CPWF Project Report

The International Training and Research Program on Groundwater Governance in Asia: Theory and Practice

Project Number 42

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Program Preface

The Challenge Program on Water and Food (CPWF) contributes to efforts of the international community to ensure global diversions of water to agriculture are maintained at the level of the year 2000. It is a multi-institutional research initiative that aims to increase the resilience of social and ecological systems through better water management for food production. Through its broad partnerships, it conducts research that leads to impact on the poor and to policy change.

The CPWF conducts action-oriented research in nine river basins in Africa, Asia and Latin America, focusing on crop water productivity, fisheries and aquatic ecosystems, community arrangements for sharing water, integrated river basin management, and institutions and policies for successful implementation of developments in the water-food-environment nexus.

Project Preface

CGIAR-CPWF Project **"International Training and Research Program on Groundwater Governance in Asia: Theory and Practice"** was designed and implemented by International Water Management Institute (IWMI) to address the deficiencies in human capacity of managing groundwater in the two large basins of the world- the Indus-Gangetic basin and the Yellow River basin. The basic premise of the project was that proper groundwater management needs to be built on informed knowledge of professionals from the region, with emphasis on inter-disciplinary knowledge and understanding of the actual groundwater situation in the rural areas. This objective was achieved through development of an international courseware on the subject and actual enhancement of the capacity of existing institutions and about 80 professionals working at junior and senior levels and engaged in media dissemination in the basin states involved in groundwater research and management so that they could undertake more integrated, multi-disciplinary and sustainable approaches to groundwater governance.

CPWF Project Report series

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Location-specific hydro-geological assessments and numerical groundwater models dominate, while the larger and integrated issues of socio-economic impacts, political economy, groundwater institutions, property rights, and approaches to resource governance and management and specifically integrating science into management decisions have attracted surprisingly little scientific interest. Cross-Cutting and synthesis research under this Project broadly addressed this gap in the Indus-Gangetic River basin and the North China plains. The innovative "International Training and Research Program on Groundwater Governance in Asia: Theory and Practice" through its two cycles improved the knowledge, capacity and decision making of 78 professionals from five basin countries. The program increased the awareness, understanding and research capabilities of the participants with respect to the inter-linkages of the groundwater use, with the physical setting of the resource, the socio-economics, and legal, policy and institutional perspectives across different parts of the Indus-Gangetic and Yellow River basin. The direct participation of policy planners as 'actors' in the program helped in straight, uninterrupted and fast transfer of the knowledge.

The second component of the program was Cross-Cutting research implemented by the program participants and synthesis by the project team. The salient highlights of this component included the following:

i. Groundwater irrigation requires affordable and secured energy supply. Cost recovery of energy production (which sometimes is deferred in certain regions) and efficiency gains will become increasingly important. Proper understanding of groundwater-energy nexus is critical for the development of properly targeted policies, investments and subsidies.
ii. In many cases, general poverty and poor infrastructure systems and poorly developed markets limit the farmers in fully optimizing the production levels. Supportive poverty alleviating initiatives are required especially the north-eastern parts of South Asia (eastern India, Nepal and Bangladesh), to realize the development potential inherent in groundwater irrigation.
iii. The recent hike in diesel prices in South Asian countries have proven to be the proverbial 'last straw on the camel's back' for the livelihoods of small farmers and tenants and different farmers have adopted different coping strategies varying from agriculture exodus to switching the power source and investments in water conservation.
iv. Analysis of the institutional reform process in South Australia, provided several useful options in South Asian context and these included integrated water resource management, recognizing the connectivity between surface and ground water systems, system of water markets and water trading, continual improvement of data and scientific information, and extensive public consultation for effective decision making.
v. In the eastern Indo-Gangetic basin, informal groundwater markets are very common as high flat rate electricity tariff provides an incentive to pump owners to sell groundwater. However the recent trends show that pump owners are likely to be winners by being able to earn higher profit from selling water, while the water buyers will lose out.
vi. The basin wide analysis of Indus-Gangetic basin showed that stage of development and utilization of the groundwater resource has limited relationship with the abundance of resource availability. But, a mismatch between the basin hydrological conditions and the energy policies are leading to over-exploitation of the resource in the Indus basin and constraining the optimal use of the resource in the eastern Gangetic basin.

EXECUTIVE SUMMARY

Significant challenges are involved in the sustainable, equitable and efficient utilization of groundwater resources in the two major river basins of Asia: the Indus-Gangetic river basin in South Asia and the Yellow River basin in China. Poor understanding of the resource and potential management options and associated weak governance leads to over-exploitation of groundwater in some areas, while under-utilization co-exists in other parts. More than one billion population in the basin states of India, China, Pakistan, Bangladesh and Nepal today depend on groundwater for irrigation. Registering and regulating the groundwater use of these farmers is a huge task. To compound the problem, there is not much research on groundwater use and that which is carried out often excludes the people and institutions which use and manage this resource. The borrowed western models of direct and legal management are quite untenable under the Asian context. It was under this gap in knowledge and capacity for groundwater governance that a three-year research and capacity building program was designed and implemented. The objective of the program was to engage key public groundwater agencies in the Indo-Gangetic River Basin and Yellow River basin in a collaborative enterprise to increase the integrated understanding of contemporary groundwater use and develop a toolkit and network for pro-active groundwater governance. The project "Groundwater Governance in Asia: Capacity Building through Action Research in the Indo-Gangetic and Yellow River Basins" (http://www.waterandfood.org/gga) was funded by Challenge Program on Water and Food (http://www.waterandfood.org) and implemented by International Water Management Institute (http://www.iwmi.org) along with a host of both national and international partners. The program had two main components: the Training and the Cross-Cutting Research.

The training part of the Project, "The International Training and Research Program on Groundwater Governance in Asia: Theory and Practice" was about five-week interactive classroom program designed to develop cross-disciplinary learning and understanding of the realities and challenges of groundwater use and management in the Asian context. The program was quite ambitious in the sense that it tried to integrate three major aspects of groundwater management challenges: (i) it intended to work across two major river basins in Asia, (ii) it intended to integrate various disciplines, and (iii) it intended to integrate theoretical as well as practical issues of groundwater exploitation and use. Three thematic areas were reflected in the curriculum: physical science of groundwater, agronomic aspects of groundwater irrigation, and socio-economic, policy and institutional aspects related to groundwater use. In total, 78 participants, or fellows from five countries (India, Pakistan, Nepal, Bangladesh and China) enrolled and completed the program. The candidates were characterized into three groups: the Junior Professional Research Fellows (JPRF), the Senior Professional Research Fellows (SPRF), and the Media Fellows (MF). Both JPRF and MFs attended all the five modules of the program: Resource Characterization, Agricultural Water Use; Social Sciences, Economics and Institutions; Research Methods and Writing Skills; and Policies and Governance. The SPRFs attended the 'Policies and Governance' Module and also gained a compressed version of the discussions that had taken place and contributed to the debated topics. In addition there were included field trips, hand-on to software and modeling tools, personal work and group discussions, films and interactive games. The detailed curriculum was developed or adapted specifically for this program and dedicated papers and presentations were prepared by lecturers and trainers. All this vast body of knowledge has been collated and arranged and put on as a Courseware on a CD and also hosted on the project website.

Second component of the project was 'Cross-Cutting and Synthesis Research' phase of a duration of about 15 weeks for the Junior and Media fellows and 2-3 weeks for Senior Fellows. The Senior Fellows were exposed to contemporary groundwater issues, management challenges and approaches pertinent to a developed country through a study-cum-research visit to South Australia and/ or Kansas, USA. Based on their learning

and experiences, the Senior Fellows were requested to write an individual scientific paper on a preferred topic related to groundwater management in the study country but viewed from the perspective of the context of their own country. All such papers from the two phases have been compiled and are processed for publication.

The junior and media fellows undertook research in their home countries. This research spanned several representative locations across the Indus-Gangetic and the North China plains. The primary objective was to synthesize realities of groundwater use across the locations and disciplinary boundaries and train and equip a critical mass of groundwater managers to grasp the complex challenges of groundwater governance. The media fellows were given a role to focus on media/ awareness aspects of the groundwater use in their particular study area. Research questions and instruments were framed in order to understand groundwater issues from each of the three overarching perspectives: the physical resource, socio-economic, and policy and institutional perspectives. All this field and synthesis work was developed in the form of high quality incisive research papers and have been published in the form of a high quality international publication through the CRC Press, Netherlands and the International association of Hydrological Sciences (IAHS) as a standard hard-bound reference book (http://www.tandfbuiltenvironment.com/books/Groundwater-Governance-in-the-Indo-Gangetic-and-Yellow-River-Basins-isbn9780415465809) .

Some of the key messages from the research included: "Groundwater and rural livelihoods are rural livelihoods are intricately linked in many parts of South Asia and China and millions of farmers depend on this resource for irrigated farming. Evidence from primary surveys and supplementary studies shows that intensive use of groundwater takes place under various constraints such as threats of resource depletion and lack of energy supply and other conditions for higher agricultural outputs. Such constraints seriously affect the poorest farmers, and potentially jeopardize food security in a wider and longer term perspective. Continued groundwater irrigation requires huge, increased and secured energy supply. Cost recovery of energy production and efficiency gains will become increasingly important. Making policy makers aware of the close link between energy and groundwater irrigation is critical for the development of properly targeted policies, investments and subsidies. Implementation of general poverty alleviating measures is equally important for these regions and especially the north-eastern parts of South Asia (eastern India, Nepal, and Bangladesh) to realize the development potential inherent in groundwater irrigation." Several of these studies have been published in the international journals, global conferences and important policy roundtables. Some of these policies have made very good impacts during the lifetime of the project itself and has been very well captured under the impact pathways reports.

The project also put in place an exhaustive and intensive evaluation of the program during both the cycles of the program. Findings from the first cycle served to significantly improve the Second Cycle of the program. Results from the evaluation are presented in the main report. In general, the program was rated 'highly successful' and achieved more than the expected at the launching of the program.

Besides the international training courseware on " Groundwater Governance in Asia: Theory and Practice" the project has developed a number of useful outputs including the videos and posters, simulation games and peer reviewed papers, book chapters, books and conference proceedings.

1. INTRODUCTION

Groundwater irrigation has emerged as the mainstay of agriculture in the Indo-Gangetic basin of South Asia and the Yellow river Basin of the North China plains. It is estimated that groundwater extraction in India has more than quadrupled (from 50 to 210 km^3/ annum) between 1970 and 2000 (Shah, 2005). Similar figures for China are from 20 to 75 km^3/ annum over the same period. Significant challenges are involved in the sustainable, equitable and efficient utilization of groundwater resources in the major river basins. Poor understanding of the resource and potential management options and associated weak governance leads to over-exploitation of groundwater in some areas, while under utilization co-exists in other parts (eastern Gangetic basin)of the basin. Proper and efficient management of groundwater in these regions is an immense task and cannot be achieved in the short term. The experience and solutions available from the developed world (Australia, USA, Spain) where groundwater is also under stress can not be copied to this region, and most national governments and authorities are struggling with keeping up with new challenges and responding to previous and new impacts of excessive use and degradation of the resource (Villholth, 2009). In the Asian context, the problem is huge and complex. It is estimated that approximately one billion people in the countries of India, China, Pakistan, Bangladesh and Nepal rely on groundwater, often as their only source of irrigated agriculture (Sharma and Villholth, 2006). Farmer financed groundwater irrigation capacity has caught up -and in some regions, even surpassed- public irrigation. In India, out of some 20 million farmers one in every five already owns a tubewell; and during the coming years, this number will likely grow at a rate of around 0.8- 1.0 million/year. Moreover, through localized, fragmented pump rental markets, a representative pump owner sells irrigation service to an average of three neighboring plots (Mukherji and Shah, 2002), implying that finding Indian farmers who do not use groundwater irrigation at all would not be very easy. This is also the case with Bangladesh, Pakistan Punjab and north China (Shah et. al., 2003; Mainuddin, 2002). In the first attempt to estimate the size of the groundwater economy, it was calculated (Table 1) that the market value of groundwater used in these regions is likely to be around $ 15 billion/ year, and the value of agricultural output made possible by it is likely in the range of $ 40-60 billion/ year. For the poor agrarian economies of South Asia and north China, this makes groundwater irrigation a big business, and an even bigger livelihood generator (Mainuddin 2002). It is generally accepted that access to groundwater irrigation is a major contributing factor to poverty alleviation in Asian countries, through the more wide-spread and equal use opportunities provided by groundwater (Deb Roy & Shah, 2003), but it is also recognized that several factors limit this poverty reduction potential . A significant factor is that groundwater resources in

Table 1. The size of Asia's groundwater economy

Particulars	India	Pakistan Punjab	Bangladesh	Nepal terai	North China plains
Wells (million)	20	0.5	0.8	0.06	4.5
Average output/well (m3/hr.)	25	100	30	30	30
Average hours of operation/well/year	330	1090	1300	205	800
Price of pump irrigation ($/ hour)	1	2	1.5	1.5	0.96
Groundwater used (km3)	215	54.5	31.2	0.37	106
Value of groundwater used/ year in $ billion	8.6	1.1	1.6	0.02	2.5

Source: Shah (2006)

many places today are exploited to a level which are unsustainable in the medium and long-term, because of intensive pumping, degradation of quality, or both (Alauddin and

Quiggin, 2008; Qureshi et al., 2008). Another important factor that limits the poverty alleviating potential of groundwater in these regions is the poor targeting of support to groundwater development and the inherent low capabilities of various population groups to take advantage of the of the potential benefits of groundwater usage. Since the extensive groundwater development for irrigation is relatively recent and despite its scale of importance, the human understanding of both positive and negative implications remains limited (Villholth et al., 2009).

Most importantly, the human capacity available for addressing these challenges is limited in most parts of Asia, including the Indus-Gangetic and the Yellow River basins. Overall, improved human capacity is required in three key areas:

i. Equipping authorities engaged in water management to undertake groundwater management as an integral part of the total water resources
ii. Enhancing and directing ongoing research towards applicable and cross-disciplinary research relevant for the region
iii. Raising awareness of the general public on the importance of safeguarding the groundwater resource for the benefit of all stakeholders.

A problem tree developed for the Project is given below (Fig. 1)

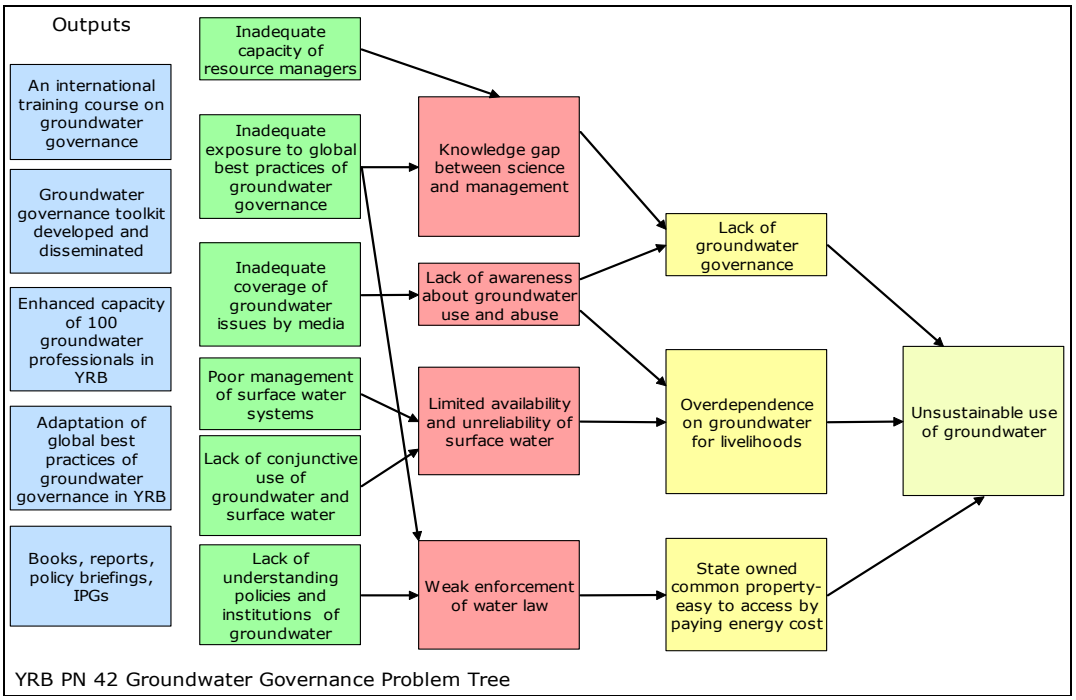

Figure 1. Problem tree for the Groundwater Governance in Asia and expected outputs from the Project

None of these aspects are covered sufficiently under the present courses and discourses on groundwater governance and remains a major limitation. Against this backdrop and to make an honest endeavor, a large scale project within the CGIAR Challenge Program on Water and Food (CPWF, http://www.waterandfood.org/) was designed to address deficiencies in human capacity of managing groundwater in the two river basins. The basic premise of the Project was that proper groundwater management needs to be built on informed knowledge of professionals from the region, with emphasis on inter-disciplinary knowledge and understanding of the actual groundwater governance situations at the field, farm and basin level.

2. PROJECT OBJECTIVES

The overall goal of this project was to contribute to the protection and better management of a fundamental component of the natural capital of the IGB and YRB, namely groundwater, and by that safeguard the livelihood of individual inhabitants and families dependent on this resource.

This goal of the project was achieved through enhancement of the capacity of existing institutions in the basin states involved in groundwater research and management to undertake more integrated, multi-disciplinary and sustainable approaches to groundwater governance. By involving practitioners directly in training and applied groundwater research, the project intends to seed a process of enduring change in the groundwater management sectors of the basin states (i.e. India, China, Pakistan, Bangladesh, and Nepal). Keeping in view the time, availability of the budget and other logistic requirements the Program was run for the two comprehensively developed and implemented cycles.

There are three specific objectives of this research project, which together contribute to the project goal of improving groundwater governance in the IGB and YRB. These objectives are:

i. To engage about 80 young and senior functionaries from government, civil society, media and academia in an inter-disciplinary program of training and policy research in groundwater governance to create and disseminate a base of knowledge that helps them in developing a better understanding of the pertinent groundwater issues, their own roles and practical ways to manage groundwater.
ii. To develop, disseminate and promote a practical toolkit for effective and proactive groundwater governance in different socio-ecological settings in the basins
iii. To promote policy dialogue on groundwater management in the region based on project findings and policy recommendations developed as part of the project

3. GROUNDWATER GOVERNANCE IN ASIA: TRAINING AND RESEARCH PROGRAM

The CPWF project on Groundwater Governance in Asia (GGA) was designed and directed by the International Water Management Institute. The program consisted of two annual cycles of a comprehensive training and research program called 'The International Training and Research Program on Groundwater Governance in Asia: Theory and Practice'. The target for the capacity building program was professionals actively in water from the five basin countries (Pakistan, India, Nepal and Bangladesh and China), preferably with groundwater research, management and media coverage. The project was quite ambitious in the sense that it tried to integrate three major aspects of the groundwater management challenge:

i. It intended to work across two major river basins in Asia, where conditions are variable but at the same time subjected to similar constraints and problems.
ii. It intended to integrate various disciplines, both by inviting people with different professional backgrounds and present roles, but also by addressing a multitude of topics related to groundwater use and management in the program curriculum.
iii. It intended to address theoretical as well as practical issues of groundwater exploitation and management, by having both interactive class work teaching as well as hands-on field work incorporated in the program.

3.1. Groundwater Problems in the Two Major River Basins in Asia

The project covered a very large area, covering two major river basins in the word, the Indus- Gangetic basin (2,251,500 km$^{2)}$ and the Yellow River basin (795,125 km^2) (Fig. 2 and Fig. 3). The key issues related to groundwater management varied across

Figure 2. Extent of Indus-Gangetic basin

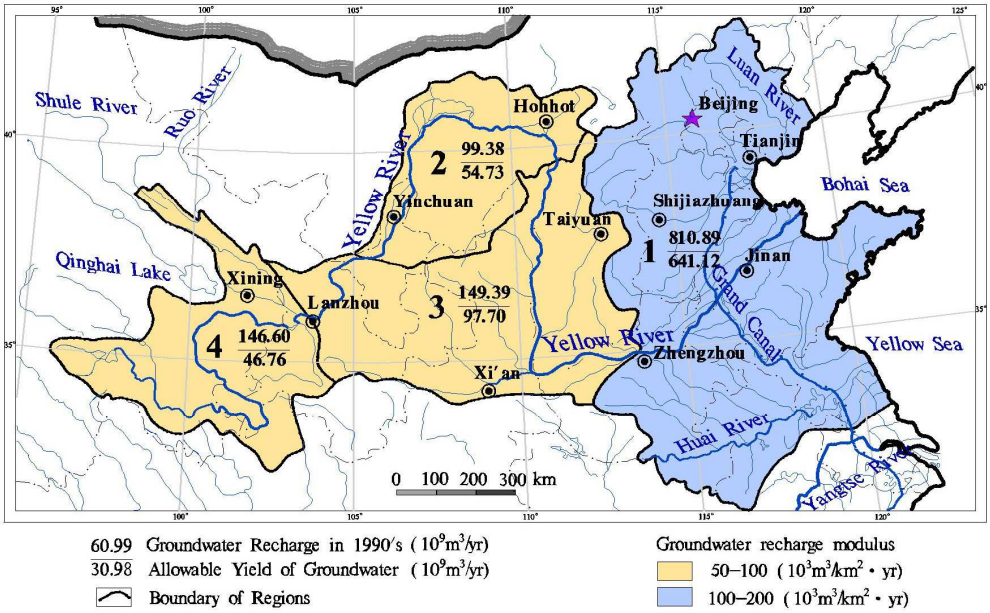

Figure 3. Groundwater resources in the Yellow River Basin and Huang-Huai plains, China

basins and the regions/ countries in the basin. The Indus river basin, principally covering Pakistan and Indian Punjab and Haryana, is faced with over-use of groundwater and declining water tables particularly in the arid areas, while the wetter areas or areas under the canal commands are mostly afflicted with water logging and salinity problems either of geological origin or due to mismanaged irrigation with insufficient drainage. The trend of continuous decline of groundwater table has been observed in many areas of Indus basin, which illustrated the serious imbalance between abstraction and recharge. Excessive lowering of the groundwater table has made pumping more expensive. As a result, many wells have gone out of production, yet the water tables continue to decline and salinity increases. In many areas of Punjab and Balochistan, groundwater tables are dropping at a rate of 1 to 3 m per year.

The upper reaches of the Ganges River in northern India and Nepal terai, have abundant groundwater supplies. Groundwater development in Nepal holds great promise for small-scale tubewell development and livelihood improvement. The middle reaches of the river, located in north-western part of India (western Uttar Pradesh, Delhi) face problems similar to those in Pakistan, namely over-utilization and salinity. Moving down the Ganges, the areas become increasingly wet and well supplied by the river water and the precipitation. The unexploited resource can potentially improve the agriculture and livelihood options in the region. The deltaic region in West Bengal (India) and Bangladesh also have copious aquifers and large recharge potential but faced with arsenic contamination in certain pockets. However, the promise of groundwater development has not developed accordingly, due to structural and institutional hindrances.

In the Yellow River basin, groundwater is increasingly being developed to supplement surface water irrigation in upper and middle reaches, while use of groundwater irrigation is more common in the lower reaches as well as in the North China Plains, raising concerns over continually declining groundwater levels. Though groundwater use in agriculture was a major concern in the Project, it is well understood that groundwater conditions (quality and quantity) are severely impacted by urban and industrial use in many parts of the basins, especially in the middle reaches of the Indus, middle reaches of the Ganges and the whole of North China Plains. Quality aspects were not very well

documented except for the Zhengzhou Municipal region in China and arsenic contamination in Bangladesh, but it was well recognized that quality could cause major long-term impacts. By addressing these diverse and large river basins and making comparisons across the regions, a comprehensive and integrated understanding of the groundwater situations was obtained under the Project.

3.2. The Inter-Disciplinary Approach of the Program

Understanding sustainable groundwater management in the developing world requires blending three distinct perspectives: (a) the resource perspective; (b) the user perspective; and (c) the institutional perspective. The project had a premise that global knowledge development as well as capacity development on groundwater use in agriculture so far is dominated by the 'resource perspective'; and a critical value-adding contribution is to be made in expanding global knowledge and capacity in user and institutional perspective. Recognizing this challenge that groundwater management has to achieve through integrated approaches and knowledge beyond a single discipline, the whole program was designed to incorporate knowledge from various disciplines of learning. The class room sessions covering these topics were a mix of general theory, explanation of the concepts, tools and terminology, applied theory, and cases illustrating these concepts and ideas.

The project addressed the following target groups and beneficiaries in the basin states:

i. Nodal governmental institutions and agencies involved in groundwater assessment and management, e.g. the Central Groundwater Board (CGWB) in India, the Water and Power Development Authority (WAPDA) in Pakistan, the Department of Irrigation in Nepal, Bangladesh Water Development Board (BWDB) in Bangladesh, and Yellow River Conservancy Commission (YRCC) in China
ii. Universities and other research agencies and nodal departments in the field of natural resource management
iii. Media workers involved in the coverage of natural resources news and topics
iv. Civil society members, e.g. non-government organizations (NGOs), aid agencies and extension agencies who have ground level contact with the direct users of groundwater
v. Farmers (both men and women), rural entrepreneurs, rural and urban consumers, and all those who are directly or indirectly associated with groundwater use

The target number of participants per country was based on the estimated significance of the groundwater economy of that particular country (Table 2). As an illustration the list of participants, categorized per country, background and profession for Cycle-I of the program is given in Table 3. In this cycle, 33 participants or fellows were selected for the program. The candidates were characterized into three groups: Junior Professional Research Fellows (JPRF), Senior Professional Research Fellows (SPRF) and Media Fellows (MF). Media people were also invited and journalists from Nepal (2), China (1) and Bangladesh (1) participated in the two cycles. The idea behind this was to investigate the existing and potential role of news media in disseminating groundwater policy discussions and increasing public awareness in the region. All the participants were made aware of the role that communication at various levels and across disciplines plays in making groundwater issues better known to the general public. The media/ communication angle was incorporated in various ways throughout the program: special sessions in the curriculum were devoted to the importance of communication, knowledge sharing and awareness raising, the media fellows were given assignments to develop videos from the field that could be used in explaining to the general public of that country what groundwater meant to the farmers today and what constraints were associated with its further development.

Table 2. Country-wise distribution of YPRFs, SPRFs and MFs, according to estimates of country-level groundwater economies

Category/Country	India	China	Bangladesh	Pakistan	Nepal	Total
Size of groundwater economy[1]	8.6	2.5	1.6	1.1	0.02	13.8
Share of GW economy, %	61	18	11	8	0.1	100
YPRF	30	14	8	6	2	60
SPRF	2	2	2	2	2	10
MF	2	2	2	2	2	10*
Total	34	18	12	10	6	80
Share of YPRF, %	50	23	13	10	3	100

[1] Direct value of groundwater used in agriculture, in billion (10^9) US$/year. Based on estimates given by Shah et al. (2003).* Due to lesser response from Media Fellows, number of YPRFs and SPRFs were enhanced.

The gender concern was addressed by ensuring the entry of qualified women to the program. In total 10 women fellows entered the program in the two cycles.

Table 3.Distribution of participants of GGA training and research program during Cycle-I and Cycle-II

Particulars	**Cycle-I**	**Cycle-II**
Total number of participants	33	45
Average age (for Junior fellows)	32.5	31.6
Average age (for Senior Fellows)	46.2	47.5
Percentage of women participants	12%	17.7%
Average number of years of experience (Junior fellows)	5 years	6 years
Average number of years of experience (Senior fellows)	15 years	17 years
No. of participants from:		
India	11	14
China	9	12
Bangladesh	5	8
Pakistan	4	6
Nepal	2	5
Others	2	-
Background		
Natural sciences and engineering	25	30
Economics and social sciences, media	8	15

3.3. Integration of Theory and Practice

The overall schedule of the program is shown in Table 4. Basically, the program had two major components: a theoretical interactive classroom sessions, games and small visits (upto 5 weeks) and an action research phase under actual farming conditions (upto fourteen weeks). Participants had to complete both the parts successfully in order fulfill the program requirements and obtain program certificate. The program completed with a joint summary and synthesis workshop of one week duration where all participants attended to present their research findings, discuss cross-cutting issues and evaluate the program. The summary and synthesis workshops were organized at New Delhi during 2007 and at Kathmandu during 2008. The program for SPRFs was more condensed in

order to accommodate their busy working schedules and high responsibilities. The common language throughout the program was English. The advertising for the program was done through internet and a Project website (http://www.waterandfood.org/gga), through national newspapers and magazines and through email and regular postage to relevant institutions.

Table 4. Schedule for the 'Groundwater Governance in Asia' training and research program

Component	Number of weeks	Duration for the different fellows	
		Junior Professional Research Fellows and Media Fellows	Senior Professional Research Fellows
Training Course	5	5 weeks	1 week (the last of the five weeks)
Research phase	14	5 weeks in the field+ 9 weeks for analysis and writing	3 weeks in the field in an advanced country (USA/ Australia)+ 1 week for report writing
Writing workshop	1	1 week	0
Summary workshop	1	1 week	1 week

This integrated multi-disciplinary and cross-regional approach is anticipated to:

i. Promote cross-disciplinary and cross-regional fertilization of learning, with opportunities for comparative policy research;
ii. Produce future leaders with a broad vision;
iii. Create cross-regional and inter-disciplinary networks and partnerships on groundwater governance beyond the lifetime of the project.

The complete program and its sequencing are presented in Figure 4.

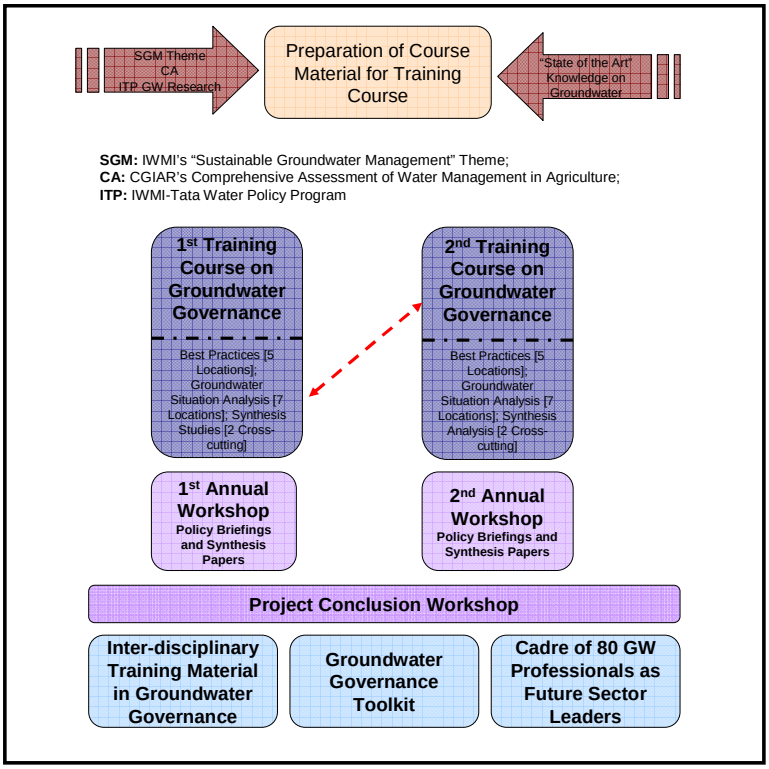

Figure 4. Framework of Groundwater Governance in Asia program

3.4. The Classroom Training Program: Toolkit for Groundwater Governance

The project commenced with the preparation of curriculum and study material for about five-week training course. It was designed to impart world class inter-disciplinary training in groundwater governance based on integration of the three-stringed themes, disciplines or perspectives: i. the resource view (physical, technical and environmental aspects), ii. The socio-economic view and iii. the policy-institutional view. Experts from all relevant disciplines were drafted in for curriculum formulation and teaching. Input and experience from previous research and activities in the region were utilized, e.g. from IWMI theme 3 ("Sustainable Groundwater Management" (SGM)), the Comprehensive Assessment of Water Management in Agriculture (CA), and the IWMI-Tata Water Policy Program (ITP) (See Figure 3). The more detailed program for the training course is given in Table 4. The three perspectives were developed as three different modules. In addition, a separate module was devoted to scientific methods, research preparation and short field tours. This part constituted about 30 per cent of time and included field/ laboratory visits, hands-on to software and modeling tools, personal work and group discussions, films and interactive games. The last week, when all JPRFs, SPRFs and Media fellows participated, was dedicated to the integrated aspects of groundwater governance (Table 5). The SPRFs participated only in this week and gained a concise version of the discussions that had taken place throughout the previous four weeks and at the same time contributed to a lively and practical view on the debated topics. The detailed curriculum was developed or adapted specifically for this program and dedicated papers and presentations were prepared by the resource persons. In total, more than 40 resource persons, including several from outside the basin countries, were engaged in the 5-week program during both the cycles. The entire course material has been harmonized to a common format and arranged under the following modules:

i. Module O : Introduction to the basins and GGA program
ii. Module I: Characterization of the groundwater resource
iii. Module II: Agricultural water use
iv. Module III: Economics and social sciences
v. Module IV: Groundwater management research methods
vi. Module V: Groundwater policies, institutions and governance

Each module has an introduction showing a brief note on each of the topic (title, contact of the resource person, what the trainee shall learn from this topic), and detailed lecture notes and the PowerPoint presentation for easy comprehension. Besides there is information on all the resource persons, field visits a special program on 'Groundwater View', Groundwater game, village case studies and the related material.

The course was conducted in collaboration with a number of host institutions located in the Indus-Gangetic basin. Besides the International water Management Institute- New Delhi Office, the main host institution was the Department of Water Resources Development and Management (DWRDM), at Indian Institute of Technology (IIT), Roorkee, Uttarakhand (http://www.iitr.ac.in/department/WRT/pages/index.html). Central Soil and Water Conservation Research & Training Institute (CSWCRTI), Dehradun; Indian Institute of Remote Sensing (IIRS), Dehradun; Wadia Institute of Himalayan Geology (WIHG), Dehradun; and Punjab Agricultural University (PAU), Ludhiana also hosted parts of the program. Finally, the Punjabi University, Patiala provided good support for the field visits and studying village anthropology of the study village, Bhajjal in Hoshiarpur district of Punjab. Based on the experience and feedback gained during Cycle-I, the program was improved during Cycle-II.

Table 5. Details of the topics covered under various modules under the Groundwater Governance in Asia training program (Final version)

Module O: Introduction to the basins and the program - Introduction to the Indo-Gangetic and Yellow River Basins - Groundwater governance in the Indo-Gangetic and Yellow River Basins - Yellow River basin: groundwater, people, problems and policies - Indus-Gangetic basin: high potential low productivity - Science for managing groundwater: introduction to groundwater characterization
Module I: Characterization of Groundwater Resources - Basic hydrology**,** sub-surface water flow processes, basic hydrogeology and hydro-chemistry, soil water processes and environmental physics - Modelling of groundwater flow systems, groundwater modeling and decision making, an illustrated collection of groundwater problems, application of surface geo-physics to groundwater investigations - Basics of remote sensing (RS), overview of geographical information systems (GIS), role of remote sensing in surface water assessment and hydrological modeling, RS & GIS for groundwater prospects and quality zonation - Groundwater quality and chemistry, groundwater and human health and environment, participatory water quality monitoring - Augmenting the resource: concepts and practices of artificial groundwater recharge, water harvesting techniques- design of small dams and hydraulic components; action and science in water harvesting and recharge - Well design and construction, selection and maintenance of irrigation pumps
Module II: Agricultural Water Use - Introduction to agronomic concepts; introduction to hydro-pedology - Understanding and improving water productivity - Estimation of crop water requirements, estimation of water requirements of important crops and foods - Soil-water-plant-atmosphere relationships for improving water productivity in Indus-Gangetic basin - Managing salinity and drainage problems for higher production in Indus-Gangetic and Yellow River Basin - Introduction to agricultural farming systems in IG basin; water efficient agricultural farming systems for IG basin and China plains - Water saving irrigation for rice, water saving agricultural technologies in YRB, irrigation water saving technologies for managing agro-ecologies of IG Basin; innovative water saving technologies for rainfed and irrigated areas- lessons from China - Micro and sprinkler irrigation for increasing water productivity; managing the water demand- role of irrigation water saving technologies - Groundwater: making sense of nature's fixed deposit
Module III: Economics and Social Sciences - Introduction to epistemology and anthropology, history of anthropology, political anthropology, anthropological approach; economic anthropology; economy and cultural reason - Political leadership among Swat *pathans*: a model summary and questions; anthropology of technology; rituals and symbiotic activity; introduction to kinship and gender; hierarchy and caste; notion of culture; theoretical sociology through important authors - The Punjab case studies- social anthropology of Bhajjal village in Hoshiarpur

district; sociological concepts and its application in study of groundwater - Governance and water rights, reforms, comparative case studies - Groundwater game: aquifers and people, gaming simulations of cooperation and competition among groundwater irrigators - Using social sciences to understand groundwater use and governance - Groundwater and human development: challenges and opportunities in livelihoods and environment; issues in the governance of groundwater use - Groundwater markets and agricultural development: A South Asian overview
Module IV: Groundwater Management Research Methods - Basic statistics and research methods in economics - Strategic communication to build support for increasing environment awareness in groundwater use and management - Research questions, questionnaires, data entry and report writing - Presentation skills, writing up qualitative research - Research methods in sociology and social anthropology, theoretical aspects of social science research - Knowledge sharing- communication and awareness, sharing of research outcomes and key objectives - SPSS training notes and manuals and hands on practice
Module V: Policies, Institutions and Governance (JPRFs+MFs+ SPRFs) - Groundwater institutions and governance: introduction to key ideas and concepts; Understanding groundwater politics through a political ecology perspective - Understanding water institutions: structure, environment and change process - Bhakra canals and groundwater management in Punjab and Haryana - The electricity-groundwater conundrum: the case for a political solution for a political problem; energy-irrigation nexus in water abundant regions of South Asia: evidence from West Bengal, India - Review of groundwater resources, institutions and policies in water abundant West Bengal (India) - Community management of groundwater: experiences of FAO Andhra Pradesh Farmer Managed Groundwater Systems (FAO APFMGS) - Adaptive approaches to groundwater governance: Lessons from Saurashtra recharge movement - Groundwater markets in India: A legal and institutional perspective - Local self governance and environmental decision making: potential and practices in U.S. and India - Physical approaches for groundwater management in Asia - Arwari River Parliament: An innovative approach to community water resource management from Rajasthan, India - Shared well irrigation systems in Punjab; groundwater legislation in Tamilnadu (India) - Governing groundwater: comparative analysis of national institutions and policies; an overview of groundwater use and abuse in India: some socio-political, economic and political perspective - Institutional aspects of groundwater irrigation in Nepal - Changing profiles of groundwater irrigation institutions in Bangladesh - Groundwater institutions in Punjab, Pakistan; irrigation management in Pakistan and India; comparing notes on institutions and policies - Groundwater markets in North China plains: impacts on irrigation, water use, crop yields and farm income; the development of groundwater markets in China: a glimpse into progress; the development, challenges and management of groundwater in rural China; groundwater and its development in YRB; groundwater governance in Zhengzhou, China: plan and progress - Groundwater as the Cindrella of water laws, policies and institutions in Australia

Table 6: Groundwater Governance in Asia – Training program schedule during Cycle-II (2007)

GGA Class Room Training Schedule, 2007							
HOURS/DATE	9H00-10H00	10H00-11H00	11H00-12H00	12H00-13H00	14H00-15H00	15H00-16H00	16H00-17H00
13/11/2007	**Registration**	**Inaugural function for the GGA course**		Participants Intros Session	Course Kick-off: Basin-Module Intros; TS/ BRS/ SK/ NB/ ST/ AM		Documentation/ disbursements/ : MR, MB, AK, NR
14/11/2007	0: Introduction: Connecting GW science with practice	1.1: Making sense from data in hydrology, SJ*(*Initials of Resource persons)			1.2 Tutorial 1: Rainfall modeling, Water Balance, SJ, SK*		2.1 A history of groundwater science, SK
15/11/2007	2.2 How to teach yourself groundwater hydrology, X1		2.3: Tutorial 2: Self-learning using softwares on GW Flow nets, Anisotropy, Well test			2.4: Case Discussion 1: Using people's knowledge in hydrology	
16/11/2007	Introduction to Resource Use Module: BRS	Soil-water-plant-atmosphere relationships; AKS		4.1: Tracking GW pollution, SK		4.2: Tutorial 4: Salinity intrusion and water logging in Western IGB , SK	
17/11/2007	4.3 Quick WQ studies with field kits, DA	4.4 Case Discussion 2: Can Arsenic pollution of GW be prevented?		5.1 Experiences from field on groundwater recharge		5.2 What is the maximum groundwater we can recharge ?, based on Horton paper and Gehlo case and field experiences	
18/11/2007	Move from New Delhi to Roorkee						
19/11/2007	Understanding and Estimating Crop Water Requirements: Theory and Tutorial (SKS)			Water requirements of imprtant foods: BRS	Understanding and Improving Water Productivity: Theory and Practical (AKS)		
20/11/2007	Irrigation Water Saving Technologies: AK		Water efficient agricutural farming Systems IGB : MSG		Innovative Water Saving technologies for Rainfed and Irrigated Areas of China : HWP		

21/11/2007	Water savingss in Rice: BRS		Managing Salinity and drainage problems: SKG	Conjunctive use of water resources : KVGK	
22/11/2007	Simple to complex GW Models: the tradeoffs: DK		Tutorial: GW Models : DK/ SK	Concepts and Designs of MI systems: SA Kulkarni	
23/11/2007	Remote Sensing and GIS in Water Resources Planning (IIRS, Dehradun): SKS				
24/11/2007	Watershed/Geology field visit: GW recharge, discharge; SW-GW links; Water chemistry; Forest-water linkages; Impacts of pumping				
25/11/2007	Yoga and meditation camp (Optional) or free time				
26/11/2007	0: Introduction to Economics, Social Science and GW governance (MG)	1.1 Economics and the GW game: An introduction (SK/TS)	1.2 The Game (SK/TS)		
27/11/2007	2.1 The sociology of groundwater governace (DP)	2.2. Case Studies: Class, income, gender and GW outcomes (DP)		1.3 Key lessons in the economics of GW (SK/TS/MG)	
28/11/2007	3.1 GW and the "problem of the commons" learning exercise (MG)	3.2 When is the commons not common? Rules for approaching GW governance (MG)	3.3 Options when the commons is common - thinking about the final week (MG)	Epistomology or Theory of knowledge including a presentation on 'How to transform field data into readable research papers' (TS)	15 minutes video on 'Getting you think differently about your data' followed by discussion of a chapter from Freakonomics (AM)
29/11/2007	Basic statistcis and research methods in economics (UA)		Research methods in sociology and social anthropology (VS)	Tutorial: Design of questionnaires and interview schedules (AM)	

30/11/2007	Village field visit and field work (conducting PRA activities and questionnaire surveys) (AM/NB)			
12-01-2007	Brief introduction to SPSS for simple statistics and econometrics, e.g. t test, ANOVA and OLS regression (UA/AM)	Tutorial: A set of exercises based on real data. Some questions could be: Do pump owners differ significantly from the non-pump owners, if yes, how? What determines pump density in a region? Is groundwater use limited to canal command areas? (AM/UA)		
12-02-2007	Move from Roorkee to New Delhi, Senior Fellows join			
12-03-2007	Introduction to GW institutions, policies and governance (TS)	Institutional Economics of water: RMS	Groundwater Institutions in North Gujarat: AP	Land tenure and groundwater rights: RMS
12-04-2007	GW institutions in West Bengal (AM)	GW institutions in Balochistan: FvS	Groundwater Institutions in Indian Punjab; RT	Groundwater Institutions in Nepal terai: Dibya
12-05-2007	The Arwari Parliament: RS	Andhra Pradesh Farmer Managed Groundwater Systems: PSR	Groundwater Institutions in Bangladesh: SM	groundwater Institutions in North china plains: JW
12-06-2007	GW Management in Australia: JM	Groundwater Regulation in China: JW	GW Management in the Westtern US: JN	Panel Discussion: JW, JM,JN,TS
12-07-2007	Physical approaches to GWG: DK	Adaptive Approaches: SM	Energy-Irrigation Nexus: TS, BR,AM, SM	Pump Irrigation and Politics: AM/TS
12-08-2007	**1. Planning Meet for CCR of JPRF : AM/ JW/ SM/ DR/ AN/MG/**		**2. Planning Meet for SPRF visit to Australia: JM/ BRS/ TS**	
12-09-2007	Free Time for Delhi visit (SPRF Depart)			
12-10/11-2007	**Planning Meet for CCR Workshop for JPRFs with site coordinators and resource persons: AM/BRS/ SM/ NP/ JW/MG/AN etc.**			

4. THE RESEARCH COMPONENT OF GGA PROGRAM

The research component of the program consisted of engagement for a period of about 15 weeks for the JPRFs and MFs and about 3 weeks for the SPRFs. JPRFs and MFs conducted research on a relevant groundwater management theme under actual farming and groundwater use conditions in their own respective countries. SPRFs proceeded for a study visit to a matured groundwater economy in an advanced country such as USA and Australia. All participants attended the final Writing and Synthesis Workshop.

4.1. Junior and Media Fellows Research

This research was called cross-cutting research (CCR) because the main goal was to synthesize realities of groundwater use and management across the geographical region as well as across the traditional disciplinary boundaries. The integrated framework of Cross-Cutting research is shown in Fig. 5.The other primary objective was to train, equip

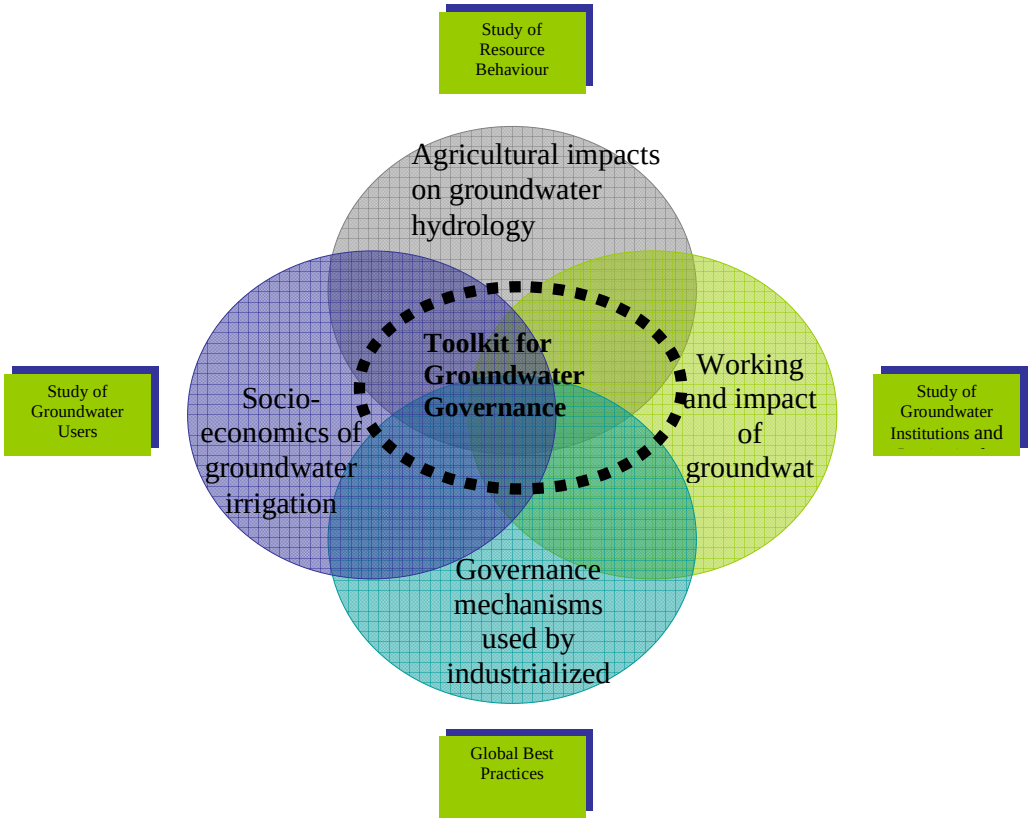

Figure 5. Framework for Cross-Cutting Research (CCR) under Groundwater Governance in Asia program

and enable present and future groundwater managers to understand and appreciate complex challenges of groundwater governance through first hand field experience and to facilitate interaction, discussion and cross-learning among the participants with diverse backgrounds. The media fellows were given a role to focus on media/ awareness aspects of the groundwater use in their particular study area. Locations of the Cross-Cutting research sites across the IGB and YRB are shown in Fig. 6 and Table 7.

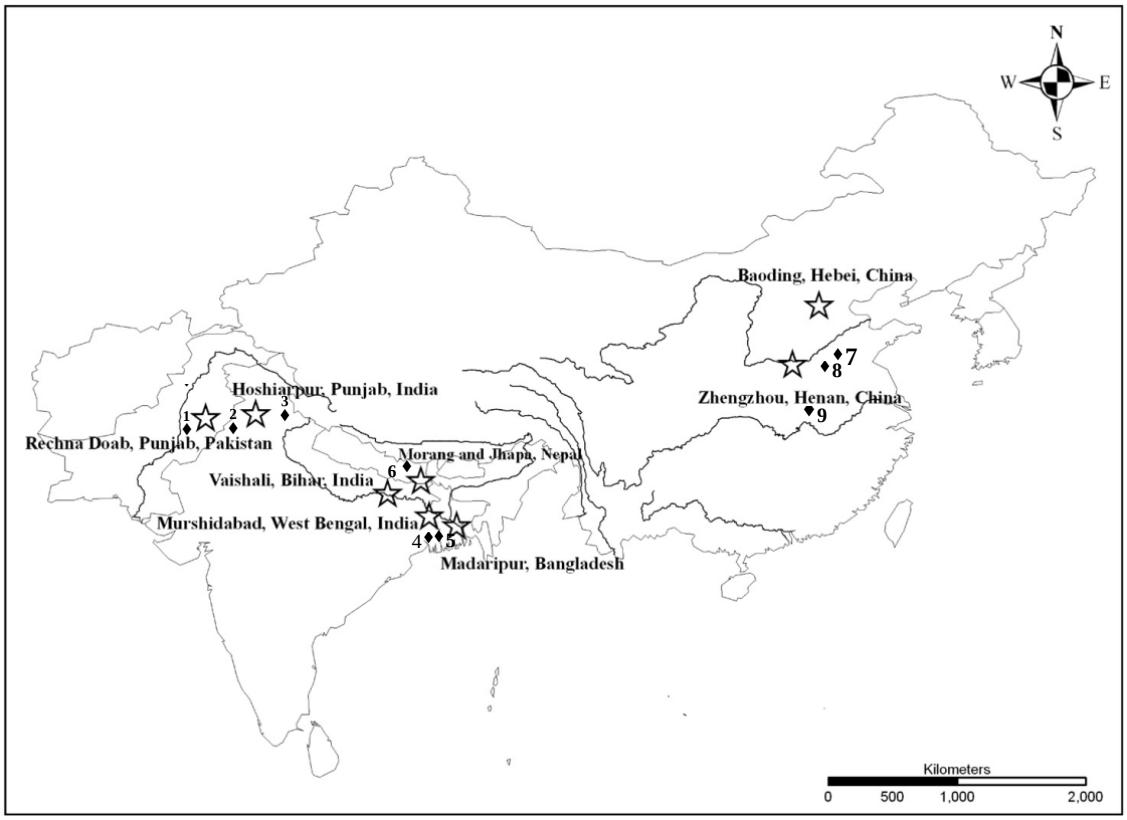

Figure 6. Sites for the Cross-cutting Research sites across the Indo-Gangetic and Yellow river basins (depicted by 'star' for Cycle-I and 'diamond' for Cycle-II, numerals refer to location sites as given in the Table-7)

Table 7. Description of the cross-cutting research sites during Cycle-I and Cycle-II of the GGA program

Country	Location –Cycle I	Location- Cycle II
Pakistan	1. Punjab province, Gujranwala and Jhang district	1. Near Lahore, Punjab
India	2. Punjab state, Hoshiarpur district 3. Bihar state, Vaishali district 4. West Bengal state, Murshidabad district	2. Haryana state, Kurukshetra district 3. Uttarakhand state, Haridwar district 4. West Bengal state ; Bankura, Bardhman, Hugli, Nadia, North-24 Parganas districts
Bangladesh	5. Madaripur district	5. Ghatail Upzilla of Tangail district
Nepal	6. Eastern Nepal terai districts of Morang and Jhapa	6. Hirminya Village Development Council of Banke district
China	7. Hebei province, qingyuan and Manchung counties of Baoding municipality 8. Henan province, Xinmi and Xingyang counties of Zhengzhou municipality	7. Henan and Hebei province ; Xian County, Ci County, Yanjin County, Kaifeng County 8. Henan province; Zhongmu county 9. Henan province, Kaifeng City and Zhongmu county

Groups of two to four fellows worked on a particular site and conducted surveys in between 3 to 20 villages each. Fieldwork was conducted for a period of five to six weeks

based on research instruments, primarily questionnaires, checklists and rapid appraisals. During the first cycle, the research questions were somewhat common for Indus-Gangetic basin and Yellow river basin. IWMI resource persons developed a set of questionnaires which were discussed and improved during a three-day pre-CCR training session prior to the field work. During the second cycle, each group was helped to define a particular problem and a research question in its study location and assisted in developing the set of questionnaires for understanding and solving the problem. Research questions for Cycle-II are given under Table 9.All the groups were provided with a site-coordinator to take care of the logistics, introducing to the functionaries and other research organizations in the area and help in collection of secondary data. Additionally, two resource persons were assigned to provide intellectual guidance and support on the technical and contextual part of the research and to review the reports. A mid-term field work review visit was undertaken by IWMI researchers to ensure quality of data collection and provide additional inputs.

Groundwater management research questions and instruments for the cross-cutting research (Table 8 and Table 9) were framed in order to understand groundwater issues from each of the three overarching perspectives: the physical resource, socio-economics and policy and institutional perspectives. Each group interviewed between 60-85 farmers for the data collection and developed a comprehensive paper on their findings, integrating all three perspectives and including some key parameters to enable comparisons across the sites. Following the field data collection phase, a period of nine weeks was devoted to the analysis and synthesis of results and for the draft report writing within the groups. The groups were also provided with a report writing template to facilitate a paper presentation around a common structural and content framework. Fellows were also encouraged to write individual papers on the specific areas of interest and relevance and some fellows did come out with very interesting papers such as arsenic contamination of groundwater in Bangladesh, groundwater markets in China etc.

Table 8. Research instruments for the Cross-Cutting Research during Cycle-I of Groundwater Governance in Asia program

i.	RI-1: Village level interview schedule
ii.	RI-2: Individual (pump owners and non-pump owners) interview schedule
iii.	RI-3: History of irrigation checklist
iv.	RI-4: Well driller's information schedule
v.	RI-5: Groundwater officials interview checklist
vi.	RI-6: Media news content analysis checklist

During Cycle –II of the program a different approach was followed and each group was encouraged to formulate a specific groundwater management problem in the study area-though a basket of commonly occurring problems in the region was made available. The group with the help of the resource person refined the research problem, defined a set of precise research questions and then formulated a set of research instruments and a plan for data collection from the secondary sources so that the suitable explanation was provided for a potential solution to the perceived problem. The approach still remained integrated in nature with a special focus to come out with policy prescriptions for the groundwater managers for a quick and wider solution to the groundwater problem of the region. Some of the specific research topics studied during the Second Cycle included the following:

i. Shallow tubewell irrigation business in Bangladesh: A field study in Dighalkandi Union under Ghatail Upzilla of Tangail district (Bangladesh)
ii. Groundwater use, productivity and profitability across command area of Pabnawa minor of Bhakra irrigation system (India)
iii. Transition to flat to metered agricultural tariff system in West Bengal india: who gains and who loses? (India)

iv. Accelerated power development reform program and preference of farmers for electricity tariff system- evidence from Uttarakhand, India (India)
v. Conjunctive water management across reaches of tertiary canal system in Punjab Pakistan (Pakistan)
vi. Electricity availability and its effect on small farmers' access to groundwater in Nepal terai (Nepal)
vii. Structure and management of irrigation water use in the conjunctive irrigated area in Yellow river basin: A case study in Zhongmu, Henan (China)
viii. Quality and governance of irrigation water in Kaifeng of China (China)
ix. Assessment of phreatic water quality and rationality of the management and development of groundwater in Zhongmu county (China)
x. Groundwater market operation in North rural China: how is the diversity and how it is showing diversity (China)

Table 9. The research perspectives of the cross-cutting research under the GGA program (Cycle-I and Cycle-II)

The resource perspective	The research themes
i. The physical resource perspective	*Groundwater resource inventory* - Nature and characteristics of aquifer - Groundwater quality - Discharge from wells and tubewells *Groundwater extraction technologies* - Historical evolution of groundwater extraction mechanisms *Technological options for groundwater supply augmentation*
ii. The social and economic perspective	*Economics of groundwater use* - Estimation of land and water productivity - Cost and benefits of groundwater irrigation - Comparison of groundwater irrigation with rainfed and canal irrigation systems *Groundwater irrigation and equity* - Who has access to groundwater and at what cost *Positive and negative externalities of groundwater use* -Coping strategies in case of negative externalities
iii. The policy and institutional perspective	*Groundwater institutions* - Formal institutions such as groundwater law - Informal institutions such as water markets and water sharing arrangements *Groundwater authorities and their role* - Vision, mission and strategies - Legal aspects of groundwater governance *Politics of groundwater* - Farmers mobilization around groundwater issues - Media coverage of groundwater and related issues *Managing the energy-irrigation nexus* - Distortions caused by subsidized/ free power pricing - High diesel prices and groundwater use

Though each study provided deep local insights into the seriousness of the groundwater management problem and the potential solutions for its alleviation, in general the studies highlighted that groundwater situation in South Asia (Indus-Gangetic basin) and North China (Yellow River basin) faces severe constraints. The studies presented an integrated view of the problem and also attempted to present solutions encompassing all the three perspectives. Maintaining the benefits already accrued and ensuring future food security and livelihoods in these regions constitute a major challenge deserving

continued interest from researchers and policy makers. Climate change and other factors of global uncertainty, like population growth and urbanization, change in consumption patterns and competition among the different sectors, pose further complex dimensions to the water scarcity issue. These studies showed that continued groundwater irrigation requires huge, increased, affordable and secured energy supply. Cost recovery of energy production (which sometimes is deferred in certain regions) and efficiency gains will become increasingly important (Nelson and Robertson, 2008). Making policy makers aware of the close link between energy and groundwater irrigation is critical for the development of properly targeted policies, investments and subsidies. Research and development also needs to focus on the use of renewable energy sources, such as solar and wind energy. Though groundwater and access to the resource appear to be a significant constraining factor for many poor farmers, it was well demonstrated that in many cases, general poverty and poor infrastructure systems and poorly developed markets for other inputs limit the farmers in fully optimizing the production levels. Hence, supportive poverty alleviating initiatives are required in these regions, especially the north-eastern parts of South Asia (eastern India, Nepal and Bangladesh), to realize the development potential inherent in groundwater irrigation (Villholth et al., 2009).

The field level data indicated that farmers are ingenious in their adaptation and coping strategies when it comes to optimizing the benefits of groundwater irrigation, at the personal as well as community levels. Such strategies need to be investigated in more detail and used to further support poverty alleviating measures for the farmers. In both the basins, migration to better endowed regions, whether to work as farm laborer or for urban livelihoods is a common trend. The drivers, conditions and obstacles for this trend need to be better understood in order to improve these adaptation measures and facilitate the conditions under which they occur. Such measures may enhance other policies and direct economic activities towards more sustainable development (Deshingkar et al., 2006).

Sufficient scope exists for improving local level groundwater management through support to capacity building, awareness raising and financing of specific activities and investments. However, experience has shown that local groundwater initiatives require intensive external effort and need to be well documented, disseminated and replicated widely, to make investments viable and ensure impacts on broader scale.

Presently, information on the resource availability is not in a format and content suitable to make good development plans. Often, lack of groundwater- related data is a critical constraint for developing such understanding and policy recommendations based on informed knowledge. However, a comprehensive, integrated and multi-disciplinary understanding of the resource base along with knowledge of the functioning of the socio-economic, developmental, and political environment in which groundwater irrigation occurs is fundamental. As the groundwater constraints affect mostly the poorest farmers, and potentially jeopardize food security in a wider and longer term perspective; the potential technologies and policies need to take all these aspects into account.

4.2. Senior Fellows Research

The Senior Professional Research Fellows' research phase consisted of about three-week study-cum-research visit to a developed country which uses significant amounts of groundwater for irrigation and other productive uses and are faced with considerable management challenges. The objective of the study visit was to familiarize the participants to contemporary groundwater issues, management challenges and approaches and policies suitable for a matured groundwater economy. It was expected that such an experience would equip the SPRFs with tools and knowledge as well as a useful network with which to expand their ability to address groundwater governance challenges in their own management environment in the respective home countries.

After a considerable research and correspondence with the institutes dealing with groundwater governance issues in the developing countries and also the interest shown by the SPRFs in their application forms, it was found that USA and Australia were the preferred countries. Hence, agreements were made with the (i) School of Law-University of Kansas (Prof. John Peck), USA, and (ii) Centre for Water Governance, School of Commerce (Prof. Jennifer McKay), University of South Australia, Adelaide, Australia. During the Second Cycle, all the fellows preferred for the Australian study visit. Individual programs for each group of fellows addressing groundwater relevant problem areas were drawn up. The program included lectures by the resource persons of high repute, institutional visits, field trips to areas with significant groundwater use and various innovative technologies or approaches and interactions with the groundwater practitioners/ user groups (Table 10). The participants were also exposed to the local media for expressing their viewpoints on the most pertinent groundwater management issues. Based on their learning, personal interaction with experts and practitioners, secondary data and reports and literature surveys the senior fellows were requested to

Table 10. Program components and topics covered in the study visits by the Senior Professional Research Fellows

United States of America- Kansas	Australia- South Australia
• Kansas socio-economics • Kansas water rights administration • Interstate issues on Missouri river • Interstate issues with Colorado and Nebraska • Municipal water reuse, reservoir sedimentation, aquifer storage and recovery project, water pollution • Land use changes- from ranch to game reserve • Kansas irrigation economy • Ogallala aquifer and sustainable agriculture • Retracting groundwater rights and farmer compensation	• State-level administration of laws and policies • Environmental court, conflict resolution • Aquifer storage and recovery work • Water recycling/ reuse • Groundwater irrigation techniques and regulation • Groundwater and forestry plantations • Groundwater users associations • Functioning of groundwater markets • Groundwater and grapevine economy

Develop an individual scientific paper on a preferred topic related to groundwater management in the study country but viewed from the perspective of the context of their own country. Some of the topics covered by the SPRFs in their individual papers are listed below:

i. Institutional aspects of groundwater governance in North Indian states(India)
ii. Groundwater management in India: Problems and perspectives (India)
iii. Water use in agriculture in Indian Punjab: Present situation and future perspective (India)
iv. Challenges with uncertainties and prospects from community based scientific approaches in groundwater governance and management in hard rock aquifers (India)
v. Water policies and plans: Limitations to groundwater governance in Bangladesh and learning from South Australia's experience (Bangladesh)
vi. Arsenic contamination of shallow groundwater in Bangladesh: management and governance activities (Bangladesh)
vii. Need of groundwater in Nepal: how urgent? Lessons from South Australia (Nepal)

viii. Groundwater issues and governance policies in Pakistan (Pakistan)
ix. Establishment of water saving society in China: Characteristics, policies and challenges (China)
x. Groundwater management for Northern China (China)

All the SPRFs were encouraged to organize a seminar on these developed papers and their experiences from the visit in their respective departments and provide useful inputs to the existing and new groundwater governance laws in the home country. As a pleasant surprise, most of the SPRFs informed that these seminars were highly successful and greatly appreciated and some of them really made very long lasting policy changes to ensure the sustainable use of groundwater governance in the basin countries. Very useful and impact making publications have arisen out of this component of the groundwater governance research.

4.3. The Writing and Synthesis Workshop

Each cycle of the Groundwater Governance Training Program was concluded with about two-week intense session- comprising a one-week writing workshop for the junior and media fellows and a one-week synthesis workshop for all the participants, including senior fellows, project team members, resource persons, site coordinators and invited guests. These Workshops were organized at New delhi during Cycle-I and at Kathmandu during Cycle-II. The objective of the writing workshop was to develop the reports/ papers in a harmonized style, help the participants with any analysis difficulties and better interpretation of the results. All the groups and the senior fellows presented their findings to the entire group and incorporated the comments/ queries received from the house. On the final day, a sort of convocation was held to deliver the Program Participation Certificates through the hands of a dignitary. Best group and theme papers were given special recognition and small awards which also instilled a sense of competition and excellence among the participants.

5. PROGRAM EVALUATION AND FEEDBACK

A systematic and well-structure evaluation procedure was designed and implemented to assess the strong and weak points of the program. Overall feedback from the participants is given in Table 11 and Fig.7. While higher than average score (of 8.4) was obtained in terms of session objective, comprehensibility, participation and presentation, the participants attributed a lower than average score to session content and overall session benefits and repetition of same or similar sessions in the next cycle. Scores for

Table 11. Overall course feedback score: Cycle-I

OVERALL SCORES	Obj. and Relevance (3)	Content (6)	Comprehension (4)	Participation (2)	Presentation (3)	Benefit (4)	Overall score (22)
Max. Possible Score	3441	6882	4588	2294	3441	3628	25234
Actual Score	3119	5630	3956	1973	2985	2669	20332
Percent Score	0.91	0.82	0.86	0.86	0.87	0.79	0.84
Scaled Score (1 to 10)	9.1	8.2	8.6	8.6	8.7	7.9	8.4

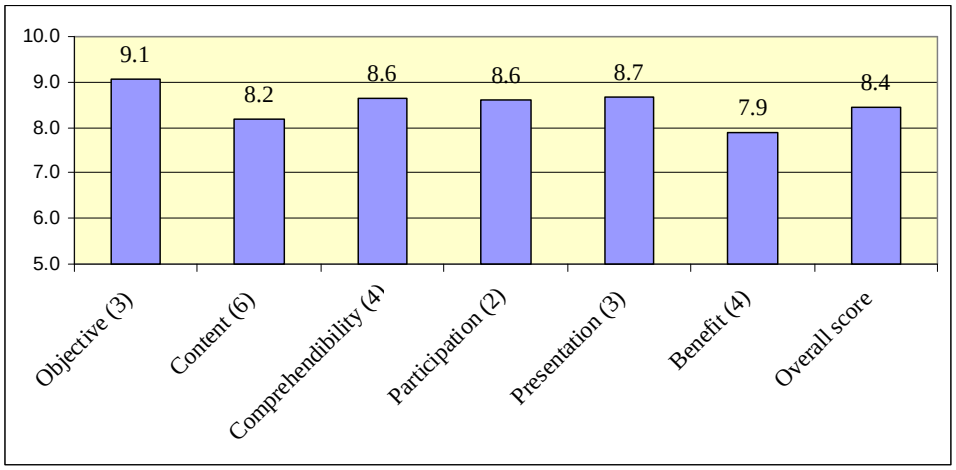

Figure 7. Overall scores for first cycle of GGA School

the Cross- Cutting Research (CCR) phase are given in Fig. 8. Scaled scores for the study-visit by the senior fellows are shown in Fig. 9.

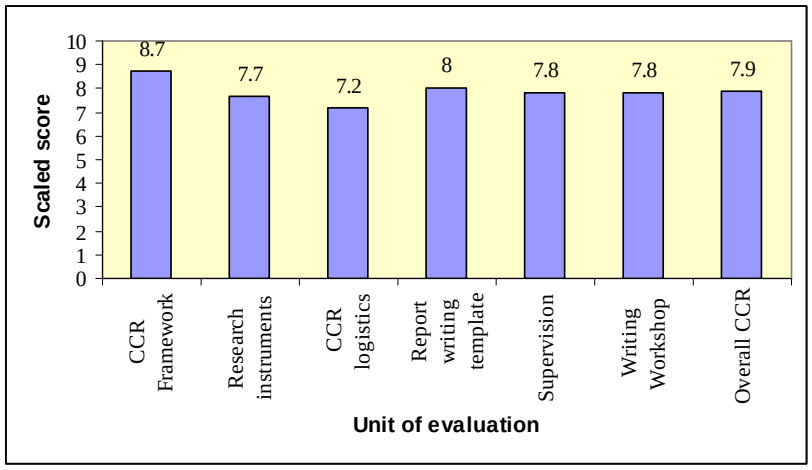

Figure 8. Scaled score for various components of CCR- Cycle-I

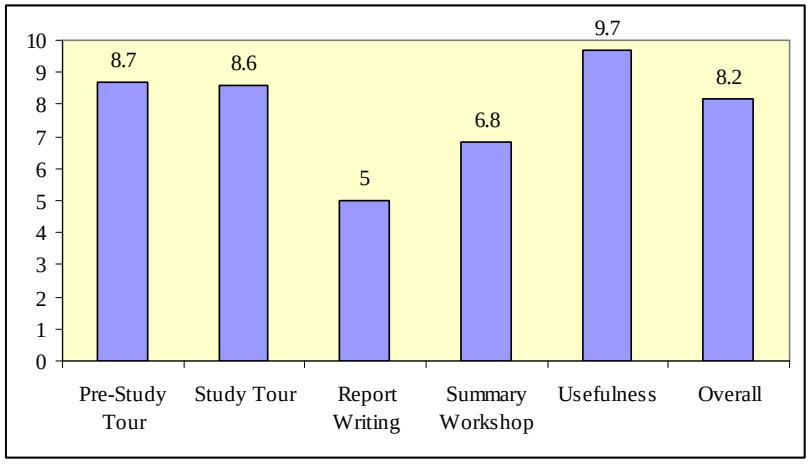

Figure 9. Scaled score for various components of SPRFs study visit- Cycle I

Based on the feedback provided by the participants, there were several good suggestions for improvement of the second cycle. Some of the major suggestions included the following:

GGA Training School

i. Reduce the duration of the School from 5 weeks to 4 weeks (agreed)
ii. Make sure that venue of the School is at one place (or maximum two places) so that time and energy is not lost through continuous travelling (agreed)
iii. Work on improving the curriculum of the School. This can be done by better coordination among module designers. Avoid too many traditional lectures; instead introduce simulation games, interactive exercises, 'hands-on-learning' sessions etc. (agreed)
iv. Target the 'right' people from the 'right' organizations. Give special emphasis on involving participants from groundwater departments. (agreed)
v. Announce schedules and plans well in advance and adhere to them at all costs in order to reduce confusion among participants. (agreed)

Cross-Cutting Research (CCR) Phase

i. Integrate CCR phase with topics discussed during the GGA School (agreed)

ii. Devote more time to research methodology with special focus on data analysis and interpretation. (agreed)
iii. Discuss research framework, research instruments and report writing templates and details of the study-site in detail before commencement of fieldwork. (agreed).
iv. Compulsorily provide site coordinators to all the groups to take care of logistical issues (not needed for Chinese groups) (agreed)
v. Continue the mid-term review process during fieldwork (agreed)
vi. Arrange a data entry and analysis workshop right at the end of the fieldwork at the respective field sites before the participants leave for their home bases.
vii. Involve supervisor right from the beginning and not only during the report review phase. (agreed)
viii. Publication plan for research outputs must be well formulated right from the beginning. (agreed)

SPRFs Study Tour

1. Ensure better coordination between IWMI supervisor and host country supervisors. (agreed)
2. Define research problem before embarking on the study tour and work on that specific problem. (agreed)

Suggestions and scores received during the first cycle greatly helped in improving the program for the Second cycle and most of the suggestions were agreed and acted upon while designing and implementing the Second Cycle. A more rigorous and near real-time evaluation process was again designed and put in place during the Second Cycle. The evaluation was based on the questionnaires administered to the participants at various times and after various milestones in the program in addition to a plenum discussion held during the synthesis workshop. The questionnaires covered each of the lecture/ course session, the various modules, the program components, and the program in its entirety. The resource person for each of the session also provided useful feedback to each of the session and the program in general. Kirkpatrick's four levels of training evaluation were used to evaluate the training programme. The evaluation was done at four levels which have been listed below:

i. Reaction evaluation
ii. Learning evaluation
iii. Behavior evaluation
iv. Results evaluation

All the captured data was analyzed following a rigorous method by assigning proper weights, percentages and averages to the different components. At the end the person responsible for the analysis made a presentation during the synthesis workshop for wider acceptance, criticism and comments. The entire exercise was developed into a suitable evaluation report for the two cycles of the program. The evaluation was based on the five modules of the training program (Table 12) given below:

Table 12. Description of GGA training modules: Cycle-II

Module Number	Module Name	Session conducted	Number of days	T	FV	CS	G
1	Resource Characterization	15	6	3	1	3	0
2	Agricultural Water Use	13	6	0	0	0	0
3	Economics and Sociology	9	3	0	0	1	1
4	Research Methods	8	4	2	1	0	0
5	Institution, Policy, Governance	20	7	0	0	0	0
Total		65	26	5	2	4	1

(T: Tutorial, FV: Field Visit, CS: Case Studies, G: Games)

Some of the findings of the evaluation made during Second Cycle are presented below through the graphics (Fig. 10, Fig. 11, Fig. 12, Fig. 13, Fig. 14, Fig. 15).

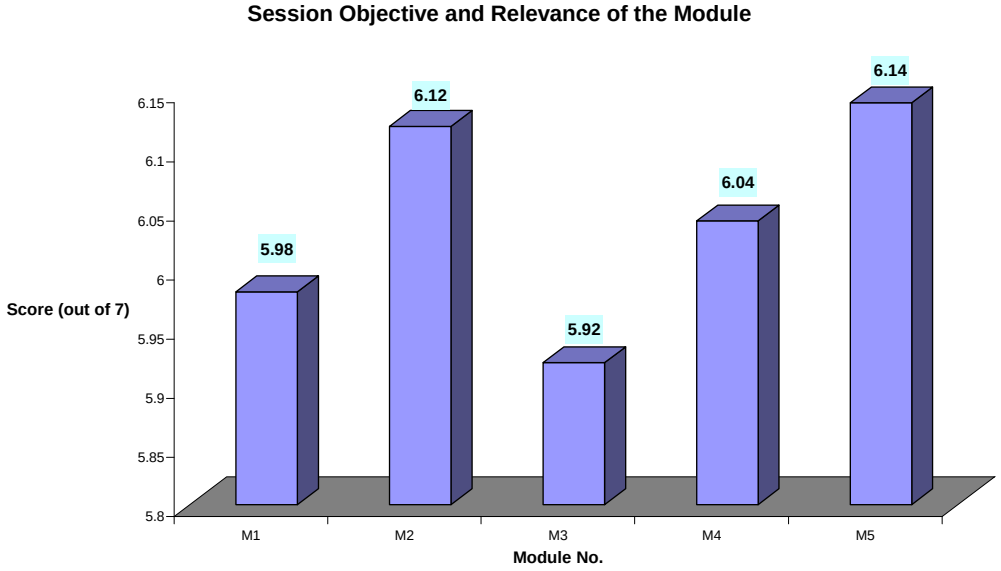

Figure 10. Comparison of modules based on session objective and relevance

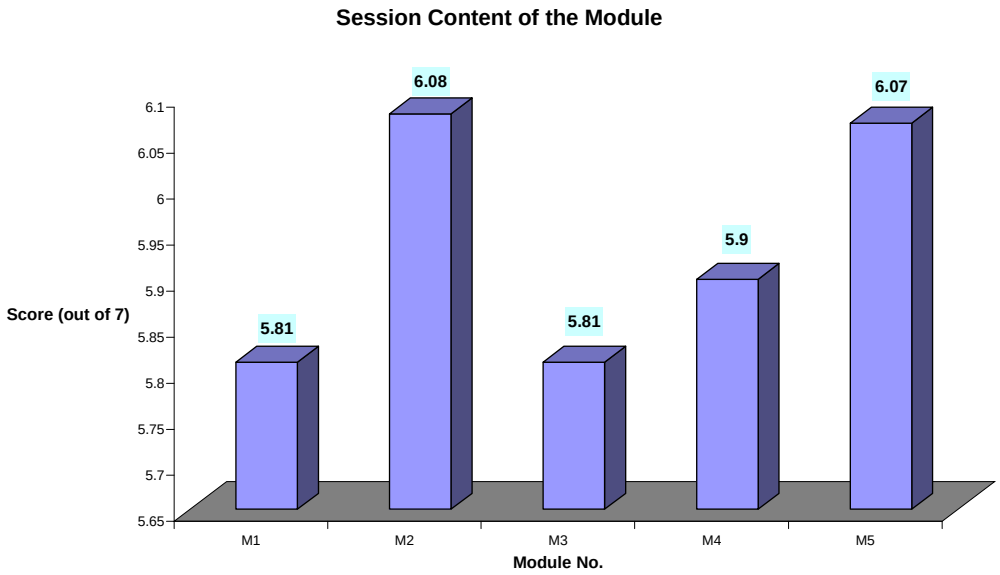

Figure 11. Comparison of modules based on session content

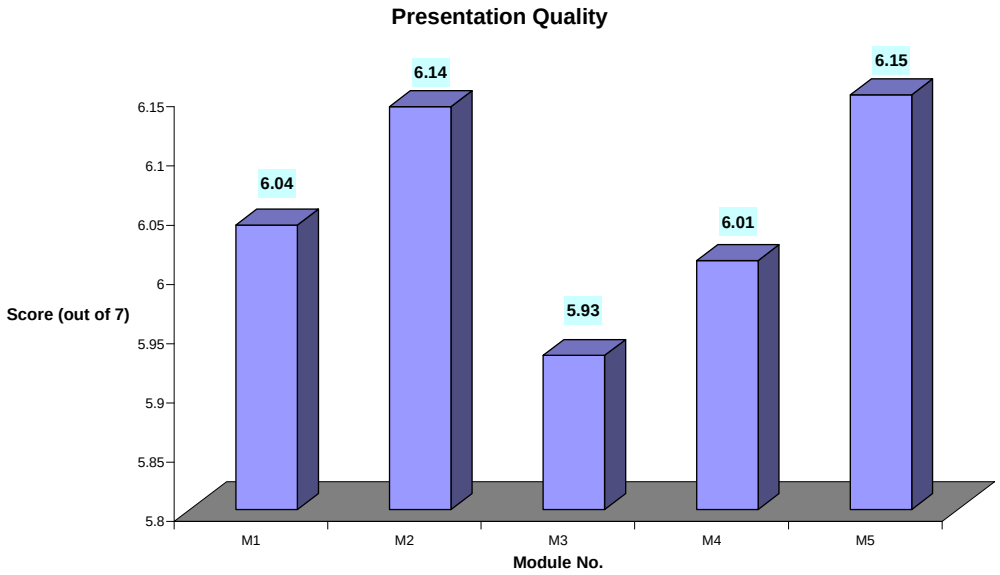

Figure 12. Comparison of modules based on presentation quality

Figure 13. Comparison of modules based on course benefit.

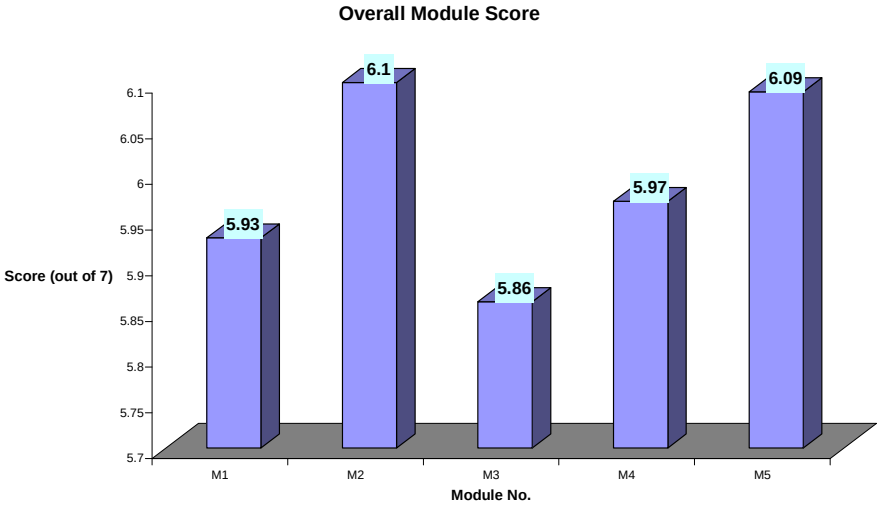

Figure 14 : Comparison of modules based on overall performance

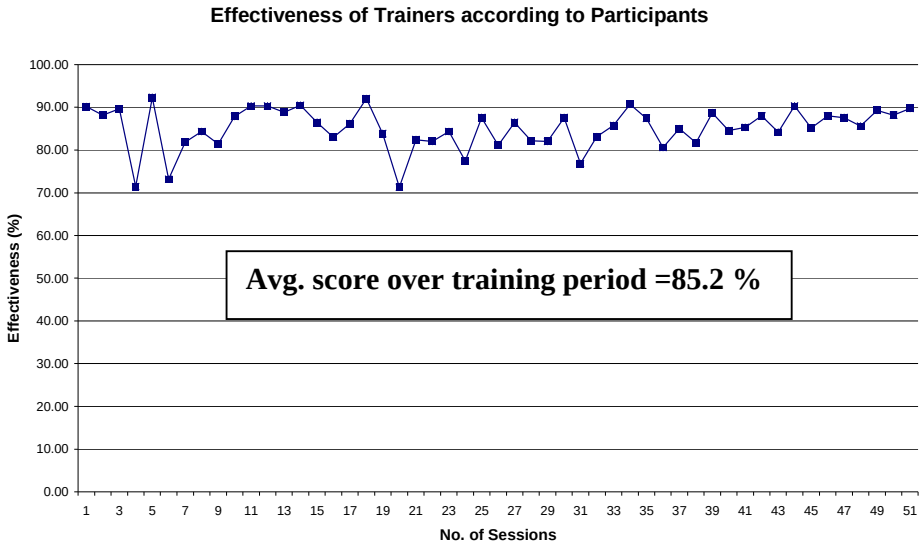

Figure 15. Effectiveness of trainers based on participants' feedback

The training program was largely successful in meeting the aspirations of the program participants as was evident from the post-training higher mean score for most of the program objectives and the composite score for the entire training program (Table 13). The training programme also yielded similar level of motivation as was expected by the participants about the fact that the training programme will improve their organizational performance and help them develop new projects. Data for Pre-training testing instruments was collected on the first day of the program and for the Post-Training Program on the last day of the program.

Table 13. Comparison between pre- and post- training scores for achievement of training objectives by participants (based on scale of 1 to 7)

Program objectives	Mean Score		Sig.(2-tail)	Correlation	Sig.
	Pre-training	Post-training			
1. Provide an opportunity to develop interdisciplinary and holistic view about groundwater	6.2	6.35	0.361	0.214	0.184
2. Based on problem solving approach	5.95	6	0.756	0.464	0.002
3. Produce a toolkit for effective groundwater governance in different social settings	5.83	5.95	0.535	0.133	0.406
4. Produce a toolkit for effective groundwater governance in different ecological settings	5.68	5.98	0.154	0.232	0.145
5. Bring sufficient diversification in terms of professional background of the participants	6.3	6.58	**0.039**	0.149	0.36
6. To create practical knowledge about groundwater	6.1	6.44	**0.056**	0.057	0.724
7. to clarify the roles of participants in managing groundwater	5.81	6.12	0.085	0.165	0.302
8. to provide advanced knowledge on the area of expertise	5.93	6.18	0.133	0.11	0.5
Composite Score	**5.99**	**6.22**	**0.052**	**0.235**	**0.156**

According to participants, the organizers (IWMI) have appropriately selected the theme of the training programme and it has been significantly relevant for them as per their expectation (Table 14).

Table 14. Perception of participants about role of key training organizer, IWMI (based on scale of 1 to 7)

Training aspects	Mean Score		Sig.(2-tail)
	Pre-training	Post-training	
Theme of training programme	6.12	6.24	0.56
Quality of participants	4.20	6.34	0.00
Quality of trainers	5.66	6.24	0.00
Location of training programme	4.66	6.34	0.01

Other key recommendations made out of the program evaluation:

1. **Creation of awareness about programme:** It is very important that the information regarding training programme reaches to best people across different parts of these five nations. Therefore a database of these institutes should be made and the information should be disseminated electronically as well as by sending the hard copy of the brochure.
2. **Selection of participants:** In any multidisciplinary training programme, there should be proper representation from different fields. It is important to involve more people from media and policy in the programme which is related to the issues of the masses.
3. **Selection of trainers:** Efficient trainers should be given more sessions and the number of trainers must be reduced to 2/3rd of current number so that proper linkages could be established between the sessions and modules.
4. **Module coordinators:** It was found that the sessions which were coordinated by module coordinators saw more participation from fellows. Therefore, the coordinators must be available for managing time and enthusiasm of the participants.
5. **Duration of training programme:** Most of the trainers and participants complained about availability of time. Considering the intensive nature of the training programme, 5 weeks should be the ideal training duration.
6. **Inclusion of practical tools:** At least one more field visit should be included in the training programme. The selection of these villages/locations should be based on contrasts between them in terms of nature of water use, socio-economic profile etc.
7. **More interaction between fellows:** SPRFs should be trained along with JPRFs and MFs for two weeks. JPRFs felt that the interaction broadens their knowledge to great extent.
8. **Quarterly/semiannually newsletters** related to the groundwater governance issue across these five nations and across the world may be published and circulated.
9. **Using resource persons as knowledge pool:** The participants should be encouraged to be in touch with the trainers. All the lectures should be compiled electronically as well as module wise booklets must be developed. This will help the organisers to distribute the training materials beforehand.
10. **Evaluation of participants:** Interim evaluation could be done by the site coordinators and supervisors but final evaluation must be done by a panel of highly experienced resource persons.
11. **Diversifying into other training programme:** The lessons from GGA training programme should be utilized properly in design and implementation aspects when IWMI organises other training programme(s) in future.

6. OUTCOMES AND IMPACTS

6.1. The Groundwater Governance in Asia Program

The Groundwater Governance in Asia Project provides an intensive inter-disciplinary training covering all facets of groundwater governance in the Indo-Gangetic and Yellow River basins and conducts Cross-Cutting Research in various pilot sites to develop, adapt and validate new technologies and their use strategies, in partnership with key stakeholders which the project hopes to influence. Whereas the training improves the overall capacity of the professionals and researchers, the pilot site trials lead to the participants—farmers, scientists, extension workers, etc.—going through experiential learning cycles that lead to individual and collective changes in attitudes and perceptions, experimentation, adaptation and adoption (Outcomes 6 to 8 in Figure 16). End-user adoption increases in the pilot sites based on positive feedback and promotion by the first adopters and scaling out begins as the technologies and strategies begin to spread to other villages. At the same time scaling up begins as the project boundary partners, who are taking part in the field work, gain ownership of the project outputs and begin to promote them in their own organizations (Boxes 9 to 11 in Fig. 16). Early adopters begin to see real increases in income as a result of adoption and this helps fuel continuing positive feedback which drives an acceleration of adoption from farmer to farmer Positive feedback also drives an increase in institutional knowledge and support for the project outputs (boxes 1 to 4). The outcomes under boxes 9 to 16 (Fig. 16) are that one might expect to at least partially achieve before the end of the project. Purpose level outcomes, such as eventual wider adoption; community level livelihood improvements, and creation of a favorable policy environment at different scales will only be achieved after the end of the project. Achieving the project goal (boxes 14 to 16 of Fig. 16) and the CPWF goals (box 17 of Fig. 16) is likely to take even longer.

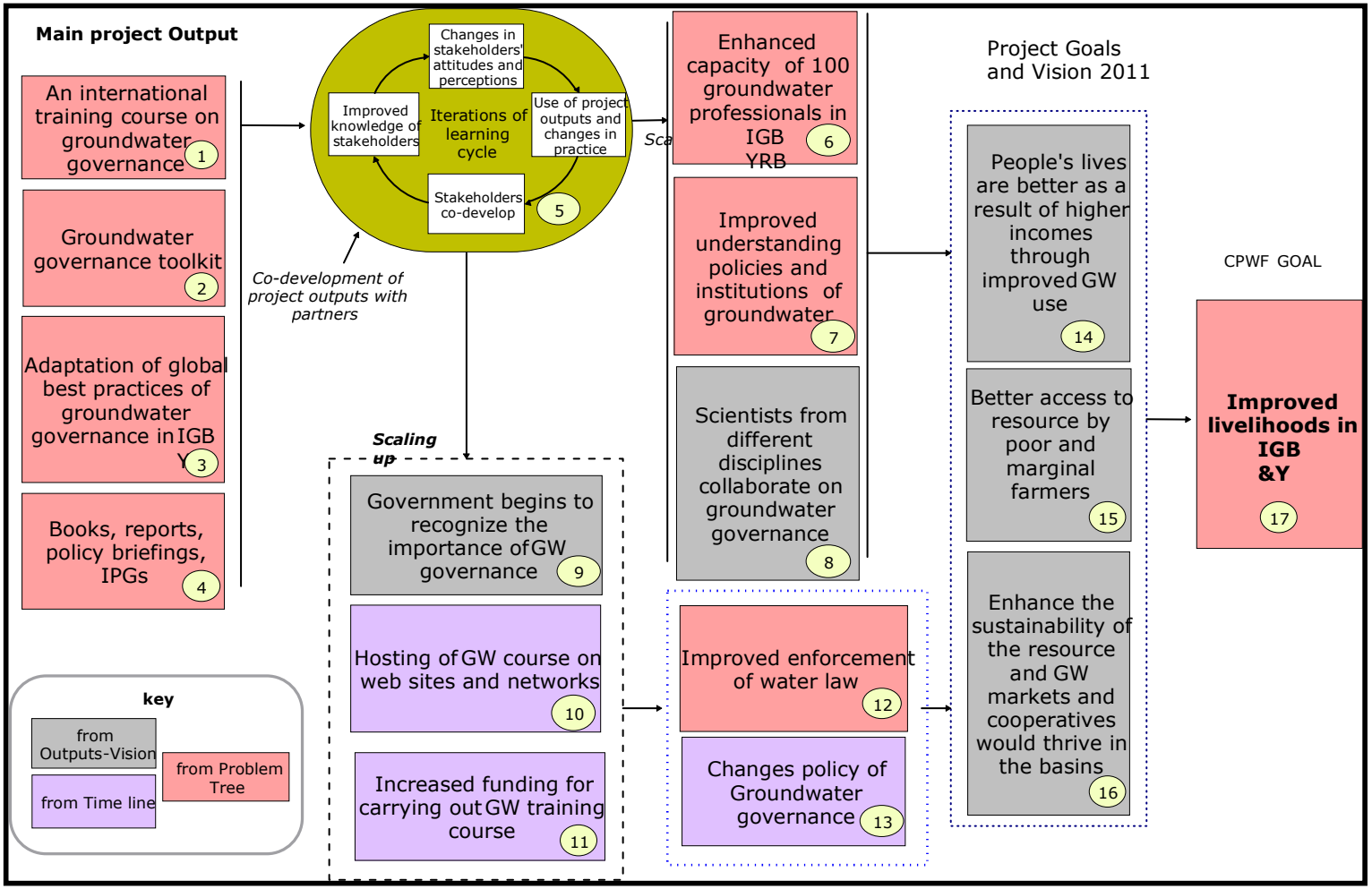

Figure 16. Adoption theory model for Groundwater Governance in Asia (PN 42) Project
(IGB: Indus-Gangetic River basin; YRB/Y: Yellow River Basin)

The network diagrams present extension of project outputs now (Fig. 17(a) and possibly 2-3 years after the project (fig. 17(b), developed for Yellow River Basin) (YRCC: Yellow River Conservation commission, CUG: China University of Geosciences; CGS: China Geological Survey; CCAP: Chinese Centre of Agriculture Policy; AIT: Asian Institute of Technology)

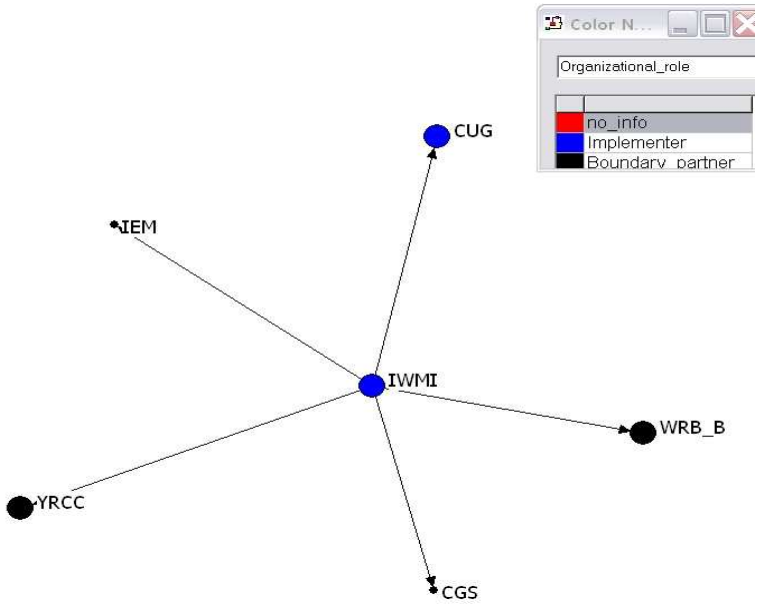

Fig.17(a). Network diagram of the Groundwater Governance in Asia project during the Project life (Yellow River basin Component)

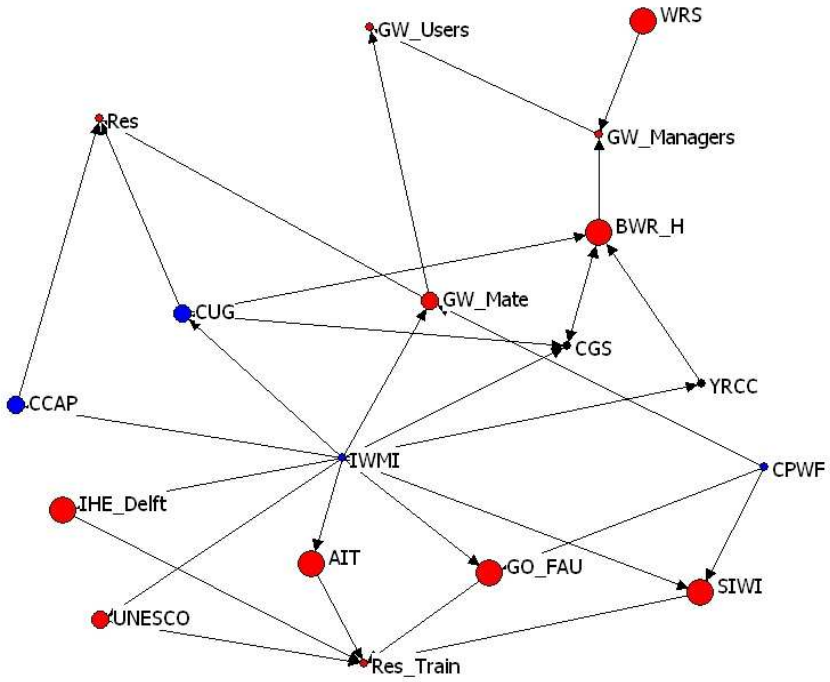

Fig.17(b). Expected Network diagram of the Groundwater Governance in Asia project after 2-3 years of completion of the Project (Yellow River Component)

The project has developed very useful outputs and made some very perceptible changes and impacts at various levels during the life of the project itself. A summary of some of the impacts is given at Table 15.

Table 15. Summary Description of the Project's main Impact Pathways

Actor or actors who have changed at least partly due to project activities	What is their change in practice? I.e., what are they now doing differently?	What are the changes in knowledge, attitude and skills that helped bring this change about?	What were the project strategies that contributed to the change? What research outputs were involved ?	Please quantify the change(s) as far as possible
1. Scientists/ researchers from different disciplines	Better appreciation and collaboration in groundwater governance	Interdisciplinary knowledge of hydrology, agriculture, economics, social sciences and research methods	- Integration of science and management - Integration of regions and basins	A well trained cadre of 80 professionals in two basins now acting as change agents in the respective organizations.
2. Groundwater managers/ resource managers	More sensitized towards farmers' needs, greater concern and appreciation of the users needs.	Interdisciplinary knowledge of economics, sociology and the cross-cutting research in respective countries.	- Grass-root level Cross-cutting Research under actual conditions - Role play simulation games	- Developing of individual strategy papers/ action plans - Presentation of seminars to the departments
3. Policy makers	- Greater attention to rural areas - Understanding nexus between energy and groundwater	Better formulation of the new policies and governance mechanisms	- Exposure to best management practices - Exposure to better managed groundwater systems in USA and Australia	A new regulation on Subsoil Water Management formulated and got enacted by one of the Senior fellows from Punjab (India), similar initiatives expected elsewhere
4. Media persons	More authentic and farmer centric coverage of groundwater issues, use of different medias	Better understanding of hydrology, economics, sociology and policy	Inclusion of media persons as the participants in the program, as resource persons	Groundwater issues, over-abstraction, contamination, energy pricing have become more visible and vocal.

Of the changes listed above, which have the greatest potential to be adopted and have impact? What might the potential be on the ultimate beneficiaries?

The following changes seem to have the greatest potential in the immediate and medium-term:

i. The subject of 'Groundwater Governance' shall become a component of teaching, training and/or refresher courses in universities and institutes. More and more Conferences/ Seminars/ Policy discussions shall be organized around this topic by the academia and other user/ manager groups.
ii. At least 80 junior and senior groundwater professionals in the five basin countries (Pakistan, India, Nepal, Bangladesh and China) in the Indus-Gangetic and Yellow River Basin have better understanding of socio-economic and institutional perspectives and they shall disseminate this knowledge to colleagues and institutions and become the change agents.
iii. Governments in these countries have begun to recognize the importance of groundwater governance.
iv. Agriculturists and other users in water scarce areas realize the importance of energy and water savings.
v. People in general, managers in the water resources and energy ministry/ departments recognize that groundwater governance is very important for long-term sustainable use of the resource.
vi. **It is a pleasure to enclose a letter of Appreciation from the Director of Agriculture, Punjab, India (senior Fellow) highlighting the impact of the Project in formulating Groundwater Regulatory Laws for the Punjab state (Annexure-V)**

What still needs to be done to achieve this potential? Are measures in place (e.g., a new project, on-going commitments) to achieve this potential? Please describe what will happen when the project ends.

i. The human-resource pool with enhanced capacities generated through this project is rather small considering the vastness of the two large basins. The effort needs to be continued for few more years through a project with similar objectives. Alternatively, the trainers or policy managers need to be engaged hand-held to have a more lasting impact.
ii. The literature/ material/ outputs describing the subject of groundwater governance need to be distributed more widely and at an affordable cost.
iii. The website of the Project (www.waterandfood.org/gga/) needs to be maintained and enriched with the latest material added on the subject.

At the same time , even when the project comes to a close the following shall continue to happen:

i. The cadre of groundwater professionals with integrated knowledge shall continue to make change in the groundwater governance in their respective organizations and influence the decisions of their colleagues both up and down the hierarchy.
ii. The material for the International Training Course on Groundwater Governance shall continue to be available most easily through the project website (www.waterandfood.org/gga/) and also on DVDs through the request.
iii. The international publications like the " Groundwater Governance in the Indo-Gangetic and Yellow River Basins: Realities and Challenges" published by the International Association of Hydrogelogists (IAH) as Selected Papers (15) and

Taylor and Francis shall have a very long-lasting impact on the professionals and shall be widely referred.

iv. The teaching aids like the "**Groundwater View",** "Groundwater Simulation Game" developed during the project shall be of great help in training the future professionals.

v. The study results and the research instruments developed during the Cross-Cutting research phase of the project shall be of great value to the researchers and development departments.

Each row of the table above is an impact pathway describing how the project contributed to outcomes in a particular actor or actors.
Which of these impact pathways were unexpected (compared to expectations at the beginning of the project?)

i. Change in the existing groundwater abstraction laws causing over-abstraction in a well developed state like Punjab (India) right during the project life through the efforts of a senior project participant was unexpected.

ii. Change in the mindset of Groundwater Managers and who look at farmers as partners in GW management and as stakeholders instead of exploters was unexpected.

iii. Addition of themes/ subjects of "Groundwater Governance" by the orthodox professional bodies of Geologists/ Hydro-geologists/ Hydrologists during their discourses and Conferences etc. was unexpected.

iv. On the negative side, reluctance on the part of engineering/ technology institutes to have "Groundwater Governance" as a separate course was unexpected.

Why were they unexpected? How was the project able to take advantage of them?

Most of the 'unexpected' were rather pleasant surprises (i-iii above) and project needed to be self-congratulating. For implementation of item iv (above) more sustained efforts are required.

What would you do differently next time to better achieve outcomes (i.e. changes in stakeholder knowledge, attitudes, skills and practice)?

i. More intensive and large program for the Senior Groundwater Professionals.

ii. Publication of the course material in the form of a well-edited and reviewed text book on "Groundwater Governance" for wider circulation and acceptance.

iii. Exchange of participants from one-country to another country of the basin for higher cross-learning experiences.

iv. More intense collaboration with the groundwater managing bodies in the different countries.

6.2. International Public Goods

The project has been able to produce the following tangible items as the international public goods:

i. International Training Courseware on "Groundwater Governance in Asia".
ii. A high quality interactive teaching aid on " Groundwater View" developed in collaboration with DHI, Copenhagen
iii. A dedicated website on " Groundwater Governance in Asia" containing all the material and resources was developed and is available at www.waterandfood.org/gga
iv. A number of international publications on the subject of groundwater governance (books, proceedings, bulletins, posters, research papers, media reports) have been developed and available worldwide- list given under the list of publications.
v. Set of questionnaires/ research instruments for implementing cross-cutting research in the basin countries. Standardised questionnaires for program evaluation which shall be useful for evaluation of a similar capacity building program, worldwide.

6.3. Partnership Achievements

This project has helped in achieving a very large and effective network of the partnerships. These partnerships were at three different levels:

i. *Project Team*: A very close-knit partnership of the project team (covering IWMI offices in Colombo, Delhi, Lahore, Kathmandu, and Anand) and other colleagues helping in project implementation. This partnership was the core team which conceived, conceptualized, designed and finally executed and evaluated the program. The innovative approach to the program and several of the new concepts of program integration, integration of the basin boundaries and regions, direct involvement of the stakeholders who shill be critical for improving the groundwater governance and exposure to the global best practices on groundwater governance were the major impacts of this partnership. Details of the project team are at Appendix-I.

ii. *Project Partners*: A strong network of the partner institutions and institutes of advanced learning from both developing and developed countries provided resource persons, case studies, teaching material, cross-cutting research sites, media stories and logistics for the program. These partners were extremely important as they brought the global knowledge on the subject, contributed and shared with the program participants and made their institutions available to host the program. These partners were equally useful for the interactive classroom sessions and the long phase of the Cross-Cutting research. Most importantly this group was critical in creating the project outputs and the long-lasting project impact. Details of the project partners, also referred as 'Resource Persons' are at Appendix-II.

iii. *Project Participants*: A very large network of participating institutions from all the basin countries sponsored about 80 young, media and senior professionals who participated in the two cycles of the program during 2006-07 and 2007-08. This partnership was from the developing countries of India, Pakistan, Bangladesh, Nepal and China. This group of the partners was the real ambassadors of the program and helped in realizing the program hypothesis, 'the *research results and policy prescriptions have higher chances of adoption and improvement, when those responsible for the task are the direct program*

participants'. The vast pool of professionals developed under the program helped it in two ways: firstly, each one of them brought their rich institutional and personal professional and regional experiences to enhance the coverage and depth of the program; and secondly and also more importantly after their 5-month long engagement with the program their mindset and understanding of the groundwater governance issues considerably improved and they started implementing the new learning and experiences in their respective professional and policy decision-making activities. Details of the project participants during the two cycles of the program are at Appendix-III.

7. RECOMMENDATIONS

Groundwater Governance in Asia Training and Research Program responded to an well defined need for strengthening human resources and capacity building within the groundwater management framework. To optimize the investment made and to ensure a larger impact and more sustainable effort, several actions need to be made and shall include the following:

i. It shall be very desirable to build a recognized platform for debate and experience and resource sharing, consisting of a network of individuals and institutions involved in the management of groundwater resources in the two basins. Such a platform be called the **"Groundwater Management Research Alliance"**: groundwater users, groundwater scientists and groundwater managers.
ii. Priorities of individual countries/ regions may differ depending upon the nature and extent of the problem, the historical perspective of groundwater use and management, cultural values and political realities, it was apparent that awareness raising and capacity building is an overriding requirement at all levels in society to enhance the understanding, sensitivity and commitment towards improving the use of groundwater in Asia and other regions. Specially designed programs on the line of GGA structure and methodology shall be very helpful to meet such a critical need.
iii. It shall be highly useful to anchor this program with some of the existing institutions in the region ensuring ownership and at the same time building up capacity and funding options for conducting this program on a recurrent basis. Virtually the program is available at www.waterandfood.org/gga and encouraged to access by the groundwater professionals.

Some of the important recommendations emanating from the Cross-Cutting Research include the following:

i. Groundwater irrigation in Asia (Indus- Gangetic Basin and North China plains) faces severe constraints. Maintaining the benefits already accrued and ensuring future food security and livelihoods in these basins is a major challenge.
ii. Continuation of groundwater irrigation requires huge, increased and secured energy supply. The energy policies of the countries must be aligned with the groundwater use and sustainability policies. Cost recovery of energy production and efficiency gains will become increasingly important.
iii. Access to groundwater is a major poverty reduction tool even when small farmers do not have their own pump sets and purchase water from the neighboring pump owners. Yet, it was recognized that in many cases general poverty and poor infrastructure systems and poorly developed markets for other inputs limit the farmers in fully optimizing their production. Hence, other poverty alleviation measures may be put in these regions especially states in eastern region of India, Nepal terai and Bangladesh
iv. There is a good scope for local groundwater management through support to capacity building, awareness raising and funding of specific activities and investments. However, experience shows that local groundwater initiatives requires intensive external support and need to be disseminated and replicated widely to have large scale impacts.
v. A comprehensive, integrated and multi-disciplinary understanding of the resource base along with the knowledge of the functioning of the socio-economic, developmental and political environment in which the groundwater irrigation occurs is fundamental for arriving at an appropriate groundwater governance policy for any region, country or the whole basin.

8. PUBLICATIONS

8.1. Books/ Proceedings

1. Sharma, Bharat, R.; Villholth, K.G.; Sharma, K.D. (eds.). 2006. Groundwater research and management: Integrating science into management decisions. Proceedings of IWMI-ITP-NIH International workshop on "Creating Synergy between Groundwater Research and Management in South and Southeast Asia", Roorkee, India. Colombo, Sri Lanka: International Water Management Institute. 282 p. (www.waterandfood.org/gga)

2. Giordano, M. and Villholth, K.G (eds). 2007. The agricultural groundwater revolution: Opportunities and threats to development. CAB International: Wallingford. UK and Cambridge MA: 336pg. . (www.waterandfood.org/gga)

3. Mukherji, A.; Villholth, K.G.; Sharma, B.R.; Wang, J.(eds.) 2009.Groundwater Governance in the Indo-Gangetic and Yellow River Basins: Realities and Challenges, International association of Hydrologists Selected Papers:15; CRC Press, Taylor and Francis Group, Oxford, UK, 328 p. (Hard back) http://www.tandfbuiltenvironment.com/books/Groundwater-Governance-in-the-Indo-Gangetic-and-Yellow-River-Basins-isbn9780415465809 (also at (www.waterandfood.org/gga)

4. McKay, Jennifer; Sharma, Bharat, R. (eds.) 2009. From Colossal Anarchy to Sustainable Development: Groundwater Governance in the Indo-Gangetic and Yellow River Basins and Australia – Case Studies of Feasible Approaches. 16 chapters. Draft sent to UNU Press, Tokyo. Manuscript under review.

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10. Sudan, Falendra K and Jennifer McKay.2007. Institutional aspects of groundwater governance: experiences from South Australia and lessons for India. *International*

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Appendix- IV

Abstracts of Some Key Publications

***International Journal of Environment and Development*, Vol. 4, No.1, 1-32, June 2007**

INSTITUTIONAL ASPECTS OF GROUNDWATER GOVERNANCE: EXPERIENCES FROM SOUTH AUSTRALIA AND LESSONS FOR INDIA[#]

Falendra K. Sudan*, Jennifer McKay**

A national agreement on water reform was reached in 1994 and the COAG agreed to a comprehensive water reform agenda that explicitly linked, for the first time, economic and environmental issues with a package of reform measures. The agreement focused on establishing water allocations and entitlements separate from land tenure, backed by secure access to water. It also provided for trading in water entitlements, making water available for ecosystems, as well as institutional reform, public consultation and education, and research. Based on the 1994 COAG agenda, there has been some progress across all jurisdictions, but much remains to be done if the goal is to meet the reasonable expectations of future generations. A strong commitment and ongoing cooperation of governments and stakeholders will be a key factor in sustaining and driving the momentum of groundwater governance reform. The continuing efforts on integrated water management, cross-border cooperation, improving irrigation practices and water use efficiency will be necessary to ensure improved productivity and environmental sustainability of water resources and secure access to water for all. A number of important lessons have been learnt by analysing the institutional reform process in South Australia, which can be applicable in Indian context too and these includes integrated water resource management, recognising the connectivity between surface and ground water systems, effectively balancing management of the environment and the need for certainty of access for water users, system of water markets and water trading, continual improvement of data and scientific information, and extensive public consultation for effective decision making.

INTERNATIONAL ASSOCIATION OF HYDROGEOLOGISTS

Groundwater Governance in the Indo-Gangetic and Yellow River Basins Realities and Challenges

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The role of groundwater in agriculture, livelihoods, and rural poverty alleviation in the Indo-Gangetic and Yellow River basins: A review

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ABSTRACT: Groundwater and rural livelihoods are intricately linked in many parts of south Asia and China where millions of farmers depend on this resource for irrigated farming. This chapter summarizes and synthesizes the results of field-based investigations related to groundwater conditions, development, use, and present constraints for small scale farmers in rural parts of the Indo-Gangetic and Yellow River basins and in the North China Plains. Evidence from primary surveys and supplementary studies shows that intensive use of groundwater takes place under various constraints such as threats of resource depletion and lack of energy supply and other necessary agriculture-facilitating measures. Such constraints afflict mostly the poorest farmers, and potentially jeopardize food security in a wider and longer-term perspective. Influencing and optimizing these groundwater-based economies has proven to be extremely difficult and this paper tries, through a comprehensive, integrated and multidisciplinary approach, to point to various means and focus areas for research and policy that may contribute to the maintenance and enhancement of accrued benefits from groundwater irrigation in these regions.

Towards better management of groundwater resources—lessons from an integrated capacity building project in the Indo-Gangetic and Yellow River basins

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ABSTRACT: It is increasingly recognized that human capacity is a major shortfall when it comes to addressing pressing challenges of groundwater management in Asia. Here, the bulk of this subsurface resource is extracted for irrigation purposes with extensive, but increasingly threatened, poverty alleviation impacts. A half-year training and research programme was carried out for the capacity building of professionals involved in groundwater management in two major river basins under water stress, the Indo-Gangetic and Yellow River basins in south Asia and China, respectively. The programme specifically addresses the five countries of India, China, Bangladesh, Pakistan and Nepal. The objective of the programme was to enhance the capacity of groundwater managers in the region through interactive and inter-disciplinary training and research activities. The aim was to contribute to a better understanding of the groundwater challenges and devising ways and means of confronting those challenges.

5 MARCH 2008 Journal of the Australian Water Association

Technical features
Asia-Pacific issues
ASIAN EXPERTS SHARE SA's GROUNDWATER EXPERTISE

But standing on Terry Buckley's farm in January, a group of 10 high level academics and senior government officials from Bangladesh, India, China, Pakistan and Nepal couldn't have helped but notice how different this setting was to farming regions at home where the scale of farming is very different with average farm sizes of less than one hectare. However, what was similar was the issue of water sharing processes, plans, policies and laws where the same problems occur. The delegation was in South Australia as part of the International Water Management Institute's (IWMI) Groundwater Governance in Asia program. It aims to build capacity in the Indo-Gangetic and Yellow River Basins through a research-based training program for professionals and senior managers actively involved in groundwater management. The professionals were here to see a sophisticated system of groundwater planning which considers the economic environmental and social sustainability aspects in future water allocation decision making.

Is Irrigation Water Free? A Reality Check in the Indo-Gangetic Basin

World Development , Vol. 37, No. 2, pp. 422–434, 2009

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Summary. — ''Getting prices right'' is the silver bullet widely advocated to developing countries infighting waste, misallocation and scarcity of water. In the vast, poverty-stricken Indo-Gangetic basin,however, high surrogate water price is driving out small-holder irrigation. With rising diesel prices, most small-holders who use borewells for irrigation find effective water use cost soaring,
obliging them to economize on water use even by quitting irrigated farming. Electrified borewell owners, far fewer, face low marginal cost but have to contend with stringent electricity rationing. Public irrigation systems grossly under-price irrigation, but these are getting marginalized despite massive government and donor investments.

Zeitschrift für Bewässerungswirtschaft, 43. Jahrg., Heft 1 /2008, ISSN 0049-8602 Seiten 19 – 40 (Journal of Applied Irrigation Science, Vol. 43, No. 1 /2008) pages: 19-40

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Diesel price hike and the energy squeeze on pakistan's smallholder irrigators

Keywords: Energy policy; smallholder irrigation economy; Pakistan

Abstract
The smallholder irrigators of Pakistan have been under squeeze due to rising energy costs, as they depend heavily on pump and tractor owners for irrigation water and agricultural operations. The recent trends of perpetual increase in the energy prices in general, and diesel prices in particular, have resulted into soaring operational costs of agricultural machinery, causing the pumps and tractor rentals to rise because of monopoly of pump owners in the informal village markets. This paper aims at bringing forth the impacts of successive diesel price increase on irrigation economy of smallholders, and their coping strategies to absorb the energy shocks and sustain their livelihoods. Based on a synthesis of qualitative assessment from 9 village level case studies carried out in NWFP, Punjab and Sindh provinces of Pakistan, where diesel and electric pumps are essential for sustaining irrigated agriculture, the paper confirms that the recent hike in diesel prices have proven to be the proverbial last straw on camel's back for the livelihoods of small farmers and tenants. While some landless tenants had quitted agriculture as a profession due in part to soaring diesel

prices, the major coping strategies of the survivors were [a] switching the power source; [b] high input – high profit strategy; c) water conservation strategy; and d) agriculture exodus strategy. The paper also suggests areas for policy intervention and further research.

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Groundwater resources potential in the deltaic floodplain area of Madaripur District, southern Bangladesh

Keywords : Groundwater, aquifer properties, groundwater-surface water interaction, water quality, recharge

Abstract
In Bangladesh, about 90% of irrigation water is provided from groundwater that has a significant role in country´s livelihood and economy. To assess groundwater system, properties of aquifer sediments and groundwater-surface water interactions in an area under Gangetic floodplain of southwestern Bangladesh, the study was carriedout. The study area of Madaripur district is covered by a sequence of active river floodplain of Holocene age within and alongside the river Ganges and it's distributaries. Most of the villages in the vicinity are trail of depositional tract, locally known as *Char*. Groundwater development in *Char* area is low compare to surrounding flood plain areas. However, huge abstraction in surrounding areas influences groundwater resources of shallow aquifer during peak irrigation. In the critical dry months when the water demand is at its peak, the river flow reduces to far below the required level. As a result, shallow aquifers are becoming the principal source of irrigation in dry season. Generally, groundwater withdrawal from upper aquifer during dry period is balanced with the vertical percolation of rain water and inflow from surrounding aquifers and rivers in monsoon. Abstracting water from shallow aquifer, directly connected to neighboring rivers, has a significant role on the movement of water between these water bodies. There is a complex aerial variability of the hydrogeologic characteristics in the region as a consequence of the floodplain depositional history of the aquifer formations. The shallow aquifer is semi-confined to unconfined in nature and generally, potential for groundwater development. However, increasing expansion of agricultural activities using chemical fertilizer and pesticide may affect groundwater quality of shallow aquifer.

Impact of metering agricultural power supply on groundwater users and market in West Bengal, India

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Abstract

West Bengal, in the eastern Indo-Gangetic basin, has abundant groundwater resources but their use is limited due to the poor economic status of the farmers and the small and fragmented land holding pattern. In this region, informal groundwater markets are very common whereby non-owners of pumps buy water from the pump owners. One of the main reasons for the proliferation of groundwater markets has been the high flat rate electricity tariff that gave an incentive to pump owners to sell groundwater. However, as part of the larger power sector reforms underway in India, the state of West Bengal is metering all agricultural tubewells. This study aims to capture the impact of metering on different stake holders. Based on primary data, the results show that pump owners are likely to be winners by being able to earn higher profit from selling water, while the water buyers will lose out. Under Time of Day (TOD) metering at the current tariff rates, the government will earn less revenue than with the flat rate system, though it may ultimately gain by reducing the Transmission and Distribution (T&D) Loss and commercial losses. The exact impact of transition from a high flat tariff regime to the TOD system on the volume of water pumped and the size of the water markets is difficult to predict and further research is needed. Set in a broader context, this paper sheds new understanding on marginal cost pricing of groundwater (through metering of electricity consumption) and the way it affects water users.

GROUNDWATER GOVERNANCE IN THE INDO-GANGETIC BASIN: AN INTERPLAY OF HYDROLOGY AND SOCIO-ECOLOGY

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Abstract
Groundwater irrigation has emerged as a major socio-technical reality and has added substantive economic gains in the Indo-Gangetic basin countries. In the Indus-Gangetic basin the hydrology and socio-ecology and the associated agriculture and human livelihoods undergo a significant shift as one traverses from the semi-arid and water scarce Indus basin in the North West to the sub-humid and water sufficient eastern Gangetic basin. However, basin wide analysis shows that stage of development and utilization of the groundwater resource has limited relationship with

the abundance of resource availability. Studies made at five sites in the basin under the CPWF Groundwater Governance in Asia (GGA) Project revealed that groundwater use produced higher benefits as compared to canal irrigation and conjunctive water use. But, small and marginal farmers with scattered land holdings do not have sufficient resources to install their own pump sets and depend upon their neighbors for purchase of groundwater. Further, a mismatch between the basin hydrological conditions and the energy policies are leading to over-exploitation of the resource in the Indus basin and constraining the optimal use of the resource in the eastern Gangetic basin. The paper presents policy options for improving the productivity, livelihoods and resource sustainability for the small and marginal farmers of the basin.

Variations in ground water use, water productivity and profitability across a canal command *in the Indo-Gangetic Basin*

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Abstract

The North-West Indo Gangetic plain, where rice-wheat is the main cropping system, is one of the most important agricultural regions in India because it contributes nearly 52% of the national food production. Increasing pressure on agriculture due to increasing food requirement, climate change, fluctuating market, fragmentation of land, etc. calls for efficient resource management. We investigated the effect of unequal distribution of canal water in land and water productivity of the rice-wheat cropping system in terms of head tail relationships in Bhakra Canal command This paper presents an analysis of water productivity, land productivity and profitability at the farmer field level in the command area of Pabnawa minor (tertiary canal) of Bhakra irrigation system. The ground water contribution in the canal command is very high. Water productivity increases from head to tail due to wastage of canal water upstream and judicious use of ground water at the tail end. Farmers practising conjunctive use have higher profitability than tube well irrigators and canal irrigators. The cost of water increases from head to tail but because of the flat rate charge for electricity there is only a small difference in the costs of water for paddy and wheat. This system of intensive irrigated agriculture is unsustainable in the long run because of declining water tables and high use of energy. Higher profitability in rice and flat rate of electricity are causing water table decline at a very rapid speed. Therefore under a business as usual scenario, continuation of the rice-wheat cropping pattern is likely.

Heterogeneity of groundwater market development and operation in North Rural China

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Abstract
The positive impacts of groundwater markets in providing access to irrigation to small and marginal farmers are well addressed in the literature. However, groundwater problems and their agricultural consequences in northern China are heterogeneous across space and thus may cause differences on the market operation. The overall goal of this paper is to explore the real operation of the development of groundwater markets. Basically, this is a comprehensive and descriptive analysis of how and, to a lesser extent, why the groundwater market is operating differently. Results show that the development level and operation style----sellers and buyers, service, tubewell characteristic, fees charging, and monopoly status----are really quite heterogeneous across regions. Water resource endowments and other factors concerned by existing researches are tested and proved the contribution of the diversity of Groundwater market in North China

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SPATIAL-TEMPORAL VARIABILITY OF GROUNDWATER QUALITY IN ZHENGZHOU AREA, CHINA

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Abstract: Hydro-chemical parameters of Zhengzhou area, China, were used to assess spatial distribution and temporal variability of groundwater quality. This present study covers all Zhengzhou municipalities which consist of Zhengzhou city and six counties. The methodology applied in this study was based on groundwater quality index (GWQI) using geographic information system. Seventy six groundwater samples were collected from deep and shallow groundwater around the entire study area and analyzed for spatial variability and nine with ten year record were collected in Zhengzhou city to cover temporal variability. Chemical parameters of groundwater such as total dissolved solids (TDS), total hardness(TH), Na, K, Mg, Ca Cl, SO_4,NO_3-N, F,As,HCO_3, CO_3 etc, were determined. The overall water quality analysis is revealed that 45.16% of the deep groundwater samples fall under the ‘’very good ‘’ category while the remaining samples fall under ‘’good’’ category. For shallow groundwater 11 samples (24.4% of the total samples) were rated as ‘‘Very good level’’ and 20 samples (44.4%) were rated under ‘‘good quality level’’. The remaining samples 7(15.56%), 4(8.8%) and 3(6.6%) ware indicated to be poor, very poor and unfit for human consumption respectively. Temporal groundwater quality analysis revealed that the highest variation that took place over the last ten years was found to be in Yinjiamen area while the least variability was found to be in ‘Beer Company’. Communities are not recommended to use groundwater where high variability of quality is observed and constant monitoring of groundwater quality is recommended.
Key words: groundwater quality, spatial and temporal variability, groundwater quality index (GWQI), Zhengzhou area.

Impact of metering of agricultural electricity supply on groundwater users: Contrasting evidence from two Indian states of West Bengal and Uttarakhand

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Abstract

As a part of the ongoing power sectors reforms in India, the states of West Bengal and Uttarakhand are in the process of metering agricultural electricity supply. Based on primary data, this paper presents a first cut assessment of this initiative. West Bengal has embarked upon metering in a well planned way to ensure its success, but this process has been entirely ad-hoc in Uttarakhand. In West Bengal, results suggest that the majority of the pump owners' would benefit from the reforms while in contrast, water buyers would lose out by having to pay higher water charges and face adverse terms of contract. However, in Uttarakhand, tubewell owners would be better off by virtue of having to pay lower electricity bills, while water buyers will remain unaffected since water prices have not increased in response to metering as in West Bengal. Metering will have very limited impact on groundwater markets in Uttarakhand, though it may have some impact in West Bengal. At current low meter tariff rates in Uttarakhand, water use efficiency is unlikely to go up, but it may increase in West Bengal where tariff rates are much higher. At current tariff rates, the electricity utilities are likely to earn less revenue than before in both the states.

Appendix V

Dr. Balwinder Singh Sidhu,
Director of Agriculture, Punjab.
ਡਾ. ਬਲਵਿੰਦਰ ਸਿੰਘ ਸਿੱਧੂ,
ਡਾਇਰੈਕਟਰ ਖੇਤੀਬਾੜੀ, ਪੰਜਾਬ।

Government of Punjab
Department of Agriculture
S.C.O. No. 85-88, Sector 34-A,
Chandigarh - 160 022

No. : 180/PA/DA

Chandigarh, Dated, the : 10-03-2010

Respected Dr. Sharma,

It gives me immense pleasure in thanking International Waters Management Institute for providing me an opportunity as Senior Research Fellow under its innovative Capacity Building and Action Research Project on "Groundwater Governance in the Indo-Gangetic and Yellow River Basins" during 2008.

2. The interactive Sessions on policy and institutions for improved groundwater governance in the region, conducted by highly experienced faculty from India and abroad were most appropriate and helped the participants to perceive the problems in proper perspective. The best feature of the program was the two weeks exposure visit regarding different uses and policy aspects of groundwater management to a number of institutions, progressive farmers, governments departments and private entrepreneurs in Murray–darling basin of South Australia. The opportunity provided for making presentation on ground water management issues in Punjab and rich discussions on these issues helped me in developing a new perspective for managing groundwater in the declining water table areas.

3. The theoretical and practical aspects and the interactions were very useful and helped the Department to formulate and implement a number of progressive interventions, policies and regulatory laws. A legislation to ensure timely transplanting of paddy viz. Punjab Preservation of Sub-Soil Water Act, 2009 has been enacted to conserve irrigation water. A programme on precision land leveling through laser assisted land levelers has been started to improve the application of irrigation water. These measures have definitely contributed in arresting the declining water table to a great extent.

I hope IWMI will continue to provide quality research and policy inputs for improving the productivity and ensuring the sustainability of water resources for the progressive farmers of the State.

With deep regards,

Yours Sincerely,

(Dr. B.S. Sidhu) 10.3.10

Attention:!
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Rasheena

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