (political and developmental) that policymakers are after. Strong messages often communicate themselves; equally, powerful communication campaigns help little when the message itself has limited appeal.

References:

IWMI-Tata Water Policy Research Program. 2012. *Capacity building as a vehicle for policy research: A compendium of ITP researchers and their research: 2001-2012.* Available at http://iwmi-tata.blogspot.in (accessed on July 30, 2013).

Groundwater in the Eastern Gangetic Plains: Research Needs for Better Management of the Resources

S. C. Dhiman, former Chairman Central Ground Water Board, Ministry of Water Resources, Government of India

The role of groundwater to meet the demand for water in the agriculture, industrial and domestic sector is progressively increasing. This necessitates its scientific management with a long-term perspective. The complexity and diversity of the hydrogeological set up in the Gangetic Plains calls for the study of all aspects of water use to identify the availability of groundwater resources, assessment of their potential, draw/abstract the water prudently, and manage its quantity and quality in a sustainable manner .

Groundwater has emerged as the primary democratic water source and poverty reduction tool in India's rural areas. Groundwater, on account of its availability, dependability and low capital cost, has made a significant contribution to the growth of India's economy. This has been an important catalyst for socioeconomic development. More than 85% of rural domestic, 50% of urban and more than 50% of irrigation requirements are being met from groundwater resources without due regard to the recharging capacities of aquifers and other environmental factors.

The unplanned and non-scientific development of groundwater resources, mostly driven by individual initiatives, has led to an increasing stress being placed on the available resources. The adverse impacts of this can be observed in the form of long-term decline of groundwater levels, de-saturation of aquifer zones, increased energy consumption for lifting water from progressively deeper levels and deterioration of water quality due to seawater intrusion in coastal areas. On the other hand, there are areas in the country where groundwater development is still at a low level in spite of the availability of sufficient resources. The basin, however, shows disparity in view of geomorphology and hydrogeology in its eastern and western parts; the EGP is richer in terms of soil, ecology and water resources due to aggradation character.

The Western Gangetic Plains (WGP), covering Uttar Pradesh and further upstream of Ganga, is degradational in nature and its agricultural system is different. In the hilly region of Nepal, isolated/localized aquifer systems of shallow depth (< 150 m depth) are formed; multiple aquifer system (> 1,000 m thick) occur in the alluvial plains of India and Bangladesh except in Bhabar and the Tarai regions in India. In Ganga, the alluvial plains, of which the EGP is a part, deeper aquifers are even extending below the sea in the Bay of Bengal.

In view of the factors mentioned above, there is a need for strategies for scientific and sustainable management of the available groundwater resources to avert the looming water crisis. Such a management strategy should consider various aspects such as the availability of groundwater resources and their development prospects.

The Ganga Basin is known for intensive cultivation (agrarian with more than 70% of the population engaged in agriculture) because of its fertile soil and abundance of water resources - both surface and subsurface. There is further scope for developments in agriculture in the EGP, covering the states of Bihar and West Bengal in India and Bangladesh, two of the most populous states in the basin, by enhancing the assured irrigation from its rich water resources through the adoption of proper planning. Although flood regularly ravages agriculture and the economy of major parts of the region, the available water resources have not been utilized to their fullest extents. People in the states of Bihar and West Bengal mostly tap the granular zones in the shallow aquifer within a depth of ~70 m below ground level (bgl). In very shallow water (mainly areas prone to waterlogging), traditional groundwater structures are commonly used. The study finds that a major part of the available annual replenishable groundwater in the aquifer has been utilized for irrigation purposes, in particular. Large parts of the region remain under waterlogged conditions due to shallow water levels (< 2.0 m bgl), which again warrants a huge loss of the resource as rejected groundwater recharge, particularly in the Kosi and Mahananda river basins. If we consider the availability of groundwater resources and its utilization, there is sufficient scope for increasing groundwater-based irrigation.

The parts of Ganga-Brahmaputra-Meghna (GBM) delta in West Bengal and the alluvial tracts along the Ganga River, and its northern plains in Bihar in the EGP, have been the continuous attention of researchers, agencies, NGOs and particularly the state governments in the last few decades mainly because of the dangerous level of arsenic (> 50 parts per billion [ppb]) in groundwater in the shallow aquifer. These aquifers are also traditionally targeted for drinking water sources.

The aquifers in the Gangetic Plains, and particularly in the EGP, are a lifeline for drinking and irrigation supplies. The resource development is within the threshold limit. A Proper management plan is required for sustainable use of the aquifers. The management plan should be based on sound scientific understanding of availability of the resources and hydrodynamics of the aquifer system. We require a knowledge-based understanding of various aspects of groundwater occurrences, movement, aquifer geometry, quality variations, and response and components of resources for its full and sustainable utilization.

Therefore, some of the areas requiring the attention of researchers are as follows:

1. There is a high loss of evapotranspiration from groundwater resources due to shallow water levels. Regional-level estimation is required for calculating the loss of the evapotranspiration component and scope for its utilization.
2. Assessment of groundwater resources (dynamic and static - deeper aquifers) and subterranean discharge to sea.
3. There should be a detailed estimation of recharge that would have taken place, but did not due to shallow water levels. This rejected recharge component is practically part of the dynamic resource. Safe yield of aquifers, considering the sub-basin configuration.
4. Subregional-scale recharge and discharge areas in relation to interaction between surface water and groundwater. Hydraulic parameters of major aquifer systems and hydraulic connections between the aquifers in multi-layered aquifer systems. This is particularly important for designing an artificial recharge plan.
5. Assessment and improvement of existing/traditional groundwater abstraction/recharge/conservation technologies (techniques) and power technologies along with their expected benefits.
6. Groundwater modeling for better understanding of aquifer systems and its relationship with groundwater movement (lateral and vertical): surface water bodies/river; impact of development activities and quality variations (arsenic and seawater intrusion) for developing sustainable water management plans.

The Aquifer Systems and Groundwater Resource Availability in the Eastern Gangetic Plains

Dipankar Saha, Central Ground Water Board, Government of India

The Ganga Basin, with 26% of India's land mass, 30% of the country's water resources and more than 40% of its population, forms one of the most densely populated regions in the world. The alluvial cover occupying the central position of the Indo-Gangetic foreland system extends mainly along the states of Uttar Pradesh, Bihar and West Bengal. The basement of the Gangetic Plains is not uniform and is marked with a number of ridges, faults/grabens and lows. The east-west elongated Middle and Upper Ganga Plains, to the west of Munger-Saharsa ridge, covers vast alluvial tracts of Uttar Pradesh and Bihar. In the east of Garo-Rajmahal Gap, the plains continue as the Lower Gangetic Plains which further merges with the large delta built by the Ganga-Brahmaputra-Meghna (GBM) river system covering West Bengal in India and Bangladesh. The GBM river system carries about 1×10^9 ton/year of sediment, building up the largest delta system in the world. Although the different units of the Gangetic Plains and the Deltaic region form a single geographical unit, spanning over northern India and Bangladesh characterized by a composite sediment transport and deposition system, geotectonic and sedimentation histories were not exactly the same in the geologic past.

The EGP in India, a geographical entity often referred to for its fertile soil and abundant water sources, primarily cover the states of Bihar and West Bengal. The area is underlain by a thick pile of quaternary sediments, made up of alternating sequences of sand, silt, clay and their admixtures in varying proportions. Upstream of the Garo-Rajmahal Gap, the east-west aligned Gangetic Plains is mainly fed by sediments from fast-eroding Himalayas in the north, and to a lesser degree from peninsular craton. The aggradation rate in this part has exceeded the down-flexing rate of the basement, causing the rate of sedimentation to exceed that of the subsidence, resulting in the deposition under high-energy fluvial process without any trace of marine incursion. The sediment wedge in this part is asymmetrical, from a few meters towards peninsular craton in the south and reaching up to 5 km near the Himalayan orogen in the north. In the east of the Garo-Rajmahal Gap, the sediments are laid on an easterly sloping basement having provenances from both the Himalayas and the peninsular craton. The sediment wedge thickens from the platform margin areas to the east and southeast. The sedimentation in this part is greatly affected by sea level changes controlling development in the delta. The quaternary sand layers within the sedimentary sequence form potential aquifer system within the top couple of hundred of meters. The inter-layered clay and sandy clay behave as aquitard/aquiclude depending upon whether the clay layers are regionally extensive and their vertical permeability. Groundwater exploration has revealed two to three principal aquifer systems within a depth of 300 m bgl, with thickening and thinning isopachs of aquifers/aquitards. In deeper aquifers, groundwater occurs under semi-confined to confined conditions. In the large inland alluvial fan areas, such as the Kosi, the Gandak and the Sone in Bihar, the sedimentary sequence up to 200 m bgl is predominantly sandy, forming some of the most prolific aquifer systems in the world. The unique example is Patna urban area, located on the eastern fringe of the Sone fan. The aquifer framework is made up of middle to coarse sand of peninsular craton provenance, inter-layered with Ganga sediments. The entire water demand of ~2.0 million inhabitants of the urban area is being supplied from underlying aquifers at 80-250 m bgl. Groundwater occurs under semi-confined conditions with considerable transmissive capacity (5,470-9,229 m^2/day). Pumping discharge of deep tube wells varies from 180 to 220 m^3/hour with a drawdown of less than 5 m. Even with a staggering annual groundwater extraction rate of 0.212 Bm^3, the long-term decline (last 30 years) of water levels has been assessed as less than 4 m, revealing the prolific nature and copious recharge of the aquifer with abundant water resources. The fluvial-lacustrine deposits in inter-fan areas and along the marginal alluvial areas are, however, characterized by aquifers with less potential. In the Lower Gangetic and Deltaic Plains in West Bengal, uninterrupted sand sequence is observed down to 150 m bgl in Nadia and Murshidabad districts. The alluvial deposits from Jalpaiguri-Cooch Behar district in the north to Medinipur 24-Paraganas districts in the south, where the aquifers are fairly thick and regionally extensive, have yield prospects higher than 150 m^3/hour. The aquifers within the older alluvium are, however, of comparatively low potential. In the coastal tract in the southern part of West Bengal forming the active delta of the Ganga-Bhagiarathi river system, groundwater occurs under confined conditions at deeper level. Freshwater aquifer occurs at 120-300 m bgl, sandwiched between the saline aquifers. Thick clay at the top hinders any direct recharge to the fresh aquifer in these areas.

The spatiotemporal variation in hydraulic head in the EGP is considerable. Presently, monitoring of water level is primarily targeting shallow unconfined aquifers. Increasing development of the deeper aquifers spells the need for monitoring the piezometric surfaces. In Bihar, the pre-monsoon 2011 measurement (May) revealed 55% of the wells (n=418) as having their water level within 5-10 m bgl. Deeper levels (> 8 m bgl) have been recorded in 8% of the wells monitored, geographically confined in older alluvium stretches in the southern part of the Ganga. During the August measurement (mid-monsoon), in 86% of the wells, the levels were recorded as less than 5 m bgl. Pre-monsoon 2011 (April) water levels in West Bengal remained by and large within 10 m bgl (n= 888). Deeper levels have been observed in Barind and Bhabar belts as well as older alluvium bordering the craton (maximum 27.4 m bgl). The mid-monsoon measurements revealed that the aquifers are recharged to a comfortable level, as water levels in 75% of the wells have been recorded within 5 m bgl. The older alluvium units in Bihar and West Bengal are not recouped to their fullest extent during the monsoon. In the Kolkata urban area, the piezometric level is significantly deep due to the heavy extraction of groundwater and remains in the 10.7-19.0 m bgl range during pre-monsoon and between 8.3 and 18.3 m bgl during post-monsoon periods.

Although the EGP is underlain by some of the most potential aquifer systems in the Indian subcontinent, a careful resource availability assessment is warranted for sustainable use of the aquifers. The area represents intensive agricultural practices which is reflected in the cropping intensities (Bihar - 135%, West Bengal - 177%). Groundwater extraction for irrigation in the area is nearly 20 Bm^3/year. Annual recharge to the shallow groundwater system is 53.8 Bm^3. The stage of shallow groundwater resources development of the region is about 40%. However, if five broad different geographical units of the EGP are considered (*North Bengal Plain*, *South Bengal Plain - east of Bhagirathi*, *South Bengal Plain - west of Bhagirathi*, *North Bihar Plain* and *South Bihar Plain*) separately, variations in the stage of groundwater development are observed. Forty-two blocks are found to be semi-critical, out of which a maximum number of blocks are located in the southern part of West Bengal covering the eastern part of Bhagirathi. Considering the volumetric availability of the replenishable resource, additional areas can be brought under assured irrigation. The rejected recharge component during the monsoon in areas with shallow water levels is yet to be determined and assessed in detail. This component can be a part of the dynamic resource once the groundwater extraction increases in areas with a shallow water table.

Table 1 shows some components of the replenishable groundwater resource, such as *groundwater availability*, *gross draft for irrigation* and *net volume available for additional irrigation development*.

Geographical unit	Broad morpho-stratological units	Net groundwater availability (Bm^3)	Gross draft-irrigation (Bm^3)	Net groundwater availability for additional irrigation development	Stage of groundwater development (average of district-wise values)	Number of semi-critical blocks
North Bengal Plain	Mainly Young Alluvium, also patches of Bhabar belt and Old Alluvium	8.39	2.06	6.07	31	2
South Bengal - East of Bhagirathi	Young Alluvium	5.54	4.08	1.47	76	23
South Bengal - West of Bhagirathi	Young Alluvium and Old Alluvium	12.44	3.95	8.08	31	13
North Bihar Plain	Mainly Young Alluvium, also pockets of Old Alluvium	16.12	6.22	8.32	46	Nil
South Bihar Plain	Young Alluvium and Old Alluvium	9.65	3.45	5.31	43	4
Total		52.14	19.76	29.25		

Table 1. Groundwater availability in different parts of the EGP.

The lump value of stage of groundwater development of the area may render a myopic view of groundwater resource availability, as it varies considerably with two cardinal parameters, yield and transmissivity of aquifers. Moreover, at pockets, the stage of groundwater development has already crossed 70%. Although no assessment unit (community development block) has shown groundwater extraction exceeding the annual recharge, 38 and 4 blocks have been categorized as being semi-critical in West Bengal and Bihar, respectively. The management should consider the rejected recharge component and dampened infiltration from the surface due to shallow water levels. The water management plan should include the conjunctive use of surface water and groundwater in command areas, and the demand-side management of the resource. Water-use efficiency, particularly for the agriculture sector, should be an integral part of the plan. Rainwater harvesting and artificial recharge should be taken up in a planned and coordinated manner, targeting the aquifer/aquifers which are to be recharged within the multi-layered aquifer system after careful consideration of aquifer-specific flow regime and its hydraulic properties.

Water Resources in Nepal and IWMI-Nepal Strategy

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Introduction

Nepal is one of the most water-abundant countries in the world, with its 6,000 rivers, total mean annual runoff of 224 billion cubic meters (Bm^3) and per capita water availability of 9,000 m^3. Yet, the National Water Plan of Nepal (2005) indicates that only 72% of the population has access to safe drinking water, only 562 MW of hydropower capacity are exploited (out of an estimated potential of 83,000 MW), and 'little consideration is given to environmental requirements'. Furthermore, over 80% of Nepal's population depends on subsistence agriculture for livelihoods (World Bank 2009). Agriculture consumes around 99% of all water withdrawn in the country (http://www.fao.org/nr/water/aquastat/main/index.stm). Yet, only 24% of arable land is irrigated, crop productivity is significantly lower than in the rest of South Asia, and the country relies heavily on food imports from India. Thus, the issue of water resources development and management looms large for the future of the country.

The hydrology of Nepal is primarily monsoon-driven. Around 85% of rainfall occurs during the four monsoon months of June to September. The temporal variability of rainfall and runoff is hence very high, and the problem of excess water during the monsoon and water scarcity during the dry season affects all aspects of life in the country. During the 2008-2009 droughts, there were power cuts of up to 16 hours per day in Kathmandu, barley and wheat crop yields dropped, and nearly 2 million people were placed in danger of food insecurity (WFP 2009). Yet, in the same year, floods during the following monsoon destroyed significant cultivated land.

Future variability and uncertainty in water availability due to climate change are of paramount importance for food security in Nepal and the larger Himalaya. The recent extremes of water shortage interspersed by devastating floods are consistent with the climate change projections for the region (IPCC 2007; UNEP 2009; Bates et al. 2008), which are gradually becoming more certain. The climate change impacts in the Himalayan region encompass changes in both precipitation and temperature, and will have wide-ranging consequences, including glacier retreat, loss or functional change of wetlands, increased flow variability, timing and amounts, and will, consequently, affect agriculture, rural livelihoods and the overall economy (Bates et al. 2008; UNEP 2009). There is an increasing trend of male migration from rural areas to urban centers. While the triggers of migration can be socioeconomic, environmental pressures seem to play a major role in the geographically challenging mid-hills and high mountains. Abandonment of farms in this region, due to increasing climate variability, results in land erosion on the fragile unmaintained terraces, women and elderly heading farming households and remittance income being the backbone of livelihoods.

The goals of the National Water Plan set out to ensure that, by 2017, 100% of the population will have access to water supplies, an additional 10,000 MW of hydropower will be developed, and 64% of all irrigable land will have year-round irrigation. Such massive leaps over such a short period of time will require speedy and targeted development investments.

Opportunities for IWMI: Synthesis of the Institute's work in Nepal

For more than a quarter century, IWMI's research in Nepal has contributed to upgrading the country's water management. Beginning in 1986, pioneering research carried out by IWMI's office in Nepal found that 'farmer-managed irrigation systems' outperform official agencies in irrigation planning and implementation. This paved the way for 'irrigation management transfer' initiatives, favoring farmer participation over bureaucratic mandate in system management. In that spirit, IWMI's office in Nepal carried out a pilot study on participatory management in the Banganga Irrigation System and research in the West Gandak System on what services local 'water users associations' (WUAs) require for effective utilization of irrigated land. Other studies carried out by IWMI in Nepal have documented relationships between irrigation access and poverty reduction; benefits to women and communities from female participation in WUAs; and the consequences of water transfer between river basins. Meanwhile, IWMI's office in Nepal broadened its research portfolio to include basin water availability and use assessments under current and future conditions in a few river basins. With agriculture being its main livelihood and the need for water, Nepal may face challenges from changing rainfall and flow patterns, along with glacier and snow melt as a result of climate change. Climate and hydrological modelling for the Koshi Basin points to higher seasonal variations, increased frequency of high flows and overall increases in rainfall in some areas. That spells more floods, more droughts and more insecurity for poverty stressed farms. There is, however, still a lot of uncertainty associated with climate change projections for the future. Research comparing outputs from climate and hydrological models has shown some worrying inconsistencies in the predicted availability of water. Although the outputs from different computer models, known as the global and regional circulation models, agree on increases in temperature, there are varying results regarding rainfall and water flows. The results are sure to add to the confusion among policymakers, who are desperate for reliable information about the likely effects of climate change on water supplies and agriculture in Nepal.

Any adaptation strategy that the government plans will have to take future climate uncertainty into account. Reducing risk and increasing resilience through physical and non-physical interventions are, therefore, good strategies. Climate change will increase the need for investment in conventional water management measures such as storage, basin transfers and improved agricultural water management technologies. These will all help to increase the reliability and efficiency of water use. However, there is also now new space for introducing other mechanisms such as climate-based insurance schemes or interinstitutional cooperation to increase community resilience. Two recent initiatives by IWMI's office in Nepal address climate change vulnerability with an eye on gender. Terai zone findings identify climate change as one of several agrarian stresses producing male out-migration, which increases workloads for women. In Dhanusha District, male and female teams trained in video production shoot their own stories on how climate change affects livelihoods, and how men and women choose adaptation priorities. Ongoing projects are addressing an even broader range of issues. On tank irrigation, it studies problems in rehabilitation, access, allocation and canal links. On groundwater, Terai zone interventions during 2013 will assess the feasibility of dug wells and sharing mechanisms, rehabilitation of community ponds, and exploring suitable energy sources for pumping. In the Kathmandu Valley, IWMI's office in Nepal will evaluate the health risks of using wastewater for urban farming.

Future opportunities

Good policies on water requires good evidence to support them. In Nepal, there is still a lack of fundamental information related to the quantification of resources, which is necessary to base appropriate recommendations for the present and the future. For example, basin-wide water balances, water accounting and water productivity information for the entire country are not available. The hydrologic characteristics, including both surface water and groundwater, have not been properly studied. Past climate trends as well as the impact of climate change on water resources and use have not been adequately assessed. The linkages between socioeconomic trends, water use and management have not been properly assessed. Furthermore, the poor performance of the bureaucracy has been commonly identified as being one of the key factors affecting the outcomes of public and donor-led water programmes in the country. The bureaucratic system has been commonly described as centralized, highly hierarchical, and prone to motivational and informational problems such as rent-seeking, corruption, and information loss and information asymmetry. Institutional reforms have been led within the bureaucratic system, based on the premise that individual behavior is primarily driven by rational choice and institutional change is key to modifying the incentives and interests of bureaucrats. Yet, institutional reforms in the bureaucracy have encountered resistance and have not yielded expected results. In order to build upon IWMI's past studies, capitalize on existing partnerships and maintain the Institute's niche, it is proposed that the Nepal office of IWMI focus on the following areas:

- Resource assessment – links to Information
    - Water availability, access and drivers of change (hydrological modelling, monitoring and field-based studies).
    - Climate change and adaptation strategies.

- Agricultural water management solutions
  - Water management and productivity in Asia.
  - Revitalizing farmer management for large-scale agency managed schemes - developing institutional reforms and incentive systems for farmer participation.
  - Innovative solutions for expanding irrigation in the hills and mountains.
  - Conjunctive water use.
  - Sustainability of farmer-managed irrigation systems.
  - Commercialization of agriculture.

- Resilient agroecosystems
  - Increasing storage and soil water retention.
  - Watershed management.

- Peri-urban solutions
  - Business opportunities for resource recovery and reuse.
  - Safe wastewater and excreta use.
  - Efficient land/water management in peri-urban landscapes.

- Uptake
  - Understanding factors that create enabling environments.
  - Initiatives aiming at changing values and attitudes.
  - Enterprise development/business modeling.
  - Effectiveness of external donor- and government-funded projects.
  - Monitoring and evaluation (M&E), and impact assessment.

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Water Management in the Ganges Coastal Zone Of Bangladesh

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Introduction

Besides its function in the hydrological cycle, water has social, economic and environmental values, and is essential for enhanced food production and sustainable development. High rates of population growth, a changing climate, rapid urbanization, expansion of infrastructure, land conversion and pollution translate into changes in the water flows, pathways and availability of water. The water resources in the Ganges coastal zone of Bangladesh are vital for crop production, ecosystem sustenance and livelihoods. These resources are largely shaped by tidal dynamics and transboundary flow, and are affected by changes in the socioeconomic and institutional systems. Salinity dictates the availability of freshwater. The quantity of freshwater that is available is likely to decrease due to the combined effects of external drivers of change, including population increase, water pollution, inadequate planning and management of transboundary waters, climate change and inefficient operation of water management projects. Consequently, there is an increasing potential for water scarcity, crisis and associated conflicts in the future. It is important to identify and prioritize these drivers of change, and assess their effects on water resources, towards building resilient water governance and management to cope with the present and projected future climate conditions. There are 139 polders in the coastal area of Bangladesh, out of which 53 are situated in the Ganges coastal zone. Water management of the coastal polders is vital for crop intensification. The present study being conducted under the CGIAR Challenge Program on Water and Food (CPWF) has identified external drivers of change and their effects on water resources.

Methodology

Selection of external drivers: The list of drivers of change has been identified using two approaches. In the first approach, a questionnaire survey was carried out among the experts in the relevant disciplines, researchers, and professionals of planning and implementing/operating organizations such as the Water Resources Planning Organization (WARPO), Bangladesh Water Development Board (BWDB), Local Government Engineering Department (LGED), BRAC, Bangladesh Rice Research Institute (BRRI) and Department of Agricultural Extension (DAE). The questionnaire was developed based on a literature review, field information and consultation with partner organizations. In the second approach, the drivers of change have been identified and ranked through community consultation in selected polders. Since these two approaches are different, there was a need to triangulate and integrate these two sets of data through a workshop involving all stakeholders. In the workshop, discussion among representatives from different fields were facilitated and that resulted in arriving at a consensus on the list of key drivers of change and their priorities.

The key external drivers of change are transboundary flow, population growth, change in water management practices, land-use change and climate change.

Modelling: The present CPWF study attempts to offer a comprehensive account of the above issues and to also achieve outcomes to contribute to the Ganges Basin Development Challenge. The effects of anticipated external drivers of change on salinity intrusion, water availability and drainage in the different polders of the coastal zone have been assessed using available water flow and salinity models based on the MIKE series. The Soil and Water Assessment Tool (SWAT) has been used to assess the flow from the Ganges Basin upstream of Bangladesh and water flow for land-use change. Figure 1 shows the assessment of impact of external drivers on water resources of the coastal zone of Bangladesh.

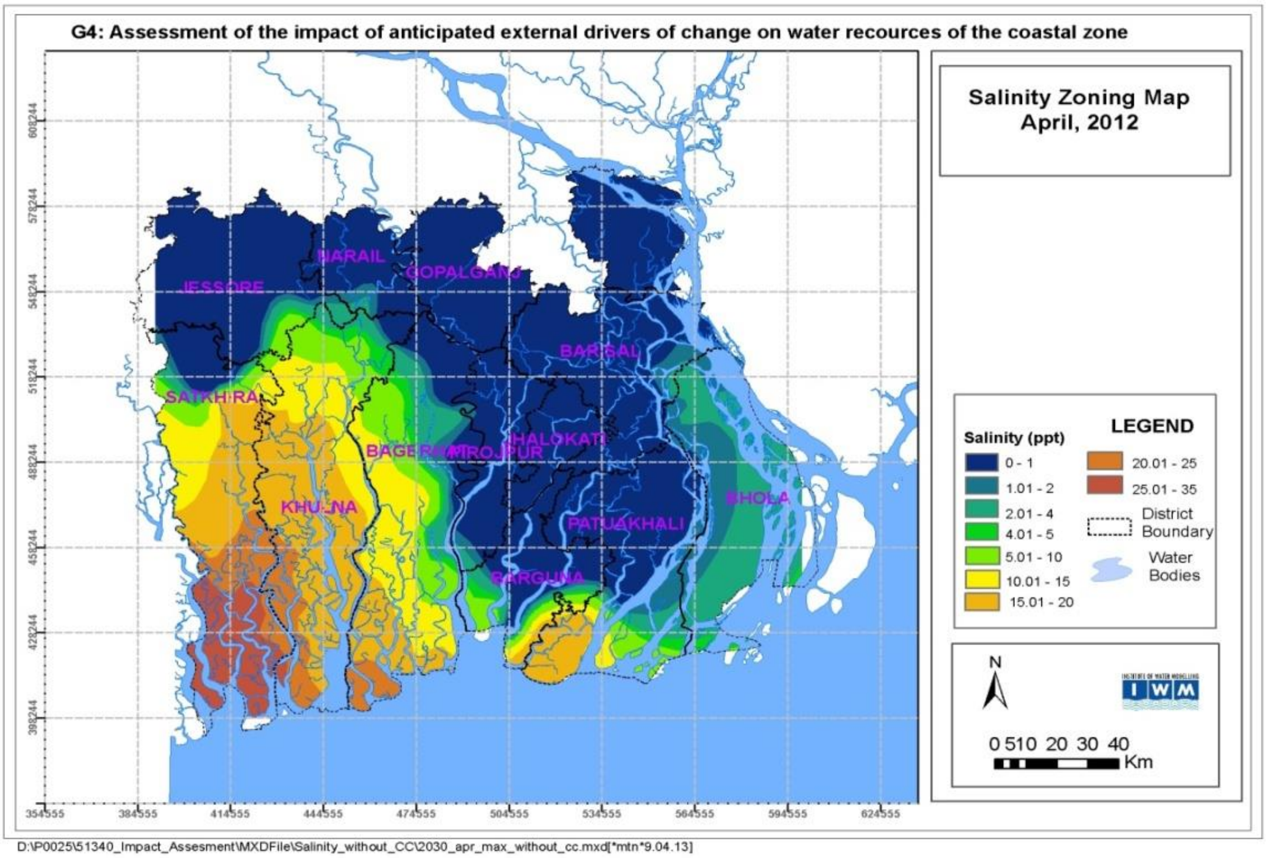

Figure 1. Assessment of the impact of external drivers on water resources of the coastal zone of Bangladesh.

Results and analysis

Saltwater intrusion is highly seasonal in Bangladesh. During the dry season, deep landward intrusion occurs through the various tidal rivers in the western part of the delta, and through the Lower Meghna estuary. Salinity starts to build up during November and reaches its peak at the end of April or middle of May. Salinity intrusion in the coastal zone of Bangladesh largely depends on freshwater flow from the Ganges. Analysis of observed data shows that average daily dry-season flow in the Ganges decreased from 1,920 m^3/s to 500 m^3/s after 1975 because of upstream water withdrawals. However, daily flow increased from 500 m^3/s to 730 m^3/s after implementation of the Ganges Treaty between Bangladesh and India.

Currently, high salinity, i.e., more than 5 parts per thousand (ppt), prevails during the dry season from December to May in the western part of the study area under Satkhira and a large part of Khulna districts, which implies that *boro* rice cultivation is not feasible due to the lack of freshwater. However, in the greater Barisal zone, i.e., in the eastern zone of the study area, salinity remains within 1 ppt during the dry season, which enables the cultivation of three crops in a year.

The effect of a decrease in transboundary flow and sea-level rise on salinity intrusion and water availability is significant. Simulation results suggest about 16% of the freshwater area is likely to become a highly saline area, which in turn might affect agriculture and aquaculture systems. Spatial variation of salinity levels is shown under present and future climatic conditions. The study shows that drainage is an acute problem under changing climate in the coastal polders. About 50% of the area of polder no. 30 remains inundated with a depth of more than 50 cm for a period of 3 days under the IPCC Special Report on Emissions Scenarios (SRES) A1B scenario in the year 2050.

Cascading Ganges: Floods and their Impact in the Eastern Gangetic Plains

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General background

The flood impact on the Gangetic floodplains and their devastating consequences highlight the increasing importance of flood hazard studies, not only at sub-national and national levels but also at transboundary basin scale as well. Each year, short-lived flooding occurs throughout the summer and early autumn but with sufficient irregularity to have adverse agricultural and societal consequences, and disruptions to social and agricultural activities. In general, the Eastern Gangetic Basin has large supplies of both surface water and groundwater but faces wide economic water scarcity (Molden 2003), especially in Nepal, Bangladesh and eastern India. Land and water productivity for most crops and fisheries are low, and the population that is dependent on agriculture (> 85%) is very poor. The Ganges often floods during the monsoon season and coastal Bangladesh is subject to cyclones, but there are dry spells and even droughts. The Ganges rises at Gangotri glacier in India. Its basin is about 1.09 million km^2, distributed between India (79%), Nepal (13%), Bangladesh (4%) and the rest in Tibet (China). The major tributary of the Ganges is the Yamuna, which joins it at Allahabad. It is interesting to note that, although water is gradually becoming a scarce material globally, and its preservation and proper utilization has become more and more important, its abundance in limited space and time has become so destructive in this part of South Asia. Therefore, harnessing of this abundant natural resource for the benefit of this region has become an absolute necessity in the present geographical scenario of the two countries.

The annual monsoon floods in the Ganga Basin are essential for preserving fertility of soils, sustaining the ecology and recharging aquifers. However, they are also often destructive and cause much misery. In fact, the impacts of flooding are widely recognized as a major factor contributing to the endemic poverty of the region. Cleary, current approaches to flood management are unable to reduce the impacts of floods on human lives and livelihoods. Therefore, reliable and timely rapid flood early warning systems on river flows have the potential of providing critical information for water resources management, agricultural optimization and flood mitigation. This paper emphasizes the necessity of spatial and temporal quantification of seasonal flooding in the Eastern Gangetic Plains using satellite remote sensing data. This will help to detect temporal changes of flood inundation areas, delineate wetlands and study its changes, flood damage assessment in urban areas, and dynamics and behavior of floods. Further, it can store surface water runoff for productive use; monitor waterlogged areas; water resources management; maintenance of wetland ecosystems; and divert global attention to changes in the water resource cycle as it is becoming increasingly important for the coexistence of riparian countries in the near future.

Detecting water surface using MODIS data

In the past, Normalized Difference Vegetation Index (NDVI) and Normalized Difference Water Index (NDWI) were used to identify water-related surfaces (Rogers and Kearney 2004). To date, more than 40 multispectral remote sensing-based indices have been developed and used to monitor water and vegetation properties. Among these, NDVI is the most widely used (Teillet et al. 1997). However, it is sensitive to atmospheric aerosols and soil background. The main reason for using Short-wave Infrared (SWIR) is because it is highly sensitive to moisture content in the soil and vegetation canopy. Various approaches have been reported that make use of the spectroscopic characterization of SWIR against water content (Gao 1996; Jackson et al. 2004; McFeeters 1996; Rogers and Kearney 2004; Tong et al. 2004). Xiao et al. (2002) showed that NDWI in paddy fields exceeds NDVI derived from Système Pour l'Observation de la Terre (SPOT) data for the same period of flooding and rice planting in the eastern Jiangsu Province, China. In recent years, Xiao et al. (2005, 2006) used anomalies between the Land Surface Water Index (LSWI) and Vegetation Indexes (NDVI or Enhanced Vegetation Index [EVI]) in an algorithm to estimate the distribution of paddy fields in South China, and South and Southeast Asia. In Table 1, a detailed description of the indices derived from Moderate Resolution Imaging Spectroradiometer (MODIS) data, along with the band number and solar spectrum, is presented. The algorithm implemented by Xiao et al. (2005) and Sakamoto et al. (2007) was referred and modified in this present study. A flowchart of the method used in this study is shown in Figure 1. The previous algorithms are examined and some components are added and excluded from it. In previous algorithms, a wavelet-based filter is used to smooth data by removing the noise component and interpolation of missing information. This algorithm creates artificial data and, therefore, that procedure is excluded from the study. Additionally, Normalized Difference Snow Index (NDSI) and Digital Elevation Model (DEM) were used in the study area, which could pose challenges to the development of a flood-detection algorithm.

Table 1: MODIS derived indices used to detect spatial and temporal distribution of flood.

Indices	Equation
Normalized Difference Vegetation Index (NDVI)	$NDVI = \frac{\rho_{NIR} - \rho_{RED}}{\rho_{NIR} + \rho_{RED}}$
Normalized Difference Vegetation Index (NDVI)	$NDWI = \frac{\rho_{RED} - \rho_{SWIR}}{\rho_{RED} + \rho_{SWIR}}$
Enhanced Vegetation Index (EVI)	$EVI = 2.5\ x\ \frac{\rho_{NIR} - \rho_{RED}}{\rho_{NIR} + 6\quad x\ \rho_{RED} - 7.5\quad x\ \rho_{BLUE}} + 1$
Land Surface Water Index (LSWI)	$LSWI = \frac{\rho_{NIR} - \rho_{SWIR}}{\rho_{NIR} + \rho_{SWIR}}$

Notes: ρ_{NIR} is the reflectance of near infrared (841-875 nm, MODIS Band 2); ρ_{RED} is the reflectance of red (621-670 nm, MODIS Band 1); ρ_{BLUE} is the reflectance of blue (459-479 nm, MODIS Band 3); and ρ_{SWIR} is the reflectance of short-wave infrared (1,628-1,652 nm, MODIS Band 6) of the solar spectrum.

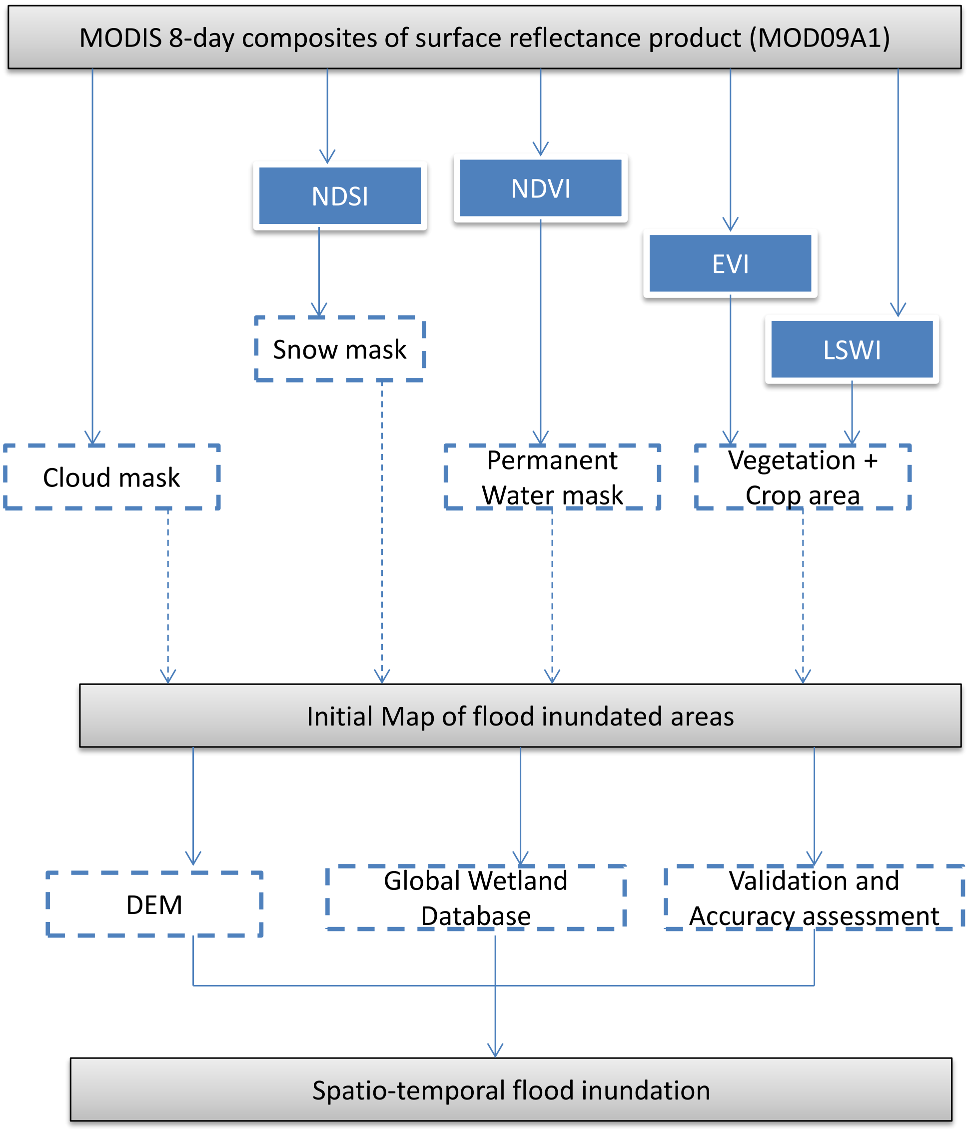

Figure 1. Flowchart for detecting the spatiotemporal changes on flood inundation.

Results and discussion: Flood event analysis of the Eastern Gangetic Plains

Datasets from Emergency Events Database (EM-DAT) and Dartmouth Flood Observatory (DFO) were integrated to assess the spatiotemporal flood distribution and its flood seasonality. First, data were filtered for countries in the Eastern Gangetic Plains, which include Bangladesh, India, Nepal and Pakistan. Second, there was a certain inconsistent reporting of flood events reported by Adhikari et al. (2010), and it was recommended to use the observation of extreme flood events since 1985. So far, the Ganges Basin analysis of flood events from 1985 to 2011 were used for this study.

Floods in the Indo-Gangetic Plains had a total of 110 flood occurrences, of which India (56) ranks the highest followed by Nepal (35) and Bangladesh (19). At the basin level, the Ganges accounts for 94 flood occurrences (Figure 2). Analyzing annual flood occurrence explains the increase in the number of floods between 2006 and 2011 (53) compared to the previous years from 1985 to 2005. In recent years, an increase in the global occurrence of floods has been reported (Jonkman 2005), and it has been suggested that global climate change taking place along with environmental degradation in the region may increase the frequency of flood occurrence. The change in climatic conditions taking place may increase the frequency of intense rainfall commonly known as 'cloudburst' (IPCC 2001; Verhaar et al. 2010). This may result in an increase in various types of disasters related to rainfall such as flash floods, landslides and landslide-dammed outburst floods.

The duration of floods in the Ganges are relatively short. An analysis of the flood duration explains that the majority of floods in the Ganges are relatively shorter floods with an average value of 3-5 days. Flood duration with 20-60 days had 20 flood occurrences and a duration of more than 60 days had only 7 flood occurrences (Figure 3). Examples of the recent 2007 floods in India, having longer duration of floods, explains abnormal heavy rains during the monsoon season that will have long-term negative effects on the country's food security and economic performance.

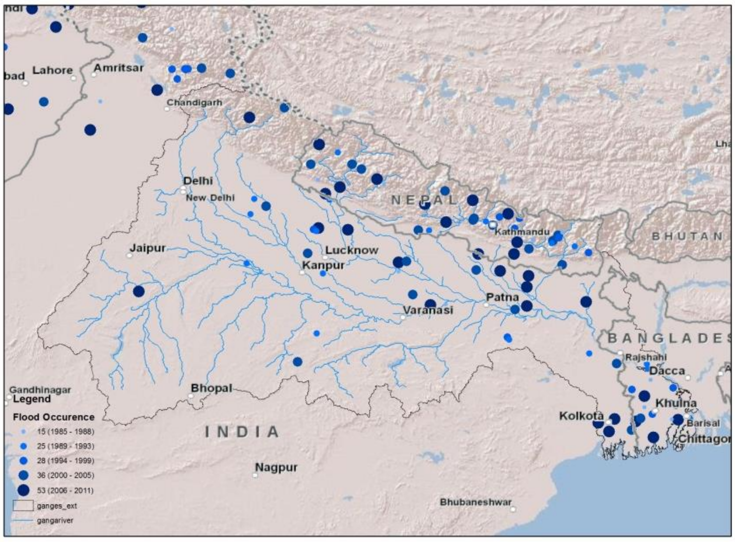

Figure 2. Spatiotemporal distribution of large flood events for the Ganges Basin from 1985-2011.

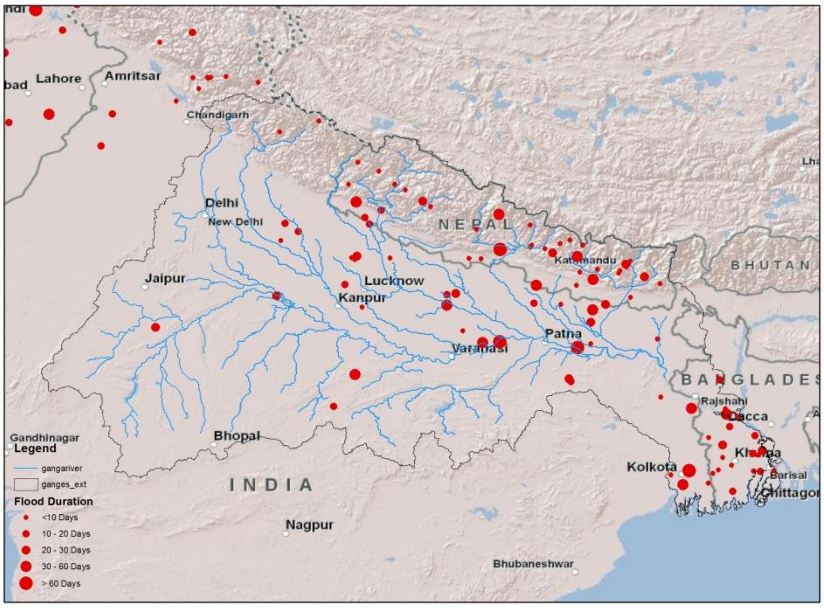

Figure 3. Spatiotemporal distribution of large flood events showing flood duration for the Ganges Basin from 1985-2011.

When considering event causative factors in the Gangetic Plains, 'monsoonal rain' is the most frequently reported cause of flooding (44.6%), heavy rain is the second most reported cause (31.2%) and is followed by brief torrential rain (8.3%) and tropical cyclones (4.5%) (see Figure 4).

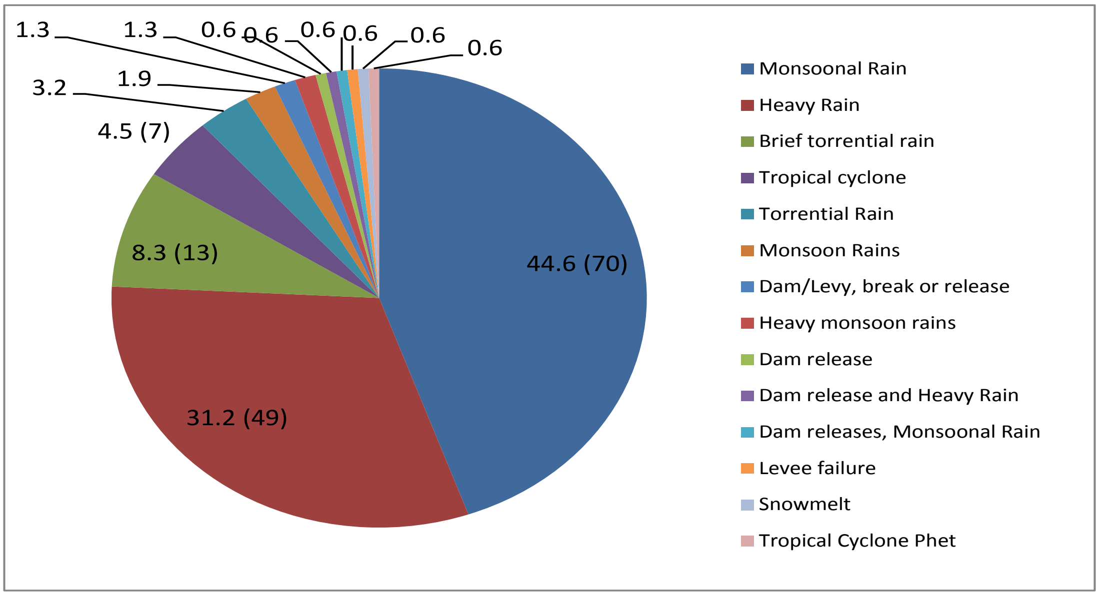

Figure 4. Causes of flooding - monsoonal rain, heavy rain and brief torrential rains are the major causes of flooding, globally. Data in parentheses show the number of flooding events.

Flooding occurs seasonally depending on the weather patterns, monsoon activity and regional tropical cyclone activity. For the Ganges, it is observed that flood events start increasing during June (18) and reach a peak in July (50) and August (42) (see Figure 5). The seasonal trend in flood fatalities is similar to that of flood events, except that the fatality numbers remain high throughout the months of August through to October.

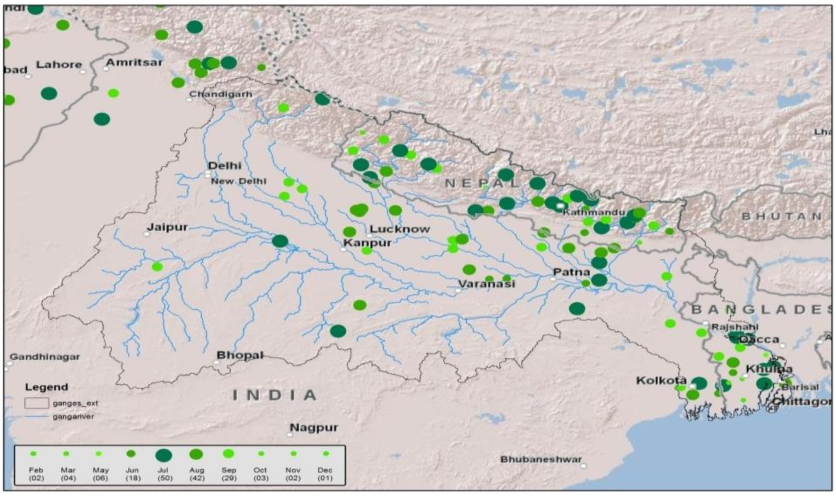

Figure 5. Seasonal distribution of floods in the Indo-Gangetic Plains between 1985 and 2011.

Comprehensive analysis of spatiotemporal flood hazards, both at global and regional level, serves as a digital, standardized database for flood hazard studies. It has helped in identifying data gaps, and the need for flood mapping and flood prediction in hydrological studies. However, the current level of flood event observation analyzed will not help in identifying flood-risk areas, which recommend continuous monitoring of floods using satellite remote sensing data. This will help in identifying flood-prone areas and hot spots for studies in climate change and flood hazard mitigation.

Spatial pattern of flood dynamics

Figure 6 shows the inundated areas mapped for the Ganges using the proposed flood-detection mapping algorithm (Amarnath et al. 2012). MODIS Terra satellite with bands 721 (SWIR, Near Infrared [NIR] and Red) can clearly distinguish surface water properties, and delineating several images will help in classifying floodwater extent.

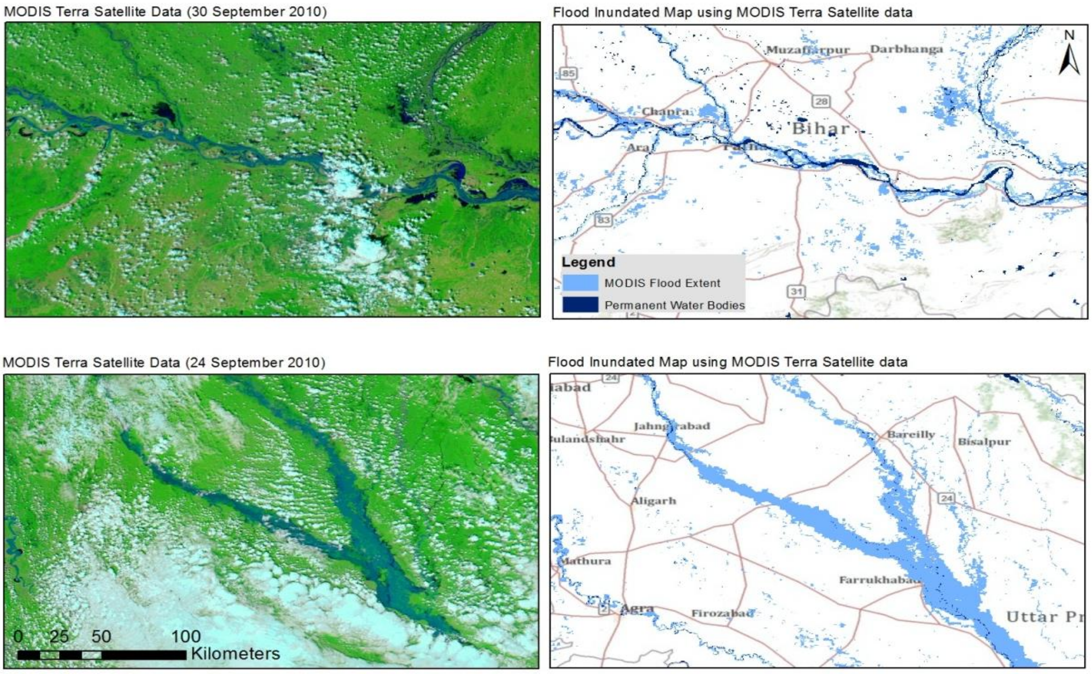

Figure 6. Comparison of MODIS Terra satellite data and the flood-inundated map for the Ganges Basin.

Detecting the maximum extent of the flooded area is effective by overlaying multiple images during the flood duration (29). Thus, the flood map products are expected to be useful in identifying temporal changes in the simultaneous recession and expansion of flood cycles at a regional scale. Flood map products can be useful in creating a flood vulnerability map and long-term flood cycle to assess flood-risk zones. Figure 7 shows the maximum area of flood inundation during floods in 2010. The light blue, green and dark blue colors in the Figure represent areas of flood, and long-term water bodies, respectively. The area of flood pixels in 2007 is the largest followed by 2010 from the years 2000 to 2011, and the area in 2001 is the smallest for the whole of South Asia. At country level, India had the highest inundated area followed by Bangladesh and Pakistan, and the least area of flooding was noted in Bhutan. It is also evident from time-series map that the extent of flooding varies from year to year. The areas which are common for both major floods should be classified as the most vulnerable areas.

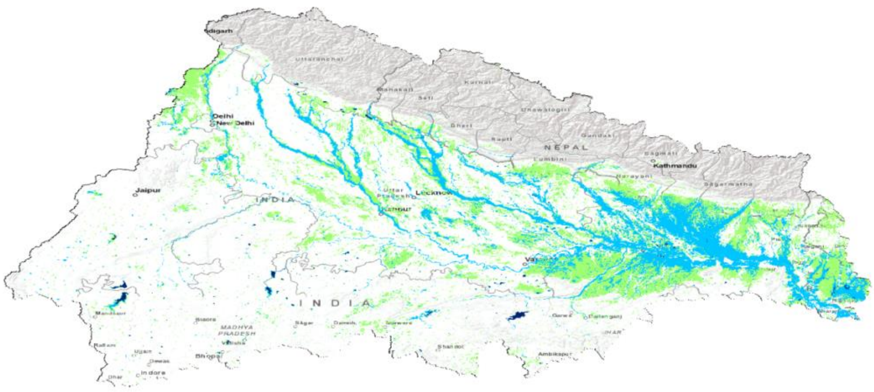

Figure 7. Maximum flood inundation extent for the Ganga Basin using MODIS images (2000 to 2011).

Recurrent flood analysis

The recurrent flood inundation period is determined by only using the flood pixels calculated from 2000 to 2011 (Figure 8). Darker pixels (blue) show the continuous inundation which we see in the rivers of Gandak, Kosi and Lower Ganga, and waterlogging in the districts of Vaishali, Darbhanga, Samastipur, Muzaffarpur and Khagaria. Analysis of river flooding shows a ~10 km inundation for the Kosi River and Lower Ganga (as much as ~23 km was measured). For the 2010 floods in Pakistan, as much as ~13-15 km of the width of the floodplain got inundated, which is the maximum inundation for the Indus River between 2000 and 2011.

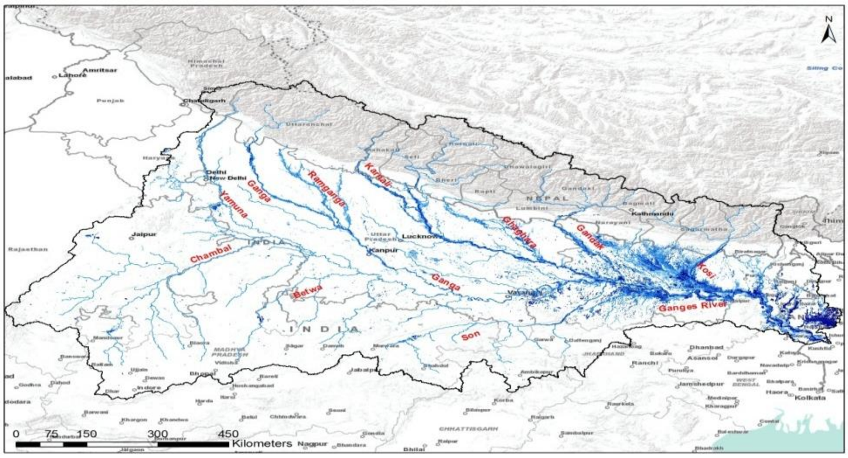

Figure 8. Recurrent flood analysis using an yearly composite of flood inundation between 2000 and 2011 for the Ganges River Basin.

Flooding has a particularly devastating impact on the 504 million or so who live in the Ganga Basin (440 million in India, 41 million in Bangladesh and 23 million in Nepal), because they are among the poorest in the world and find it hard to reconstruct livelihoods following a flood disaster. Socially and economically marginalized, and asset-poor families, often have no option but to live in vulnerable locations such as floodplains because processes of social and economic exclusion prevent them from owning land in less flood-prone areas. The number of poor and vulnerable families is almost certain to grow as a consequence of climate change.

Thus, the use of spatial dynamics of flood inundation mapping and modeling obtained using remote sensing data, hydrology and hydraulic modeling tools will be helpful in preparing strategies for flood mitigation in the Ganga Plains. This also emphasized the need for structural control measures, primarily embankments, which proved to be inadequate and detrimental, in many cases, as demonstrated by the floods in 2007. As climate change progresses, these measures are becoming increasingly ineffective because they do not address the fundamental dynamics of basin hydrology, geomorphology and social contexts. The aim of our preliminary flood-risk analysis was to provide policymakers with an understanding of the challenges and alternative strategies for reducing flood risk and responding to climate change.

Recommendations

- Regular and continuous monitoring of flood inundation dynamics using multi-resolution images will be useful in assessing seasonal and annual changes in inundation cycle.
- Monitoring of waterlogged areas, using multispectral and multi-temporal techniques, can be mapped accurately to identify seasonal waterlogging and improve access to land for crop production.
- Ensemble of remote sensing data products that include land use and land cover maps, crop productivity and vulnerable areas to relate with operational flood-mapping products.
- A specific analysis is needed on flood dynamics and the ecosystem that remain healthy in the face of a changing climate.
- Develop a flood basin plan that supports further research into the extent of climate change and its implications for water availability, communities and the environment.
- Formulation of regional water management plans based on hydrological, hydrogeological and agroecological characteristics.

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Improving the Rural Livelihoods through the Development and Management of Small-scale Water Resources of East India and Nepal

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Although the states of East India are richly endowed with natural resources, these state economies are poorly developed and contribute a mere 17% to the national Gross Domestic Product (GDP). Nepal is similarly endowed with natural resources, benefitting from a diverse topography and allowing a wide range of cropping patterns. However, there are highly concentrated areas of poverty. At state level, the database on small-scale water resources (mainly tanks, ponds/dams, tube wells) is very weak and options in the planning and management of these resources are much limited. At system- and farm-level, agricultural productivity is low due to poor tank structures, suboptimal levels of adoption of appropriate technologies, poor water control, high cost of pumping water, lack of knowledge on the multiple uses of water, and poor rural infrastructure and market access. However, the problems related to water resources are not availability but access to these resources by different households. By improving access to water, energy and markets, it is possible to enhance the livelihoods of rural households in the region.

Compared to large projects, which have a high cost and skewed benefit distribution, the development and management of small-scale water resources will enhance the access to water and livelihood opportunities of smallholders in the region through multiple-use benefits. State governments are also showing interest in developing and managing small-scale water resources through several programs, even though knowledge and expertise to carry out the required interventions are lacking. State water policy is also putting emphasis on this initiative. However, detailed research could help identify the interventions that are required. A scoping study in relation to this was conducted during 2012-2013 by IWMI with local partner organizations in Bihar, Odisha, the West Bengal states of India, and the eastern and central Tarai of Nepal. This study highlighted several possible interventions that can be taken up to improve the livelihoods of rural households. These possible interventions primarily include the following:

***Tank/pond rehabilitation options*:** A large number of existing structures are suffering from sub-optimal utilization due to the deterioration of structures and distribution systems. Modernization and improvement of the existing systems could provide additional irrigation potential and facilitate stable crop production in the command areas. Field experimentation of the improved crop and water management practices, integrated aquaculture and use of solar pumps are promising interventions in improving water resources development in the region.

Groundwater development and use, including solar pumps: Development and management of groundwater resources through low-cost pumping technologies will help improve the cropping intensity, and a well-functioning water market may also benefit the farmers that do not own wells. In some cases, where tank water supplies are inadequate, the conjunctive use of both tank and well water will enhance the cropping intensity and income from crop cultivation.

Enhancing the water-use efficiency (more crop and income per drop): The major crops grown in the region are rice, wheat and maize with very low water-use efficiency (WUE) (less than 20%). Improving the WUE by 20% is one of the major goals of the National Water Mission. Hence, introduction of improved crop and water management practices such as system of rice intensification, alternate wetting and drying, micro-irrigation, change in cropping patterns, etc., will result in increased crop yields and WUE.

Multiple uses from the small-scale water and land ecosystems: Tanks/ponds/wetlands are major sources for conserving the ecosystem and environment in the rural areas. Tanks used to provide the wetlands, soil conservation, grazing land for the animals, bird sanctuaries, afforestation in the tank area, fisheries and groundwater recharge as ecosystem functions. Selective and cost-effective rehabilitation programs with community participation will improve the overall performance of these small-scale systems.

Institutional framework for product marketing and tank management: Diverse socioeconomic conditions (in terms of literacy, caste, farm size, experience in farming, income sources, etc.) affect social capital formation in managing the small-scale water resources as well as marketing of the produce by the farmers. The direct involvement of users in major collective decisions will ensure that the decisions reflect their interests and needs. Encouraging/forming local farm groups through NGOs will help develop good marketing channels for the farm produce as well as for managing the small-scale systems. Keeping this in mind, a four-year research project to address and make interventions in developing and managing small-scale water resources in the region is proposed, highlighting the potential benefits of this project. Overall, the project will have a higher return on different components of interventions such as tank rehabilitation, groundwater development with solar pumps, improved management practices, enhancing the multiple uses and addressing socioeconomic issues in the management of the resources and product marketing. Once the project is successfully implemented, it will offer more scope for up-scaling the interventions in the entire Eastern Gangetic Plains (EGP) of India, Nepal and Bangladesh, which is home to some 300 million people.

Conclusion

It is clear that land tenure remains a critical constraint to the development of agriculture and irrigation in North Bihar and the Nepal Tarai. Yet, it is often overlooked by policymakers. There are number of ways forward to address this issue. There is a need to continually engage with land tenure reform and land reform itself as part of a broader agrarian strategy at a national and state level.

It is crucial for groundwater and irrigation policies (and the technologies promoted) to be sensitive to the needs of tenant producers who form a growing part of the cultivating population. This includes the need to promote low-cost and low-risk technologies suitable for rent-paying tenants with limited incomes. Requirements for receiving government support for the installation of wells also need to be revised, so that tenants without papers can still benefit from these schemes.

Options for the collective use of groundwater need to be better understood, as this provides one effective way in which farmers can access tube well irrigation without owning the land. There are still a number of constraints to successful collective management, including legislations in Nepal which state that only land owners or registered tenants can become members of committees.

It is also important that policymakers do not neglect surface water resources, such as ponds, which are communal resources and are critically important for land-poor farmers who cannot easily access groundwater. There is a need to better understand pond rehabilitation options, and equitable institutional management systems for these resources.

Water-Energy Nexus in the Eastern Gangetic Plains: Old Issues and New Options

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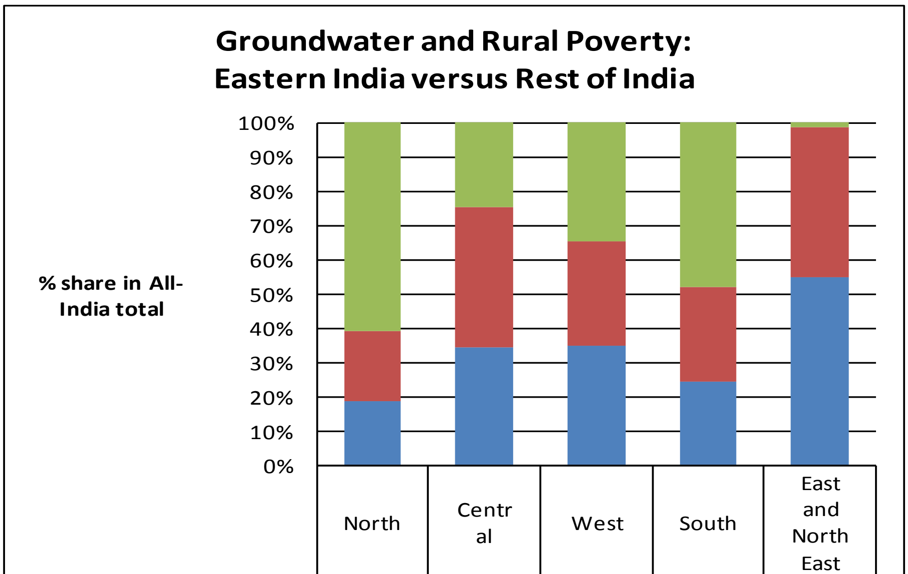
The Eastern Gangetic Plains occupy a large space in South Asia's 'rural poverty square'. The region has one of the largest concentrations of rural poor. Yet, it is rich in soils and groundwater. A major development challenge the region faces is using its abundant groundwater resources as an instrument for poverty reduction. Figure 1 compares eastern India with the rest of India. Eastern India has 32% of India's rural poor, a quarter of the country's usable groundwater resources and less than 1% of its over-exploited blocks.



	North	Central	West	South	East and North East
% of India's dark blocks	31.6	19.2	13.5	35.1	0.7
% of India;s usable groundwater recharge	10.8	31.8	11.9	20.2	25.4
% of India's rural poor	9.8	27.0	13.7	17.8	31.8

Figure 1. Groundwater and rural poverty in India.

South Asia's Green Revolution started from Punjab and spread eastward until it got stuck around Lucknow. B. D. Dhawan and other scientists associated the spread of the Green Revolution with the adoption of tube well technology. This hypothesis was vindicated when the rapid spread of shallow tube wells catalyzed a '*boro*' paddy revolution in Bangladesh, followed a few years later by West Bengal. Bangladesh, perennially dependent on rice imports, became a rice exporter; and its shallow tube well revolution played a big part in this turnaround. During the 1990s and 2000s, groundwater irrigation with shallow tube wells has spread throughout the EGP. However, its contribution to agricultural growth is now increasingly restricted by the high and rising cost of energy used for pumping groundwater. As shown in Figure 2, South Asia's groundwater story is one of energy divide. Western and southern India—with limited groundwater resources and poor aquifers— have enjoyed a veritable groundwater boom fuelled by electricity subsidies. Over recent decades, this boom has created huge sustainability threats for groundwater as well as for irrigation. In contrast, the EGP—with its rich alluvial aquifers and 1,500 Bm^3 of floodwaters to replenish these annually—has been unable to use its abundant groundwater resources due to the need of electricity to pump this water. In fact, many parts of the EGP had more electric tube wells during the mid-1970s than today. The region has faced steady rural de-electrification. Dependent on diesel which is expensive, the groundwater boom in the EGP is gradually running aground.

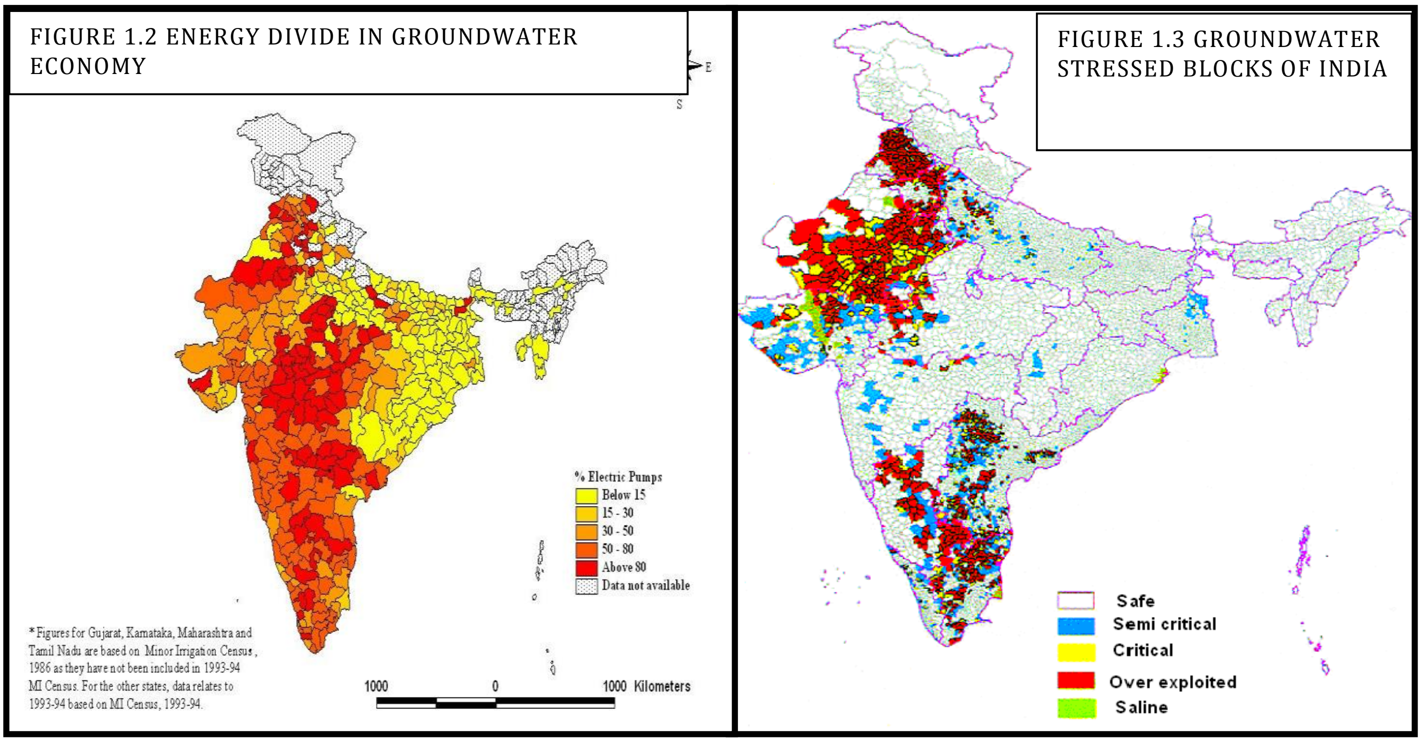


Figure 2. Groundwater and energy divide in India.

Several solutions have been suggested and tried. Bangladesh and Bihar have tried to provide a diesel subsidy to farmers to partially offset their high expenditure on diesel for pumping groundwater. There has been a growing emphasis on accelerating rural electrification in the EGP. However, electrification is a capital-intensive and time-consuming affair, especially in dispersed rural areas. The cost of developing the grid network varies more with distances than with the number of connections. Moreover, even with rapid development of the grid network, benefits may be doubtful without adding new generation capacity. Finally, rural electrification may not be of much help to sustain groundwater-irrigated agriculture unless power supplies to the agriculture sector are free or heavily subsidized, as in western and southern India where they are now trying to reduce or eliminate power subsidies.

Fortunately, new and different green energy alternatives are now becoming available to spur groundwater irrigation in Eastern India, which were not available to western and southern India 50 years ago. With the rapidly falling prices of photovoltaic (PV) cells, solar pumps have the potential to open a new chapter in India's irrigation economy in the years to come. With appropriate promotional strategies and incentives, solar pumps have the potential to attack the invidious nexus between energy and groundwater irrigation in the EGP, and change it for the better. The cost structure of solar technology—with high fixed costs, and very low variable and environmental costs (see Table 1) —imparts high operating leverage to its economics.

	Private		Social		
	Fixed	Variable	Fixed	Variable	Carbon footprint
Diesel pumps	Low	High	Low	Higher	High
Electric Pumps with subsidized power	Low	Low	High	Higher	High
Solar pumps with capital cost subsidy	High	Very low	High	Very low	Very low

Table 1. Economics of diesel, electric and solar pumps.

Rising diesel prices, and dwindling hours and the quality of farm power supplies, are likely to stimulate the demand for solar pumps. The land footprint may also influence the demand for solar pumps. In areas with high pumping depths to groundwater, the capital cost and land taken up by solar panels will make solar pumps less attractive than in large swathes of eastern India, where high water tables make solar pumping an ideal technology. Subsidizing capital investment in solar pumps and buried distribution systems, which will create competitive groundwater markets benefitting the poor, may be a game-changer for eastern India's agriculture.

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Water Management Institutions and Policies in Bangladesh

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Having an abundance of water in the monsoon and water scarcity in the dry season is a common feature of Bangladesh. In areas with flood-control structures and polders, especially in the southern region, tidal surges coupled with a rush of floodwaters cause heavy drainage congestion affecting agriculture, fishery and livelihoods. Salinity intrusion limits crop farming, which often conflicts with shrimp farming and aquaculture. The major use of water is for irrigation, industries, navigation and household consumption. Agriculture is dependent on pump irrigation, but the very low flow in the rivers and canals in the dry months seriously squeeze the scope for pumping surface water for irrigation. Pumping groundwater is the major form of irrigation for rice production, but this is also limited by the seasonal drawdown of groundwater in the peak dry months and the increasing cost of fuel for pumping. This problem is further exacerbated by the extreme climate change variables, i.e., long spells of drought, salinity and increasing arsenic contamination of groundwater. This paper reviews the institutional innovations that have taken place with respect to water use policies and strategies in the Bangladesh water sector in recent decades. The National Agriculture Policy of 1999, National Water Policy of 1999, National Water Management Plan of 2001, and Guidelines for Participatory Water Management Plan of 2001 are some of the major documents providing guidelines to an Integrated Water Resources Management. The actual work for integration of water sector development initiatives, through different project interventions by different agencies, and crosscutting roles of a number of national-level specialized institutions, have evolved under the Ministry of Water Resources, i.e., Institute of Water Modelling (IWM), Center for Environmental and Geographic Information Services (CEGIS), and Water Resources Planning Organization (WARPO). Theoretically, WARPO is supposed to provide technical assistance to the Planning Commission, Bangladesh, in the process of project evaluation, especially in assessing compliance with the feasibility study, hydro-morphological studies, defining participatory water management with a focus on cost recovery, cost sharing, and operation and maintenance of the system interventions commensurate with the national water policy and the current sixth Five Year Plan.

On practical counts, the role of WARPO is generally defined as acting as ‘clearing house’ of the projects from the Ministry of Water before submission to the Planning Commission. However, this is often done with little or no comprehensive technical exercise towards refinement in the project design or the operational plans. The time and resources available are sometimes the limiting factors. More rigorous engagement from WARPO with the lead agencies in project design is expected to reinforce the Planning Commission’s job to give judgment about the quality of the project, and suggest the budgetary allocation for the projects under review. With large-scale privatization of small-scale irrigation, groundwater pumping for rice cultivation is largely managed by the private sector, leading to a dynamic irrigation water market characterized by various forms of contractual arrangements for water delivery. Irrigation water management in the private sector resulted in a largely competitive situation with positive impacts on productivity, income and equity implications. Deregulation and withdrawal of standard and pump spacing regulations prompted the rapid growth of tube wells and irrigation coverage. This review discusses innovative institutional arrangements for developing water resources and promoting irrigation in high Barind areas in the northwest region of the country. One example is the Barind Multipurpose Development Authority (BMDA), which has created significant opportunities for augmentation of surface water and groundwater extraction facilities in the generally drought-prone flood-free highland areas. BMDA also provides support to extend farmers' access to pumped water through a variant of market-driven pre-paid coupon or metering system of fee collection. Although there are in-built subsidy contents, this approach is considered to be reasonably effective in terms of increasing land cover, plantation and irrigation coverage in the main *boro* rice season as well as providing supplementary irrigation to Aman rice, particularly during the drought season. It is noteworthy that the agency controlled water management system, which apparently works for BMDA as a location specific monopoly, is not necessarily the right approach elsewhere in the country because of relatively higher groundwater levels allowing small-scale private shallow tube wells operating in a competitive environment.

Surface water development has been mainly designed and constructed by the public sector agencies, but the intricate operation and maintenance of flood control, irrigation and drainage projects necessitated the participation of local communities in many different organizational forms such as water management associations, water users group, etc. Such participatory water management in government-built projects with canals, structures and polders has been treated as a classic case of public-private partnership. In many cases, the expected results are yet to fully materialize. This review covers the irrigation and water management programs of the major government agencies involved in surface water as well as groundwater management. The review also discusses the scale of operation in terms of number of systems, polders, area coverage, forms of groups, type of agency level support services, operation and maintenance of structures and polders, fixation and collection of fees, and sustainability of different management approaches. Recent field evidence in surface water systems and polders shows signs of improvement in raising awareness of participating farmers about the ownership and utility of the water development projects. Nevertheless, the study also revealed that the interventions produced less than expected outcomes due to poor construction and maintenance of systems. The prominent reasons for this include heterogeneity in participant's group and inadequate fee collection leading to poor resource mobilization, lack of incentives at individual level, free rider's problem, failure to maintain water level to suit rice cultivation with fish culture, siltation of canals, unreliability of water supply, and lack of synchronization of individual's timing and need for water.

Putting Bihar Agriculture on Take-Off Trajectory: Nurturing the Seeds of Growth

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Agriculture in Bihar has remained stagnant for more than a century now. Over the last 40 years, the value of agricultural output grew at a mere 0.7% per annum—the slowest growth rate among all states in India. Until recently, stagnation was blamed on the slow adoption of yield enhancing inputs such as chemical fertilizers, hybrid seeds, irrigation and agricultural implements such as pump sets and tractors. The argument was that annual flood-risk and semi-feudal production relations reduce the incentives for farmers—landowners and sharecroppers—to invest in productivity enhancing inputs. However, recent data shows that Bihar has caught up with the rest of India in terms of the use of fertilizers, hybrid seeds, tractors and pump sets in last two decades. This catch-up has happened in spite of poor institutional credit and agricultural extension infrastructure in the state. Still, agricultural productivity in Bihar continues to lag behind the rest of India. Productivity is not only low, but also highly sensitive to inter-annual variability in rainfall. This is more so the case than the rest of India even when the state has rich groundwater resources, which are considered to be the best protection against vagaries of rainfall. We argue that “the energy squeeze” faced by farmers due to their dependence on expensive irrigation with diesel pump sets, leads to farmers economising on use of groundwater which results in low and variable yields and low cropping intensity. Lack of electricity and the high price of diesel are key reasons why Bihar is unable to convert abundant groundwater resources into livelihoods.

Land Tenure and Its Effect on Water Management in Bihar and Nepal

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Introduction

Across the Eastern Gangetic Plains, over the last decade, government development agencies have been shifting their focus towards the expansion of groundwater irrigation, particularly through shallow tube wells. Groundwater is underutilized, provides water on demand and represents a decentralized irrigation resource which can be managed at a local level. At the same time, groundwater has been crucial in reducing vulnerability to drought and monsoon failures, and has facilitated an intensification of agriculture.

The focus of this paper is not, however, to investigate issues of whether groundwater from shallow tube wells is *available*, but to look at the issue of groundwater *access*. While the challenges posed for groundwater use by the availability of energy and weak institutional support is increasingly well understood, it is important to analyze the role of the agrarian structure itself in shaping irrigation uptake by different socioeconomic strata. It is acknowledged in the literature that investment in shallow tube wells and pumping equipment is out of reach for marginal producers, and they face similar financial barriers to 'purchasing' groundwater. This is important as constraints linked to household economic status are higher for groundwater use than they are for accessing water from gravity fed sources, as groundwater generally requires significant monetary investment to bore the well and operate the pumping equipment.

However, through research conducted in Madhubani (Bihar), and Morang, Dhanusha and Saptari (Nepal), this paper digs deeper to understand the production relations which lie behind these constraints and, in particular, the differences within the 'marginal' farmer group with respect to land tenure and their relation with other farmers. In large parts of the Nepal Tarai and North Bihar, farming populations are differentiated between those owning *and* cultivating most of their land and employing labor, and those cultivating mostly as tenants and working for others. The majority of landowners belong to the upper and middle castes, while the tenants and laborers are predominantly from the *Dalit* community and in some Tarai districts, from *adivasi* (indigenous) communities. In the communities studied, the proportion of sampled households engaging in tenancy varies from a third to more than half – and thus represent a significant part of the farming population.

Impact of land tenure on irrigation

In the deeply inequitable economic formation of north Bihar and the Tarai, one's position in this complex web of landlord-tenant relations has a critical role in determining investment in, and access to, groundwater irrigation which is increasingly critical for dry-season agriculture and to cope with increasingly unpredictable monsoons. Tenure insecurity impedes marginal farmers' investment in tube wells, particularly when a few households have official tenancy papers. Landlords have been found to prefer verbal contracts as there is less risk of tenants claiming the land as per government land reform legislations. The contribution made by landlords to boring wells is often limited, particularly given the growing trend for absentee landlordism in some pockets whereby landlords reside in cities and often have limited interest in developing the land. Similarly, the lack of legal tenancy rights or landownership papers impedes farmers from accessing a number of government agricultural services such as the subsidized boring of wells in Nepal.

The remaining option for tenant farmers is to 'buy' groundwater. However, given that a large portion of the harvest is often given as rent, profits from agriculture are marginal and the financial risks of purchasing water are, therefore, high. This is aggravated by monopolistic groundwater markets led by large farmer elites which drive up the price of pumping. In this context, many farmers prefer to leave the land fallow during the dry season and invest their labor in the off-farm economy, often through seasonal migration.

The incidence of landlord-tenant relationships are likely to increase in the decades to come. Research has shown that, in the context of high production costs and climatic stress, large farmers are increasingly opting to give land to tenants and passing on the risk rather than cultivating it themselves.

RESEARCH PROGRAM ON Water, Land and Ecosystems

Led by: IWMI International Water Management Institute

Agrarian Straightjacket: Constraints to Achieving Potential Yields in Rice Production

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The coastal zone of Bangladesh is the most vulnerable region of the Eastern Ganges Basin, which occupies about 30% (46,000 km^2) of the country's land area and is home to some of the world's poorest and most food-insecure 39 million people, whose livelihoods depend primarily on agriculture and aquaculture. Key challenges to both agricultural and aquacultural productivity include excessive flooding during the rainy season, lack of access to freshwater and soil salinity during the dry season, and severe cyclonic storms and tidal surges throughout the year. These challenges will be exacerbated as a result of climate change and is expected to leave the communities most vulnerable and food-insecure in the coming years.

The CGIAR Challenge Program on Water and Food (CPWF), through on-farm participatory research, has shown that productivity in the coastal areas of the Ganges Basin can be increased significantly by adopting appropriate crop and water management practices. For example, where freshwater is available in the rivers almost year-round, such as in parts of Barguna District, the low-yielding aman-grass pea system can easily be replaced by triple cropping (*aus-aman-boro* or *aus-aman-rabi*) with high-yielding and stress-tolerant rice and *rabi* varieties of suitable duration. In moderately saline areas where freshwater is limited during the dry season, such as parts of Khulna District, the productivity of the traditional aman-sesame system can be increased manyfold through the adoption of high-yielding aman varieties followed by high-yielding *rabi* crops such as sunflower and maize or *boro* rice in lower lands. In areas where water salinity is too high for dry-season agriculture, such as parts of Satkhira District, the productivity of shrimp farming can be greatly enhanced by new technologies leading to higher yields with the reduced risk of disease. Brackish water shrimp monoculture can be replaced by more resilient systems of shrimp/fish polyculture in rotation with high-yielding salt-tolerant aman rice plus fish. Further, a comprehensive geographic information system (GIS) database and the methodology for identifying production system zones in the coastal areas of the Ganges Basin is under development through collaboration between several Bangladeshi institutes (Institute of Water Modelling [IWM], Local Government Engineering Department [LGED], Bangladesh Water Development Board [BWDB] and Soil Resource Development Institute [SRDI]) and IRRI under the CPWF Ganges program. Once developed, this database is expected to guide policymakers and extension personnel to adopt appropriate high-yielding rice varieties, and crop and water management policies for higher productivity and improved livelihoods of coastal communities of the Eastern Ganges Basin.

The Government of Bangladesh constructed 135 polders in the coastal regions of the country 50 to 60 years ago to prevent tidal surges and saline water intrusion, to facilitate traditional aman rice cultivation that generally does not need appreciable drainage and fertilizer application for optimum yield (about 3 t/ha). However, due a rise in the population, the demand for food has increased and the role of polders needs to be redefined for higher land productivity. The good news from research over the past few years is that there is tremendous potential to improve food security and livelihoods through the adoption of new varieties, timely crop establishment, improved management, and intensification and diversification of cropping systems. However, these new options cannot reach their potential unless there is a fundamental change in how polders are viewed and managed, and, as a result, how investments are allocated. The four key investment needs identified are as shown below:

- Invest in polder water management, especially drainage – this is the key to increasing productivity of both agriculture and aquaculture.
- View each polder as an integrated water management unit serving the production systems, rather than simply as a structural unit comprising the surrounding embankment and sluices. With the changing scenarios, the polder functions should be changed to satisfy the water requirements for improved production, which include good drainage to avoid prolonged deep inundation of the aman crop; allow rapid drainage prior to aman harvest for timely establishment of rabi crops; allow adequate leaching of salt from the shrimp ghers prior to transplanting the aman crop; ability to intake and conserve water of the desired quality for dry-season irrigation by dredging of canal networks within the polders (this will serve to improve drainage as well as increase storage capacity); and provision of access to brackish water in regions where this can be a beneficial resource rather than a constraint to productivity and livelihoods.
- Develop land-use zones: Investment is needed in zoning according to the resources, socioeconomic profiles and production systems that prevail in individual polders.
- Improve institutional arrangements for water management – investment is needed to create a single identity in charge of water management for each polder, servicing the community within the entire polder and their production systems.

Since rivers surrounding the polders are very prone to silting-up, the most important challenge is to keep the peripheral rivers alive/active to drain-out floodwater from the large polder areas within the shortest possible time. In future, farmers of the coastal areas of the Ganges Basin may have to grow rice under partial submergence or waterlogging conditions to maintain their livelihoods. Therefore, determination of rice varietal response to different degrees of water stagnation, rice varietal improvement best suited under above scenarios, and optimization of drainage design for cost-effective rice cultivation are the critical needs to continue productive rice culture in the coastal areas of the Ganges Basin.

Replication of the Barind Model to Muhuri Irrigation Project

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Introduction

In the Barind region of Bangladesh, rainfall is highly seasonal, erratic and poverty was endemic. Farmers with few resources were only able to grow mostly one crop per year, i.e., T.Aman. Consequently, farm laborers could only work for around four months in a year and then had to move elsewhere to sustain their livelihoods. In addition, rainfall in Barind used to be the lowest in the country and desertification started to become a problem. Barind did not have the physical properties that allow for easy irrigation. Moreover, a study report of the United Nations Development Programme (UNDP) published in 1982 made the situation out to be more complicated. The report said, *"Zone 'O' lies in western Rajshahi District and consists of older alluvial deposits known as Barind Tract, Thick clay deposits have been proven by test drilling which indicate that the main aquifer does not occur in the upper 300 m (980 ft.), therefore, groundwater is relatively thin, fine grained sand zones that occur within the clay sequence. The aquifer is capable of supporting only small domestic water needs."* In fact, in 1985, the national average of irrigation coverage was 45%, whereas the coverage in Barind at that time was only around 17%. Our efforts towards the introduction of Barind irrigation started not from zero but rather started from its negative perception.

Barind Multipurpose Development Authority (BMDA) was initiated as part of the Bangladesh Agricultural Development Corporation (BADC) from early 1980s in the form of a project. The government created BMDA in 1992 under the Ministry of Agriculture and an independent Board was constituted with a combination of administrative people (representatives from the Ministry of Agriculture, Deputy Commissioners of the project areas); people's representatives, i.e., Member of Parliament (MP); Farmer's three representatives; and Chief Executive in charge of implementation of the Authority's activities.

The most important principle being followed by the Board of the Authority is that it must run with its own revenue. The earnings must cover the operation and maintenance (O&M) costs, salary and wages, and also the retirement benefits of the employees. There are provisions for incentives and penalties for the service quality rendered by the field staff. The government allocates for developmental activities keeping in written form that the required manpower will be managed by the Authority's own revenue.

Interventions

The intervention to upscale the irrigation activities were mainly undertaken through abstraction of groundwater by deep tube well. Wherever possible, and for whatever the amount, rainfall was stored by re-excavating derelict natural khals with the construction of a series of structures of cross-dams. There is also an arrangement to carry the perennial river water through underground pipes to pump the water into the khal during dry months. Barind tried to provide emphasis on the conjunctive use of irrigation water, both from groundwater and surface water sources.

How

The area of Barind was once kept out of irrigation development due to limited or no aquifer added with “Caving” [problem during drilling]. Local engineers have innovated a new technology for well construction called “inverted well”. Gradually, local engineers were able to convince the Board Members that cash transactions should be avoided to realize the irrigation charges. The Authority got the coupons printed from the government’s security printing press where money notes were being printed.

What

Barind engineers could introduce the pre-paid meter with smart cards for both groundwater and surface water irrigation. That brings the miracle change towards sustainable irrigation management. All the wells can be electrified which will ease their operation and maintenance. The introduction of an underground plastic pipe water distribution system is also one option. Providing the best possible service with reasonable and affordable service charge, and provisioning to support the farmers with crop credit facility will play a key role.

Institutional speciality

The most important aspect of Barind irrigation management is its unique institutional aspects, such as the provision of incentives and penalties for good and bad performance, respectively, of the laborers. Initially, we were told that the Ministry of Finance would not agree to incentives for a public sector project. However, they proposed that if incentives were provisioned then there should also be a penalty provision, to which we agreed. Farmers welcome the installation of pre-paid meters to avoid the cash transactions at all levels. Initially, we were a little worried but ultimately there was a very positive impact. This is the reason for the Ministry of Agriculture instructing BADC to follow the Barind model. Another great institutional achievement was that the government approved Barind irrigation projects to run its O&M costs of tube wells and pumps, electricity bills including salary wages, and retirement benefits of staff. These three institutional aspects brought the miraculous changes to Barind irrigation management.

Introduction of pre-paid meters

The introduction of pre-paid meters and smart cards is an effort for the judicious use and payment of irrigation water. We have to agree that this introduction of pre-paid meters with smart cards at least helps farmers to reduce, if not stop fully, the practice of disparity among the farmers within the irrigation schemes. Sustainability of irrigation projects depends mainly on a few factors. These are the timely provision of water supplies through immediate repair of structures during the irrigation season. Reliability of the irrigation water is most important to a farmer and also recovery of affordable service charges. To overcome the social hassle for distribution of irrigation water, it is important to construct a proper water distribution system. BMDA gave due recognition to this aspect and constructed sufficient underground pipes for the irrigation distribution system to cover the entire command area with the provision of intermittent outlets.

The introduction of the pre-paid meters showed that the command area had increased by 22% and the number of farmers within the extended command area increased by 13%.

Replication of the Barind model

The Barind irrigation project started in 1985 in three districts and 14 *upazilas* (*thanas*), and a sustainable irrigation management system was achieved in 2004. Since then, gradual expansion of the system and also replication of the Barind model started all over northwest Bangladesh for 124 *upazilas* and 16 districts, covering 34,495 km^2. The Ministry of Agriculture requested BADC to undertake a pre-paid meter project like BMDA, and they have started a project for prepaid meters since 2010. A group of seven farmers and eight BWDB staff visited the Barind projects in the last week of January, 2013. Farmers of both the projects held discussions related to irrigation. The farmers observed the details of operation of both surface water and groundwater irrigation schemes. They were so convinced with the system that they requested BWDB and Asian Development Bank (ADB) personnel in the wrap-up meeting to execute the Muhuri Irrigation Project similar to BMDA. During the above Barind field visit, a consultant of LGED was in the team and agreed to recommend the Barind irrigation management system also for LGED.

Recommendations and conclusions:

The irrigation management system started with per unit land, per unit time of operations, per unit volume of water supply and then finally introduced the pre-paid meter and smart card. It might be best possible system at this stage but needs continuous research and development and monitoring. Barind irrigation projects are good examples of groundwater as well as surface water governance. It is being recommended that a follow-up research study should be undertaken by the relevant research organizations, both national and international (may be jointly), to identify the scope of further improvement, consolidation and ultimately replication of the model if it is found to be suitable for other irrigation projects and a way of achieving a sustainable irrigation management system in the neighboring regions.

Asian Development Bank (ADB) has to provide support for the Muhuri Irrigation Project (MIP). The following is stated in Working Paper no. 2 of The Institutional Framework and Lessons for FCDI Subprojects (Interim), July 2010, of DIMMIS:

In *response to the universal concern for irrigation sustainability, that O&M will fail through a lack of user raised funding, BMDA has introduced two innovative concepts for collection of irrigation service charge (ISC):*

- *The use of coupons.*
- *Pre-paid metering system.*

The report further stated that, "The benefits of the pre-paid system, either through the use of coupons or electronic cards are:

- *all water provided is paid for in advance;*
- *there is no opportunity to by-pass the meter;*
- *the system is completely transparent with checks and balances in place to counter fraud;*
- *close friends, relatives or influential people cannot coerce the operator to deliver water free of charge; and*
- *farmers cannot be exploited by landowners who may control the well.*

Pre-paid water charges go to BMDA coffers which support the sustainability of the BMDA irrigation systems based on the following principles:

- *Water is available when, and in the quantities, required all year-round;*
- *All repair and maintenance costs are borne by BMDA;*
- *Technical support is provided free of charge to the farmers;*
- *All electricity used by pumps or other irrigation equipment is paid for by BMDA;*
- *Pump operators are remunerated by BMDA on an hourly basis;*
- *The prepaid coupons and electronic card reloading are sold by dealers who are paid on a commission basis; and*
- *BMDA pays employee salaries and support costs for its 1,036 staff members without seeking unreliable funding sourced from the government.*

BMDA procedures could be adopted elsewhere on the basis that the Authority would purchase water in bulk at the headwork from BWDB, and distribute the water through down-line irrigation infrastructure to farmers on a pre-paid basis."

Participatory Approach for the Efficient Use of Water to Enhance Water Productivity and Livelihood Improvement of Small Farmers in the Eastern Region

A. Zaman, IFFCO Chair Professor, Bidhan Chandra Krishi Viswavidyalaya, West Bengal, India

Water resources management is an important tool that can be used by researchers to address issues such as climate change, natural disasters, pollution hazards, environmental degradation, deteriorating soil health for attaining food and livelihood security, and alleviating poverty. In addition to the present status of water availability, rainwater harvesting and its economic utilization coupled with inter-basin water transfer from surplus to deficit basins need to be executed to maximize the potential of water resources. Transfer of proven and cost-effective water management technologies at a faster rate are essential to maximize crop production and minimize the gap between irrigation potential created and utilized. Simultaneously, to narrow down the wider gap between generations of water-saving technologies and its adoption at end level. Efficient use of irrigation water minimizing conveyance losses; methods and scheduling of irrigation, selection of crop(s) and crop sequence(s) in accordance with agroecological situations also played an important role for enhancement of water productivity, livelihood improvement and alleviating poverty. Farmers' participatory approach viewed as a dynamic group interaction process in which all members of a group contribute to the attainment of common objectives, share the benefits accruing from group activities, exchange information and experience of common interest, and follow the rules, regulations and other decisions made by the group.

Those who manage and use the water on a daily basis could have the chance to be involved in the process. The local stakeholders influence policy formulation, alternative plans/designs, investment choices and management decisions which has an effect on their communities and establishes a sense of ownership. Conservation, distribution and utilization of water are the basic parameters of on-farm water management. Optimum scheduling of irrigation; choice of suitable method; conjunctive use of rainfall, surface water and groundwater for crop cultivation; provision of drainage; and use of improved agro-production technology are the basic needs of successful on-farm research. Judicious application of water at the proper time increased water use-efficiency and crop yield, and reduced the evaporation, deep percolation and other losses. The participatory action research is an effective and communicative measure in the developmental processes, and involves the users in the systemic process of change to make the socio-technical system more economically viable. On-farm participation encouraged the farmers to adopt irrigation technologies for growing crops on the basis of the cost-benefit approach. On-farm water management practices proved to be efficient for the dissemination of location-specific technologies to farmer's field wherein the active involvement of farmers at every stage was ensured. A series of field experiments on water management research were conducted over the years in selected commands wherein water-saving technologies for growing crops were developed. It has been possible to introduce a few of these as a package intervention for growing different field crops. The results of these studies revealed that there were positive impacts of irrigation water use on crop and water productivity, cropping intensity, input-use efficiency, farmers' income and employment generation on the adoption of water management technologies with the active participation of farmers.

The research findings showed that the growing of crops with less water requirement during post-monsoon and summer seasons is of paramount importance for the improvement of livelihoods of small farmers in the eastern region of the country. The farmers were carrying out potato cultivation with high doses of fertilizers and more water use during the winter season. The intervention succeeded in reducing fertilizer use as well as irrigation application to the crop without affecting yield. With recommended water management practices, yield of mustard increased up to an extent of 9.0% with 36% more water-use efficiency during the winter season. Groundnut grown during the summer season was introduced with recommended water management practices wherein farmers received more yield and achieved more water-use efficiency.

The cultivation of *boro* (summer) rice depending solely on groundwater resources led to dwindling of the water table gradually and was the main concerns of the researchers in this area. The problem of arsenic, ferrous salts and other heavy metals in potable water as well as irrigation water were also creating immense health hazards and social hindrances. In this pre-implementation scenario, technologies such as residual moisture utilization in crop cultivation during the summer season and introduction of less water-consuming crops were brought for wider adoption during pre-*Kharif* and post-monsoon season. Vegetable crops such as lady's finger, pointed gourd and bitter gourd were under effective soil moisture utilization with mulching management to reduce water requirement of the crops and sesame, and less water-consuming crops were introduced under crop diversification in order to effectively replace *boro* (summer) rice in the areas.

In order to match the cost-effectiveness with economic demand, the water-saving technologies were introduced to enhance farmers' income thereby augmenting groundwater resources. There are sufficient technologies available to enable bumper production of vegetable crops such as lady's finger, and pointed and bitter gourd throughout the summer period with a less amount of water which are substantially available in farm ponds and other surface water sources. The mulching management, including the use of polythene covers, helps in reducing the water requirement of crops very efficiently. The cost of variable inputs involved mulching with straw which were abundantly available after the harvesting of *Kharif* season rice. These vegetable crops, pointed gourd, bitter gourd and lady's finger, provided a substantial yield of 1.8 ton/ha, 3.0 ton/ha and 2.0 ton/ha, with a gross return of INR 10,000, INR 30,000 and INR 25,000 per ha, and having benefit-cost ratio of 0.67, 6.5 and 1.5, respectively. The less water-consuming crops such as sesame, linseed and safflower during the winter season also saved substantial water in comparison to growing other crop(s). The farmers were overwhelmed in taking on these programs as their own and successfully turned its implementation using a participatory approach with a simple demonstration of how water from underground sources were left untouched and thereby enhancing water productivity per unit of land as well as crop. An intangible benefit accrued apart from higher economic returns per unit of land and water, thereby augmenting groundwater resources.

The farmers were found to be much more enthusiastic in accepting and adopting these simple technologies which would ensure an additional income during the *pre-Kharif and post-monsoon season*, when there was no scope of cultivating any crop without the option of keeping the land fallow. The reducing cost of cultivation was becoming an added advantage to them.

In the areas under irrigated and rainfed ecology, there are immense possibilities for the mass adoption of these technologies throughout in the Indo-Gangetic alluvial zone of the eastern region. As such, there was enough scope for up-scaling these technologies by the farmers community, itself, if they would have been given proper training on the judicious use of water resources.

The participatory action research programs are needed with the following objectives:

- *to study the water budgeting, allocation and distribution in accordance with water demand for maximizing productivity under integrated farming systems;*
- *to develop an integrated farming system model for the efficient use of available water resources and incorporating a system for improving the livelihoods of small and marginal farmers in irrigated/rainfed areas;*
- *to demonstrate two to three proven water management and/or water-saving technologies for enhancing crop water productivity in the system;*
- *to assess the economic impact and analyses of the benefit-cost ratio, including employment generation, man-days creation, recycling of energy and increasing income of the farmers.*

Constraints to Exploiting Fisheries Potential in the Indian Indo-Gangetic Basin

Pradeep K. Katiha, National Agricultural Innovation Project, KAB II, PUSA, New Delhi

The fisheries sector in India is one of the major sources of food, livelihoods and recreation, through its activities of fishing and farming in aquatic ecosystems. The sector registered one of the highest growth rates among agriculture and allied activities during the last decade and was recognized as a sun-rising enterprise. It is highly relevant for a country like India, where about two-thirds of its population live in rural areas and depend largely on natural resources for their livelihoods. The Eastern Indo-Gangetic Basin forms one of the most fertile regions of the country with enormous inland fisheries resources (ponds, rivers, reservoirs, floodplain wetlands, etc.). The existing inland fish production of the country is over 5.3 million tons, out of which the basin contributes to more than one-third. Considering the decline in fish catch from rivers over the years, measures are necessary for efficient and generous utilization of river associated systems for fisheries to enhance fish production and productivity. However, the role of rivers will continue to be crucial, being the only source of valuable natural fish germplasm. At many fora, reservoirs and floodplain wetlands are recognized as the most important water resources for inland fisheries development in the country, in general, and the basin, in particular. The estimated gap between existing and potential fish production from these waters indicated that there is potential for approximately a sixfold increase in fish production and productivity. Further, their importance derives mainly from many advantages from an environmental and social perspective. There is also a need to dovetail the twin objectives of yield optimization and environmental conservation. The scope for eco-friendly fisheries management to enhance fish production and livelihoods from these waters is well documented. It requires a congenial socioeconomic environment, necessary trade-offs between policy and governance, and research and development efforts to harness the untapped production potential.

Considering these multiple uses, fisheries is recognized as a tertiary activity. Implementation of scientific management practices towards fisheries development is constrained by a number of technical and operational problems. Scientific management practices either received low priority or was overlooked altogether in fisheries development. This resulted in arbitrary stocking and non-adherence to sound stock management norms leading to low productivity. Over-stocking, under-stocking, stocking at small size, catching fish at small size, and lack of maintenance of a stocking and harvesting schedule are the most common drawbacks noticed. The inland water bodies are under heavy anthropogenic stress, and the level of technologies and infrastructure to combat this trend is grossly inadequate. A serious problem faced by the inland fisheries sector is over-fishing. The problem is further compounded by the use of irrational fishing devices. Low level of motivation, empowerment and awareness of the sustainability of fish stock are the main constraints. Non-availability of quality fish seed for stocking is the major constraint both in time and space. In water productivity estimates, the value of fisheries and fish-related services are not reflected due to lack of valuation tools. These aquatic resources are highly scattered, unorganized and located at remote places. The markets and post-harvest infrastructure are also equally scattered and, as a result, the database containing this information is highly unreliable. These waters have great fisheries potential in addition to their fundamental functions such as flood control, power generation and irrigation, day-to-day use, groundwater recharge, *etc*. However, such potential has not been fully recognized by the Government of India. This creates problems for governance and decreases the degree of freedom for optimization of fisheries activities. It is not the complexity of technology that comes in the way of achieving higher production from inland fisheries, but is often the lack of appropriate governance arrangements that prevent development. Thus, organization of the community that manages the system plays a key role. Inadequate marketing channels and marketing infrastructure often act as disincentives for the community to produce more fish by managing the resource in an appropriate manner. The emerging marketing opportunities and consumption pattern in the country, especially the supermarket culture, can be suitably utilized to the advantage of fishers. Ownership of inland waters does not always vest with the Fisheries Department and, in many cases, it has no access and authority to manage the fisheries in these waters. The Department of Animal Husbandry, Dairying and Fisheries (DAHDF) and National Fisheries Development Board (NFDB) can take a lead role in persuading the states to follow a common policy on this issue. The state fisheries departments need to shift from a 'revenue generation' approach to a 'development approach' and, similarly, the enforcement (command and control) approach should give way to a participatory (co-management) approach.

The success of fisheries management practices in inland open waters depend directly on the stakeholders/beneficiaries involved, their capabilities and interrelationships, and their physical and limnological conditions. In order to put in appropriate management practices in place, some of the suggestions may be as shown below:

- Organization and capacity building of the fisher community towards community management and conflict resolution.
- Active participation of the community in fisheries enhancements; *in situ* raising of fingerlings, enclosures, *etc.*
- Improving the financial capacity of fishers with institutional financial support
- Development of a strong leadership of fishers to encounter multi-use conflicts, and coordinate and implement fisheries management practices successfully and bargain for better remuneration for fish catch.
- Appropriate access to the primary or other markets through metaled road, good mode of transport and institutional arrangements at the market.
- Addressing vulnerability related to access, control and distribution linked to conflicts among stakeholders. Improving policies, institutions and processes, and orienting them towards conflict reduction and defending fisher rights is necessary.
- Continuous monitoring of policy choices and trade-offs towards the impact on poverty and food security, and modify them as and when necessary.

Annexure 4. Workshop Program

A two-day international workshop convened by the CGIAR Research Program on Water, Land and Ecosystems (WLE) in collaboration with the International Water Management Institute (IWMI) and co-sponsored by the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) and the Australian Centre for International Agricultural Research (ACIAR).

Time	Day 1 - May 7, 2013 (Tuesday)	Day 2 - May 8, 2013 (Wednesday)
8:30-9:00	Registration and Introductions	
9:00-11:00	**Session 1:** Welcome and Introductions (WLE, SRPs and EGP)	**Session 5: Theory of Change and Impact Pathways** Theory of Change and Impact Pathways Recap and Formation of the Think Tanks
11:00-11:20	BREAK	BREAK
11:20-1:00	**Session 2:** Theme – Availability of the Resources	**Session 6:** Research Needs Assessment Group activity I - Focus on Themes
1:00-2:00	LUNCH	LUNCH
2:00-3:30	**Session 3:** Theme – Access to the Resources	**Session 7(a):** Output from Group Activities I **Session 7(b):** Research Needs Assessment Group Activity II - Focus on Regions
3:30-4:00	BREAK	BREAK
4:00-6:00	**Session 4:** Theme - Achievements that can be Obtained through the Use of the Resources	**Session 8(a):** Output from Group Activities II **Session 8(b):** Way Forward and Closing Remarks

Day 1: May 7, 2013 (Tuesday)

Session 1: Welcome and Introductions (WLE, SRPs and EGP)

Time	Speakers	Topic
9:00-9:10 9:10-9:20 9:20-9:30	B. Sharma P. McCornick E. Christen	Inaugural address Introduction to IWMI ACIAR's interest in the EGP
9:30-9:40 9:40-9:50 9:50-10:00	A. Sikka/A. Kumar S. Mandal S. K. Sharma	Country overview and expectations: India Country overview and expectations: Bangladesh Country overview and expectations: Nepal
10:00-10:10	T. Shah	Research to lead development in the EGP: Lessons from the IWMI-Tata Water Policy Research Program
10:10-10:20	A. Noble	Introduction to WLE
 10:20-10:30 10:30-10:40 10:40-10:50	 P. Amerasinghe V. Smakhtin S. A. Prathapar	Introduction to different Strategic Research Portfolios (SRPs): SRP on Resource Recovery and Reuse, and Activity Cluster on Peri-urban Agricultural Water Management SRP on River Basins SRP on Irrigation
10:50-11:00	B. Sharma	Overview of the Activity Cluster Water Management in the EGP

(C) Session Chair: Peter McCornick
Speakers: Peter McCornick, Evan Christen, Alok Sikka, Sattar Mandal, Shiva Kumara Sharma, Bharat Sharma, S. A. Prathapar, Andrew Noble, Tushaar Shah, Priyanie Amerasinghe, Vladimir Smakhtin

Session 2: Theme – Availability of the Resources

Time	Speakers	Overview and knowledge gaps
11:30-11:45 11:45-12:00	A. K. Gosain D. Saha	The 'Ganges Water Machine': Surface water resources of the EGP The 'Ganges Water Machine': Groundwater resources of the EGP
12:00-12:15	L. Bharati	Water resources of Nepal
12:15-12:30	Z. H. Khan/L. Muthuwatta	Water resources of Bangladesh
12:30-12:45	A. Giriraj	Cascading Ganges: Floods and their impact in the EGP
12:45-1:00		Interactive session (Questions and Answers)

(C) Session Chair: Shiva Kumar Sharma; **Rapporteur**: Vladimir Smakhtin

Session 3: Theme – Access to the Resources

Time	Speakers	Overview and knowledge gaps
2:00-2:15	K. Palanisami	Improving rural livelihoods in the EGP
2:15-2:30	T. Shah	Water-energy nexus
2:30-2:45	S. Mandal	Institutions and policies
2:45-3:00	A. Kishore	Agrarian stagnation in Bihar
3:00-3:15	F. Sugden	Access to land and its effect on water management
3:15-3:30		Interactive session (Questions and Answers)

(C) Session Chair: Sattar Mandal; **Rapporteur**: Upali Amarasinghe

Session 4: Theme - Achievements that can be obtained through the use of the Resources

Time	Speakers	Overview and knowledge gaps
4:00-4:15	A. Sikka/ B. P. Bhatt	Overview of the EGP
4:15-4:30	M. Mondal/S. Yadav	Agrarian straightjacket: Constraints to achieving potential yield in rice production
4:30-4:45	A. Zaman	Participatory approach for efficient water use
4:45-5:00	A. Zaman	Replication of Barind model
5.00-5.15	P. K. Katiha	Constraints to achieve potential in Fisheries
5:15- 5.30	A. Kumar	Innovative land and water management practices for enhancing agricultural productivity and incomes in the EGP
5:30-6:00		Interactive session (Questions and Answers)

(C) Session Chair: Evan Christen; **Rapporteur**: Bharat Sharma

Day 2: May 8, 2013 (Wednesday)

Session 5: Theory of Change and Impact Pathways

Time	Speakers	Overview and knowledge gaps
9:00-10:30	E. Weight N. deHaan	Theory of change and impact pathways in relation to Activity Cluster of EGP Gender and the EGP
10:30-11:00	B. Sharma/ S. A. Prathapar	Lessons learned from Day 1 and formation of Think Tanks

(C) Session Chair: T. Shah

Session 6: Research Needs Assessment: Think Tank Activity I
Identifying thematic research needs

Time	Overview and knowledge gaps		
11:20-1:00	Parallel sessions: Participants to select topic according to their expertise and interest		
	Availability of the Resources	Access to the Resources	Achievements that can be Obtained through the Use of the resources
Session Resource	V. Smakhtin	T. Shah	A. Kumar/A. Sikka
Session facilitators	M. Buisson M. Mascarenhas	N. de Haan S. Vyas M. Marwah	E. Weight F. Naz

Session 7: Research Needs Assessment: Think Tank Activity II
Identifying regional research needs

Time	Overview and knowledge gaps			
2:00-2:45	Think Tank Representatives: Group Activity Results - Presentation I			
2:45-4:00	Parallel sessions: Participants to select topic according to their expertise and interest			
	India	Nepal	Bangladesh	EGP - Trans boundary issues

Session Resource	K. Palanisami	A. Dixit	S. Mandal	M. Kirby
Session facilitators	E. Weight, S. Vyas	R. Bastakoti N. de Haan	M. Mascarenhas M. Buisson	P. Saikia, M. Marwah

Session 8: Output from Group Activities I and II

Time	Speakers	Overview and knowledge gaps
4:20-5:20	Think Tank Representatives	Group Activity Results: Presentation I
5:20-5:30	S. A. Prathapar B. Sharma	Way Forward and Closing Remarks

Chair: Way Forward and Closing Remarks: Peter McCornick; Group Presentations: R. Malik

Annexure 5. Group-wise List of Participants

Think Tank Activity I. Availability of the resources.

Serial No.	Participants	Organization
1	ABHIJIT MUKHERJEE	INDIAN INSTITUTE OF TECHNOLOGY (IIT) KHARAGPUR, INDIA
2	RUPAK SARKAR	UTTAR BANGA KRISHI VISWAVIDYALAYA (UBKV), WEST BENGAL, INDIA
3	DIPANKAR SAHA	CENTRAL GROUND WATER BOARD (CGWB), MIDDLE EAST REGION (MER), PATNA
4	UTTAM RAJ TIMILSINA	DEPARTMENT OF IRRIGATION, NEPAL
5	SHISHIR KOIRALA	WATER AND ENERGY COMMISSION SECRETARIAT, NEPAL
6	LAL MUTHUWATTA	IWMI, HEADQUARTERS, SRI LANKA
7	K. BRINDHA	IWMI, LAOS
8	N. RAJMOHAN	IWMI, NEW DELHI, INDIA
9	K. M. NABIUL ISLAM	BANGLADESH INSTITUTE OF DEVELOPMENT STUDIES (BIDS), BANGLADESH
10	GIRIRAJ AMARNATH	IWMI, HEADQUARTERS, SRI LANKA
11	EVAN CHRISTEN	AUSTRALIAN CENTRE FOR INTERNATIONAL AGRICULTURAL RESEARCH (ACIAR)
12	VLADIMIR SMAKHTIN	IWMI, HEADQUARTERS, SRI LANKA
13	LUNA BHARATI	IWMI, NEPAL
14	UPALI AMARASINGHE	IWMI, HYDERABAD, INDIA
15	MAC KIRBY	COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANISATION (CSIRO)
16	PANCHALI SAIKIA	CONSULTANT, IWMI, NEW DELHI, INDIA

Think Tank Activity I: Access to the resources.

Serial No.	Participants	Organization
1	SIMRAT LABANA	AUSTRALIAN CENTRE FOR INTERNATIONAL AGRICULTURAL RESEARCH (ACIAR)
2	PETER MCCORNICK	IWMI, HEADQUARTERS (HQ), SRI LANKA
3	FLORIANE CLEMENT	IWMI, NEPAL
4	MICHAEL SCOBIE	UNIVERSITY OF SOUTHERN QUEENSLAND, AUSTRALIA
5	AJAYA DIXIT	INSTITUTE FOR SOCIAL AND ENVIRONMENTAL TRANSITION – NEPAL (ISET-N)
6	RAM BASTAKOTI	IWMI, NEPAL
7	ASHUTOSH UPADHYAYA	INDIAN COUNCIL OF AGRICULTURAL RESEARCH (ICAR)
8	NICOLINE DE HAAN	CGIAR RESEARCH PROGRAM ON WATER, LANDS AND ECOSYSTEMS (WLE), IWMI
9	AVINASH KISHORE	INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE (IFPRI), NEW DELHI, INDIA
10	M. A. SATTAR MANDAL	BANGLADESH PLANNING COMMISSION, BANGLADESH
11	FRASER SUGDEN	IWMI, NEPAL
12	RAVINDER P. S. MALIK	IWMI, NEW DELHI, INDIA
13	PALANISAMI KUPPANNAN	IWMI, HYDERABAD, INDIA
14	MADHAVI MARWAH	CONSULTANT, IWMI, NEW DELHI, INDIA

Think Tank Activity I. Achievements that can be obtained through the use of the resources.

Serial No.	Participants	Organization
1	ASADUZ ZAMAN	ASIAN DEVELOPMENT BANK (ADB), BANGLADESH
2	ERIC SCHMIDT	UNIVERSITY OF SOUTHERN QUEENSLAND, AUSTRALIA
3	K. H. ANANTHA	INTERNATIONAL CROPS RESEARCH INSTITUTE FOR THE SEMI-ARID TROPICS (ICRISAT), HYDERABAD, INDIA
4	PRIYANIE AMERASINGHE	IWMI, HYDERABAD, INDIA
5	B. P. BHATT	INDIAN COUNCIL OF AGRICULTURAL RESEARCH - RESEARCH COMPLEX FOR EASTERN REGION (ICAR-RCER), PATNA, BIHAR, INDIA
6	ASHWANI KUMAR	INDIAN COUNCIL OF AGRICULTURAL RESEARCH (ICAR), BHUBANESHWAR, ODISHA, INDIA
7	SUDHIR YADAV	INTERNATIONAL RICE RESEARCH INSTITUTE (IRRI), PHILIPPINES
8	MANORANJAN MONDAL	INTERNATIONAL RICE RESEARCH INSTITUTE (IRRI), BANGLADESH
9	A. ZAMAN	BIDHAN CHANDRA KRISHI VISWAVIDYALAYA, WEST BENGAL, INDIA
10	ARNAB CHAKRABORTY	PROFESSIONAL ASSISTANCE FOR DEVELOPMENT ACTION (PRADAN)
11	SHIV KUMAR SHARMA	DEPARTMENT OF IRRIGATION, NEPAL
12	SURENDRA RAJ SHRESTHA	GROUNDWATER RESOURCES DEVELOPMENT BOARD (GWRDB), NEPAL
13	LATA SHRESTHA	RENEWAL WORLD, NEPAL
14	BHARAT SHARMA	IWMI, NEW DELHI, INDIA
15	KUHU CHATTERJEE	AUSTRALIAN CENTRE FOR INTERNATIONAL AGRICULTURAL RESEARCH (ACIAR)
16	FARHAT NAZ	IWMI, NEW DELHI, INDIA
17	ELIZABETH WEIGHT	IWMI, HEADQUARTERS, SRI LANKA

Think Tank Activity II: India.

Serial No.	Participants	Organization
1	SHALIKA VYAS	IWMI, NEW DELHI, INDIA
2	FARHAT NAZ	IWMI, NEW DELHI, INDIA
3	ELIZABETH WEIGHT	IWMI, HEADQUARTERS, SRI LANKA
4	ASHUTOSH UPADHYAYA	INDIAN COUNCIL OF AGRICULTURAL RESEARCH (ICAR), PATNA
5	B. P. BHATT	INDIAN COUNCIL OF AGRICULTURAL RESEARCH - RESEARCH COMPLEX FOR EASTERN REGION (ICAR-RCER), PATNA, BIHAR, INDIA
6	RAVINDER P. S. MALIK	IWMI, NEW DELHI, INDIA
7	TUSHAAR SHAH	IWMI, ANAND, INDIA
8	PALANISAMI KUPPANNAN	IWMI, HYDERABAD, INDIA
9	ASHWANI KUMAR	INDIAN COUNCIL OF AGRICULTURAL RESEARCH (ICAR), BHUBANESHWAR, ODISHA, INDIA
10	K. H. ANANTHA	INTERNATIONAL CROPS RESEARCH INSTITUTE FOR THE SEMI-ARID TROPICS (ICRISAT)
11	N. RAJMOHAN	IWMI, NEW DELHI, INDIA
12	K. BRINDHA	IWMI, LAOS
13	MICHAEL SCOBIE	UNIVERSITY OF SOUTHERN QUEENSLAND, AUSTRALIA
14	BHARAT SHARMA	IWMI, NEW DELHI, INDIA
15	RUPAK SARKAR	UTTAR BANGA KRISHI VISWAVIDYALAYA (UBKV), WEST BENGAL, INDIA
16	A. ZAMAN	BIDHAN CHANDRA KRISHI VISWAVIDYALAYA, WEST BENGAL, INDIA
17	ARNAB CHAKRABORTY	PROFESSIONAL ASSISTANCE FOR DEVELOPMENT ACTION (PRADAN)

Think Tank Activity II: Bangladesh.

Serial No.	Participants	Organization
1	MANORANJAN MONDAL	INTERNATIONAL RICE RESEARCH INSTITUTE (IRRI), BANGLADESH
2	ASADUZ ZAMAN	ASIAN DEVELOPMENT BANK (ADB), BANGLADESH
3	M. A. SATTAR MANDAL	BANGLADESH PLANNING COMMISSION, BANGLADESH
4	K. M. NABIUL ISLAM	BANGLADESH INSTITUTE OF DEVELOPMENT STUDIES (BIDS), BANGLADESH
5	MAHESH KUMAR GATHALA	INTERNATIONAL MAIZE AND WHEAT IMPROVEMENT CENTER (CIMMYT)
6	LAL MUTHUWATTA	IWMI, HEADQUARTERS, SRI LANKA
7	MARIE-CHARLOTTE BUISSON	IWMI, NEW DELHI, INDIA
8	MARTINA MASCARENHAS	IWMI, HEADQUARTERS, SRI LANKA

Think Tank Activity II: Nepal.

Serial No.	Participants	Organization
1	NICOLINE DE HAAN	CGIAR RESEARCH PROGRAM ON WATER, LAND AND ECOSYSTEMS (WLE), IWMI
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Think Tank Activity II: Transboundary issues.

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