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Water Policy Program

Groundwater has become the mainstay of irrigated agriculture in South Asia but its growing contribution to the agricultural economy remains underestimated and understudied.

Groundwater policy makers face two contrasting challenges in managing this chaotic economy in different regions of South Asia–accelerating groundwater use in water abundant eastern India, Bangladesh, and Nepal *terai*; and controlling resource depletion and deterioration in western and peninsular India and parts of Indian and Pakistan Punjab.

Refined understanding of the (non)existing governance structure in groundwater and fine tuning this understanding in order to try and bring about a modicum of order in this anarchic but booming economy is of great urgency.

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Water Policy Research

Highlight

Groundwater Governance in South Asia

Governing a Colossal Anarchy

Aditi Mukherji
Tushaar Shah

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Groundwater Governance in South Asia: Governing a Colossal Anarchy[1]

RESEARCH HIGHLIGHT BASED ON A PAPER TITLED:

"GROUNDWATER SOCIO-ECOLOGY OF SOUTH ASIA: AN OVERVIEW OF ISSUES AND EVIDENCE"

CONTOURS OF SOUTH ASIAN GROUNDWATER ECONOMY

Groundwater has become the mainstay of irrigated agriculture in Asia, particularly South Asia, covering countries of India, Pakistan, Bangladesh, and Nepal *terai*[2]. Throughout South Asia, the history of protective well irrigation goes back to the millennia. However, intensive groundwater irrigation of the scale we encounter today is a recent phenomenon, consequent upon the advent of input intensive green revolution in the region. In Pakistan Punjab, the number of mechanized wells and tubewells increased from barely a few thousand in 1960 to 0.5 million today. Similarly, Bangladesh saw an increase in the number of deep and shallow tubewells from mere 93 thousand in 1982-83 to almost 0.8 million in 1999-00. India saw a more spectacular rise in number of mechanized water extraction mechanisms (WEM) from less than one million in 1960 to almost 26-28 million[3]. in 2002. Nepal is no exception to this trend.

With increase in the number of groundwater based WEMs, the share of groundwater in total agricultural productivity has gone up several folds in much of South Asia. New research suggests that, in the recent decades, of the agricultural productivity of a 'representative' hectare, the portion contributed by groundwater irrigation is almost 35 percent more than that contributed by surface water irrigation (Deb Roy and Shah, 2002)[4]. Besides, groundwater irrigation is found to be significantly more productive compared to surface irrigation. Groundwater is produced at the point of use, needing little transport; it offers individual farmers irrigation 'on demand' and because it entails significant incremental costs for lift, farmers tend to economize on its use, and therefore maximize application efficiency.

In sharp contrast to the formal organization of public irrigation systems, a dominant characteristic of the South Asian groundwater economy is its spontaneous, private, and informal nature. While huge public investments in surface irrigation projects have built unwieldy irrigation

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[1] The research covered by this IWMI-Tata Research Highlight was carried out with generous support from Sir Ratan Tata Trust, Mumbai under IWMI-Tata Water Policy Programme. The research paper can be downloaded from the IWMI-Tata Website http://www.iwmi.org/iwmi-tata.

[2] *Terai* refers to the narrow strip of foothill plains of Nepal adjoining India. It is the homeland to the bulk of Nepali population.

[3] There are no firm and accurate estimates of total number of groundwater structures in India. The Minor Irrigation Census (1993) estimates the total number of groundwater structures to be 10 million. However, this estimate excludes four major states of India, viz. Gujarat, Maharashtra, Tamil Nadu and Karnataka. These states alone had almost 5 million structures in 1986-87 (MI Census, 1986-87). Based on average annual compound growth rates of groundwater structures between 1986-87 and 1993-94, we estimated that the total number of structures was anything between 19 and 20 million in 1993 and now (2002) it would be almost 26-28 million, given that every year 0.75 to 1 million structures are added.

[4] Deb Roy Aditi and Shah Tushaar, (2002), 'Socio-ecology of Groundwater Irrigation in India', in Llamas, R & E. Custodio (eds), 'Groundwater Intensive Use: Challenges and Opportunities', Swets and Zetlinger Publishing Co., The Netherlands

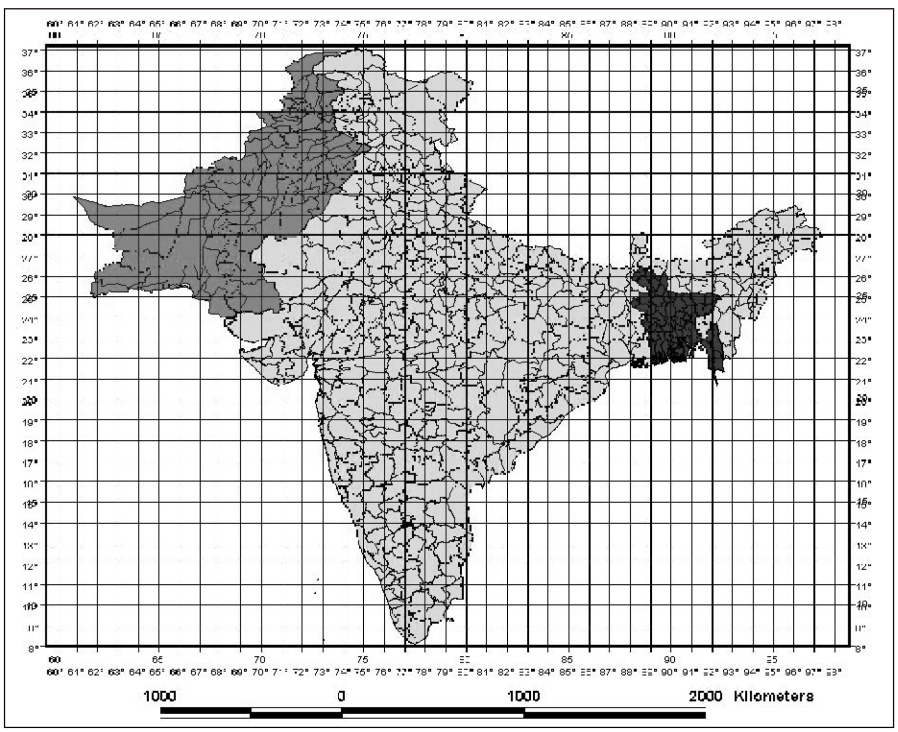
bureaucracies, private investments in wells and tubewells have created agile, wealth-generating groundwater economies, with considerably lower investments (Shah *et al*. 2001)[5]. In India, for example, in the last 50 years, public investments in surface irrigation projects have been to the tune of US $40 billion (1995-96 prices), while private groundwater investments by the farmers may well be of the order of US $16 billion[6].

BACKGROUND, DATA, AND COVERAGE

Given the huge significance of groundwater in South Asia and its growing contribution towards wealth creation, we decided to study the scale and impact of groundwater irrigation in south Asia. We carried out primary level surveys in five countries, four in south Asia and Thailand in east Asia. This paper will report findings from our village level surveys conducted in India, Pakistan, Bangladesh, and Nepal. This extensive primary survey covering every part of the country will hopefully capture the nuances of groundwater based economy in south Asia.

We decided to cover every part of the country through primary questionnaire surveys. For this purpose, we divided our study countries into a number of grids, based on latitude and longitude. From the approximate center of each grid, we randomly chose a village and collected primary questionnaire data from 12 to 20 randomly selected well/tubewell owning farmers. Two questionnaires were framed (one for tubewell owner, another for the village) and administered through various agencies in all the countries. The survey covered 2629 farmers and 3350 irrigation wells and tubewells in 292 villages spread over 200,000 hectares area. For purpose of refined analysis, we further divided all the countries (except Nepal) into different regions based on agro-climatic, geo-hydrological, and

Figure 1: Survey Plan for India, Pakistan and Bangladesh[7]



[5] Shah, Tushaar, Aditi Deb Roy, Asad S Qureshi and Jinxia Wang (2001): 'Sustaining Asia's Groundwater Boom: An Overview of Issues and Evidence', IWMI's contribution to International Conference on Freshwater in Bonn, December 3 to 7, 2001, German Development Institute, Bonn and International Water Management Institute, Colombo.

[6] US $ 600/piece for 26 million structures

[7] One village at the centre of each grid was selected for the survey. In India, we exduded states of Jammu and Kashmir, Himachal Pradesh and all the north eastern states and in Pakistan few grids adjoining Afghanistan were excluded due to logistical problems.

socio-economic factors. Thus, India was divided into six regions, Pakistan into three and Bangladesh into two regions.

Objectives

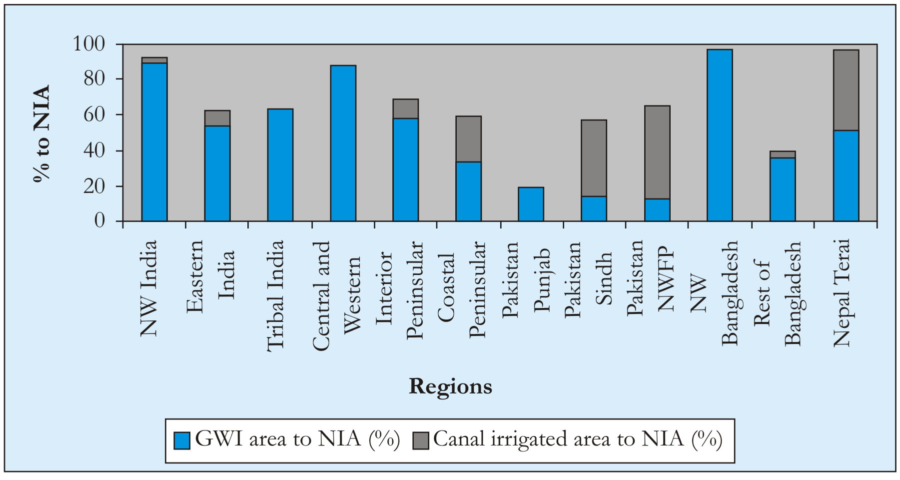
These were our research objectives:

1. Significance and size of groundwater irrigation in village economies in terms of agricultural economy and its environmental dimensions;
2. Pace and pattern of growth of groundwater structures
3. Profile of the well owners and its equity and poverty reduction implications
4. Technological configuration of the groundwater irrigation economy
5. Well owners' farming operations: What kind of agriculture does groundwater irrigation support?
6. Economics of groundwater irrigation: What are the costs and benefits of groundwater irrigation?
7. Pump irrigation markets: What are the economic institutions that have emerged in the wake of the emergence of the groundwater economy? How do these vary across space and time and why?

Size and Significance of the Asian Groundwater Economy

There is growing evidence that groundwater is becoming more and more important as a source of irrigation in much of south Asia. This growing importance of groundwater is clearly brought forth by our survey. Of the 292 villages surveyed, 132 villages or 45 percent reported high to very high contribution of groundwater to agricultural production in the village. This figure varied from as high as 100 percent in north western Bangladesh to only 18 percent in villages of the central tribal belt of India. Given the growing importance of the groundwater economy, we also estimated its size. One practical way to do so is to measure the economic value of groundwater production. Most of south Asia has an active market in pump irrigation services in which tubewell owners sell groundwater to their neighbours at a price that exceeds their marginal cost of pumping. This price offers a market valuation of groundwater use in irrigation (Shah *et al*. 2001). Table 1 provides a profile of the groundwater economy of south Asian countries using such valuation and suggests that groundwater irrigation in south Asia may well be to the tune of US $ 10 to 11 billion per year, while its total contribution to the agrarian economy could be several times higher.

Figure 2: Groundwater and Surface Water Irrigated Area in Different Regions of South Asia



Source: Primary survey conducted by IWMI in 2002

Table 1: Size of Agricultural Groundwater Economy of India, Pakistan and Bangladesh

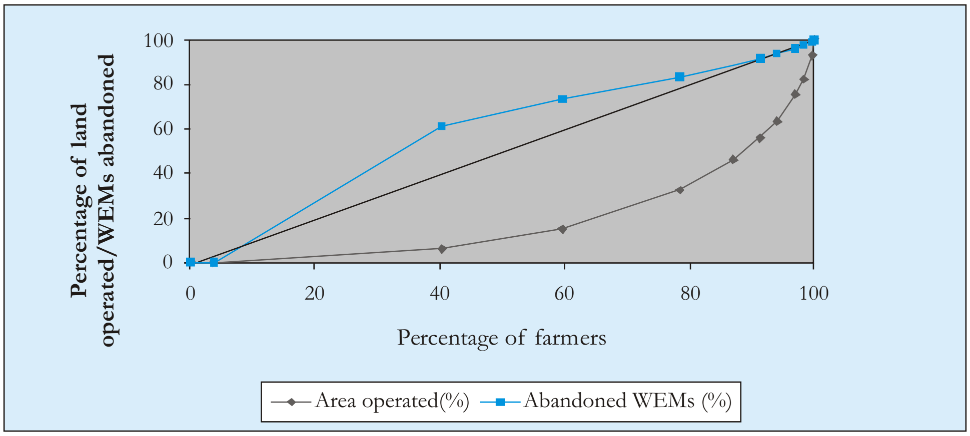
		India	Pakistan[8]	Bangladesh	Nepal *Terai*
A	Total number of groundwater structures(million)[9]	26	0.5	0.8	0.06
B	Average output of groundwater structures (m^3/hr)[10]	25	100	30	30
C	Average hours of operation /well/year[11]	330	1090	1300	205
D	Price at which pump irrigation from standard size pump sells (US $/hr)[10]	1	2	1.5	1.5
E	Estimated groundwater used (km^3) {(A*B*C)/1000000000}	215	54.5	31.2	0.37
F	Imputed value of groundwater used/year in US billion $ (E/B*D) or {(D*C*A)/1000}	8.6	1.1	1.6	0.02

Source: Given in footnotes 8 to 11

Environmental Dimensions of Groundwater Development in South Asia

No resource is an unmixed boon, neither is groundwater. Many parts of south Asia are under serious threat of resource depletion and degradation. Groundwater depletion has major environmental consequences, but it has equally serious economic consequences, especially for the poor and marginal farmers in south Asia (Figure 3). Based on our primary survey, we have

Figure 3: Lorenz Curve Showing Area Operated and WEMs Abandoned, India



Source: Based on Minor Irrigation Census, 1993

[8] Estimate for Pakistan includes only that of Pakistan Punjab which has almost 90 percent of groundwater structures in the country

[9] Total number of groundwater structures have been estimated for India based on MI Census 1987 and 1993, for Bangladesh based on MI Census 1996-97 and that of Pakistan based on estimates provided by Punjab Private Sector Development Project, 2000

[10] Average output of groundwater structures (m^3/hr) will depend among other things on average HP of pumps and depth to water table. In Pakistan, average HP is almost two or three times that of India and Pakistan Punjab has high water tables due to canal recharge. In Bangladesh, though pump HP is comparable with that of India, water table is very near the surface and WEMs pump water from an average depth of 5-8 meters in most places. So, average output of WEM in Bangladesh has been assumed to be marginally higher than that of India and that of Pakistan is 4 times that of India.

[11] Average hours of operation (hrs/well/year) and price at which water sells is based on primary data generated through survey conducted by IWMI, 2002

estimated the total number of wells and tubewells that have been abandoned by sample farmers. This figure seems to be the highest in western India and interior peninsular India, characterized by very intensive groundwater use and low rainfall, leading to groundwater withdrawal exceeding groundwater recharge.

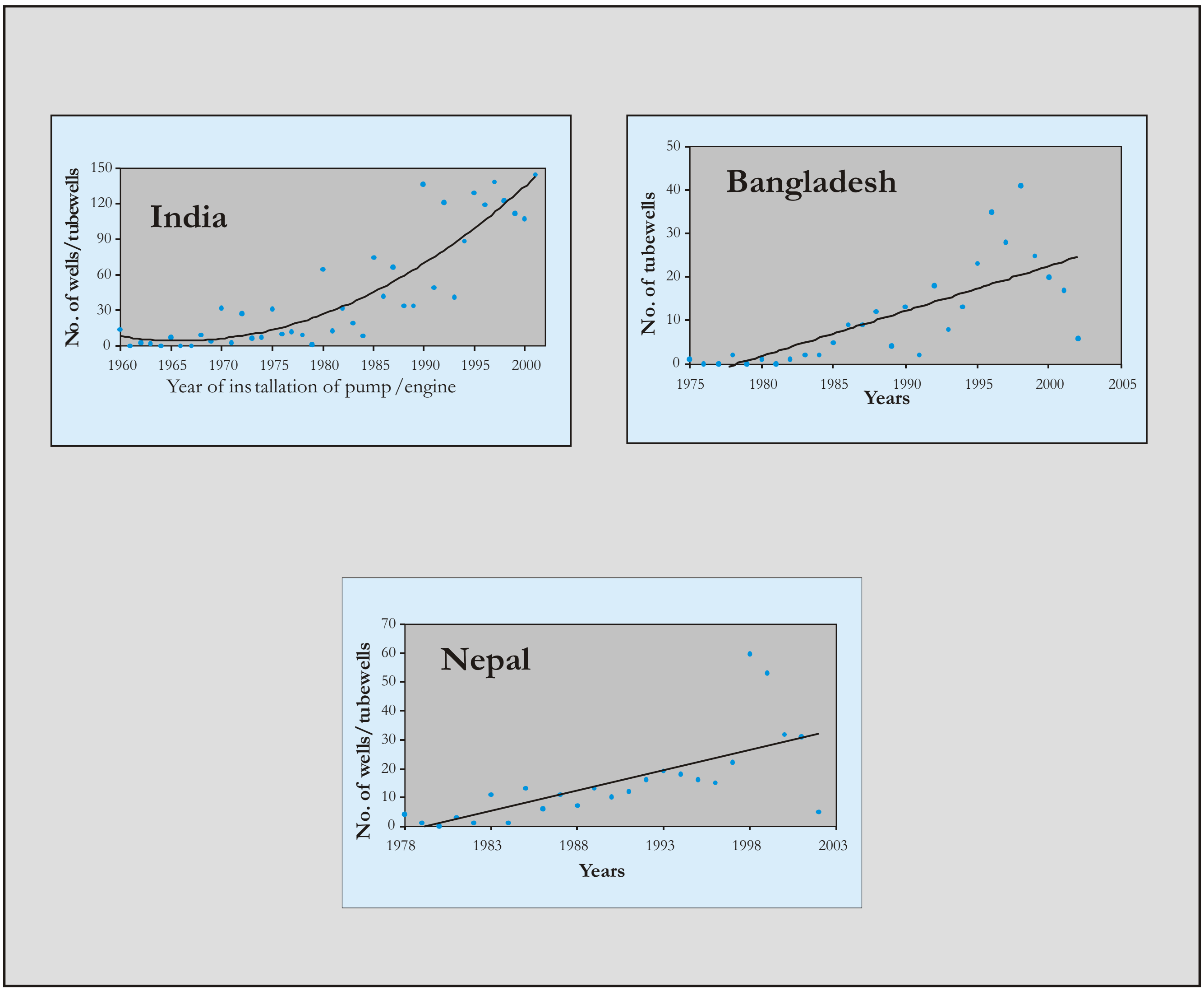
Pace and Pattern of Growth in Groundwater Structures

Perhaps the most intriguing aspect of the Asian groundwater economy has been its rapid pace of growth within the last two or three decades and most of it by individual farmers as against public agencies. Among the four countries in south Asia, India has seen the fastest rise in the number of groundwater structures during the last two-three decades. Based on year of mechanization, we plotted graphs depicting the growth in number of private tubewells in India, Bangladesh, and Nepal (Figure 4).

Who Owns Wells?

Our primary survey results show that marginal and small farmers own up to 70 percent of groundwater structures in Bangladesh, 60 percent in Nepal, and

Figure 4: Pace and Pattern in Growth of Groundwater Structures in India, Bangladesh, and Nepal

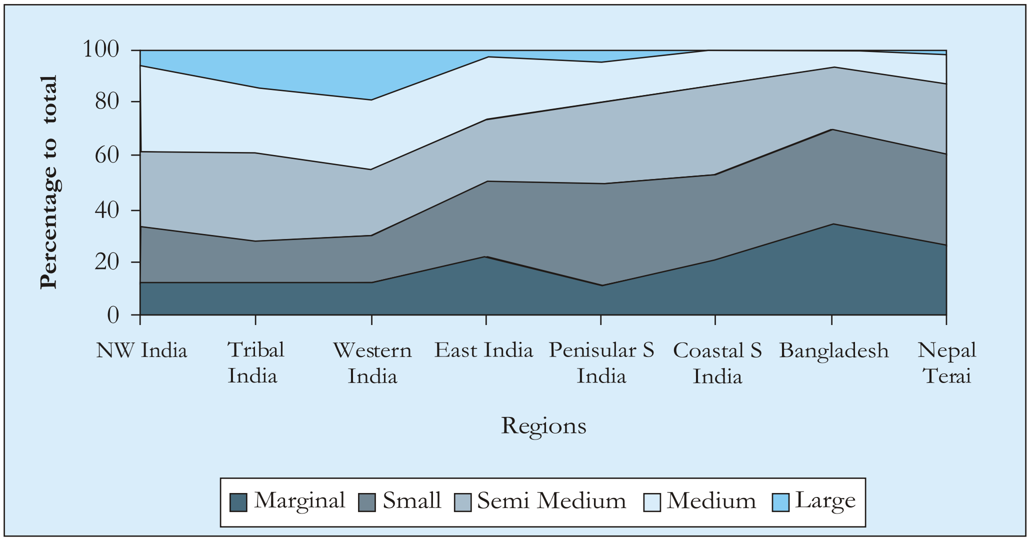


Source: Primary survey conducted by IWMI in 2002

50 percent in eastern India. Except for tribal India and western India, in all the other regions, small and marginal farmers own at least 30 percent of the groundwater structures that we surveyed. Thus, we find more skewed distribution of groundwater assets in regions that are either agriculturally backward, or regions that have experienced rapid groundwater depletion (Figure 5).

diesel. In most of south Asia, diesel operated pumps are more common than electric operated ones. There thus exists what is called an "energy divide" in much of south Asia which has wide implications in terms of water application and crop yields (Figure 6 and 7). Evidence from this survey shows that electric pump owners tend to pump for longer durations without any positive

Figure 5: Ownership of WEMs According to Farm Size



Source: Primary survey conducted by IWMI in 2002

Technological Configuration of South Asian Groundwater Economy

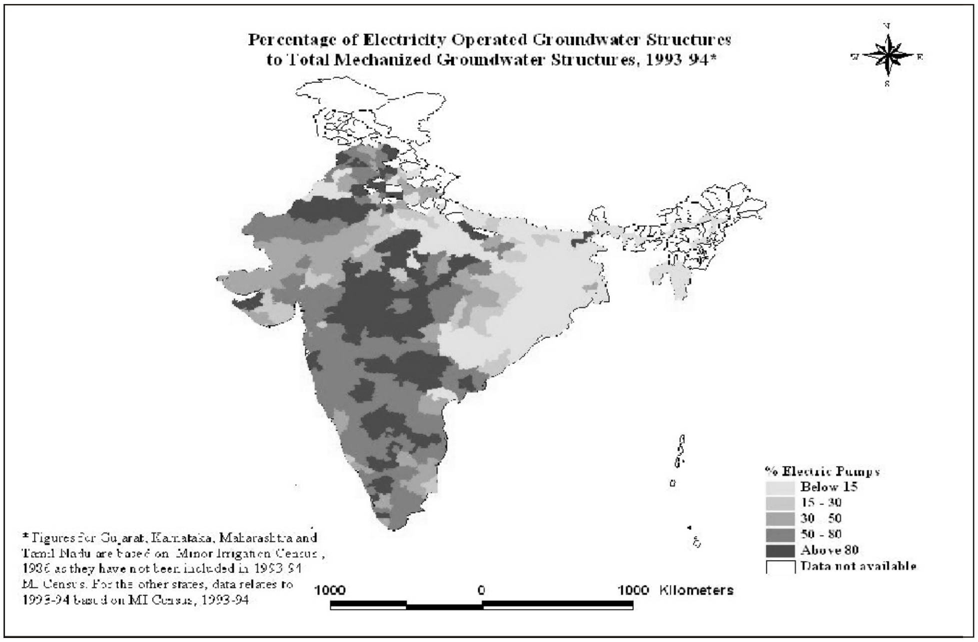
Depending on the nature of aquifer and its depth, the technological configuration of groundwater structures changes. Generally speaking, dugwells are amenable to shallow poor yielding aquifers, while shallow tubewells are constructed in areas of shallow alluvial aquifers. Deep tubewells are rather rare because they need huge investments. Tubewells and dug - cum - borewells predominate in Pakistan Punjab, Pakistan Sindh, and Indian Punjab, while shallow tubewells are important in the whole of the Ganga basin. In hard rock aquifers, open dug wells are more common. WEMs can be powered by either electricity or

impact on crop yields, mainly because the incremental cost of one additional unit of water pumped is nearly zero, given the very low or flat power tariff rates. In direct contrast, diesel pump owners tend to economize on number of hours of pumping.

Groundwater Supported Irrigated Agriculture in South Asia.

Foodgrains, such as wheat, paddy, and coarse cereals are the main irrigated crops in whole of south Asia. In addition, sugarcane and vegetables occupy large parts of land irrigated by groundwater. Though, area under sugarcane and vegetables are low in absolute terms, these crops need more frequent irrigation and therefore hours

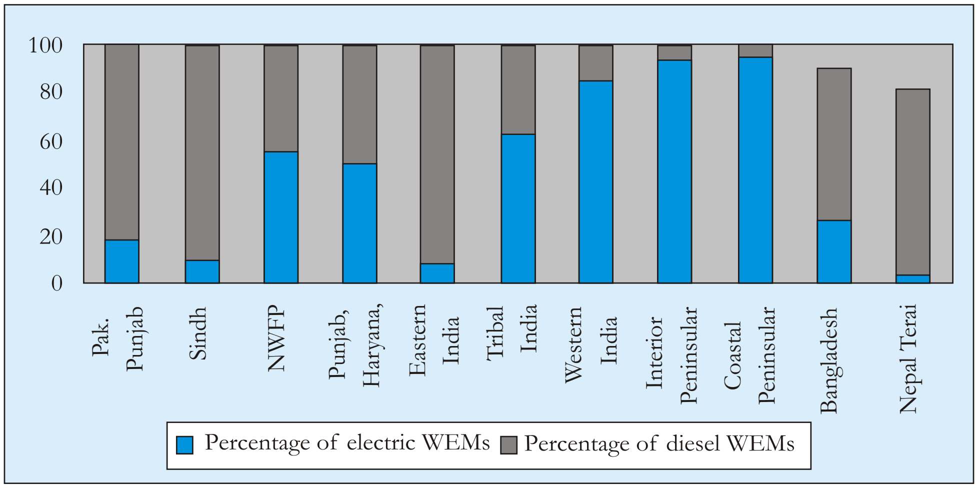
Figure 6: Energy Divide in India



Source: MI Census, GOI, 1986-87 and 1993

of irrigation per hectare are much higher than say that of wheat. Most of summer paddy needs intensive irrigation. We can therefore expect very high pumping requirements (hr/ha) for paddy. Based on our survey, we present an estimate of crop yields and hours of pumping (both diesel and electric) required for wheat and paddy, the two most important irrigated crops across regions. Wheat yields are more or less comparable across various regions, though it is still Pakistan and Indian Punjab that achieve the highest yields in the sub-continent. *Boro* paddy cultivation is a very water intensive exercise in Bangladesh and West Bengal. Paddy cultivation is water intensive in coastal peninsula and interior peninsula of India also. However, this booming groundwater-based paddy cultivation is artificially supported by high electricity subsidies, which puts a question mark on the long term sustainability of irrigated agriculture in hard rock peninsular India.

Figure 7: Distribution of Electric and Diesel WEMs in South Asia



Source: Primary survey conducted by IWMI in 2002

Table 2: Yield and Hours of Groundwater Irrigation Supplied for Cultivating Wheat and Paddy in South Asia

Region/Country	Wheat		Paddy	
	Yield (quintals/ha)	Hrs of pumping/ha	Yield (quintals/ha)	Hrs of pumping/ha
North Western India	36	91	27	352
Eastern India	26	58	55	221
Central Tribal India	31	67	28	104
Central and Western India	32	144	Not important as a crop	Not calculated
Interior Peninsular India	Not important as a crop	Not calculated	44	542
Coastal Peninsular India	Not important as a crop	Notcalculated	47	607
Pakistan Punjab[12]	35	44	31	168
Pakistan Sindh[12]	31	69	33	85
Pakistan NWFP	27	58	Not important as a crop	Not calculated
Bangladesh[13]	29	20	51	871
Nepal *terai* [14]	23	54	34	57

Source: Primary survey conducted by IWMI in 2002

Water Markets in South Asia

The role of groundwater irrigation has been crucial in the growth of agricultural production in south Asia (see Deb Roy and Shah 2002) [15]. Many scholars claim that much, if not most, of it is allocated through groundwater markets (Shah 1993 [16], Palmer Jones[17] 1994). Evidence of water markets are found in all of South Asian countries of India, Pakistan, and Bangladesh and in different geo-hydrological regimes.

Water prices vary according to regions, crops and whether an electric or diesel pump is used. Invariably, water is cheaper from an electric WEM (because of lower electricity tariff) and much higher for diesel WEMs. There are generally three modes of payment for purchased water: hourly rates (Rs./hr), area based rates (Rs./ha), and crop

[12] Conjunctive use is more important in Pakistan Punjab and Sindh, which partly explains lower pumping hours for wheat and paddy as compared to Indian Punjab which has similar cropping pattern

[13] Data for paddy in Bangladesh here refers to only *boro* paddy as this is the most important irrigated crop in the country, while *aman* paddy is mostly rainfed

[14] Paddy in Nepal Terai refers to rainy season paddy. This crop is mostly rainfed, only one or two irrigations are given from tubewell, which explains the lower pumping hours/ha

[15] Same as footnote 4

[16] Shah, Tushaar. 1993. 'Groundwater Markets and Irrigation Development: Political Economy and Practical Policy'. Oxford University Press Bombay. India.

[17] Palmer Jones R (1994), 'Groundwater Markets in South Asia: A Discussion of Theory and Evidence' in in Moench, Marcus (ed), 'Selling Water: Conceptual and Policy Debates over Groundwater Markets in India', VIKSAT and others, Ahmedabad, India

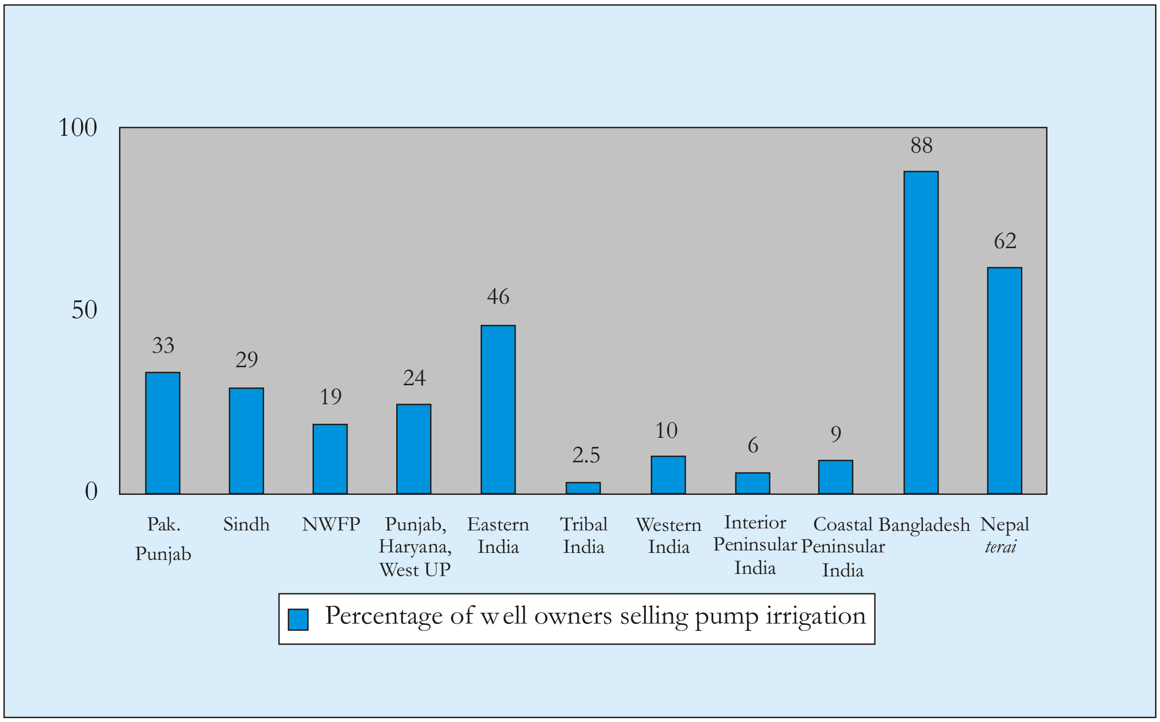
share. Hourly payment seems to be the most popular mode in most of south Asia.

Water markets have both positive and negative externality in many pockets of south Asia. Strosser and Meinzin-Dick[18] (1994) contend that increased pumping and sale of groundwater is beneficial in lowering water tables in much of the salinity and waterlogging affected canal command in Pakistan. The same holds true for much of Nepal *terai* and low flood plains of West Bengal and Bangladesh. However, in regions where groundwater is already scarce, water markets could hasten resource depletion, as possibly might have happened in north Gujarat and part of interior peninsular India.

Conclusions and Policy Implications:

There is no doubt that growing contribution of groundwater in south Asia's agricultural economy is both underestimated and understudied. Now there is an increasing awareness about the important role that groundwater has played in fostering food sufficiency in much of this poverty stricken belt of the world. At the same time, there is a realization that much of this precious resource stands the chance of rapid and irreversible exploitation in many parts of South Asia. Thus, south Asia is plagued by twin problems: resource depletion and deterioration in western and

Figure 9: Percentage of Sample Well Owners Reporting Water Sales in South Asia



Source: Primary survey conducted by IWMI in 2002

[18] Strosser and Meinzin-Dick (1994), 'Groundwater Markets in Pakistan: An Analysis of Selected Issues', in Moench, Marcus (ed), 'Selling water: Conceptual and Policy Debates over Groundwater Markets in India', VIKSAT and others, Ahmedabad, India.

peninsular India and parts of Indian and Pakistan Punjab (affected by salinity) and rural poverty ironically concentrated in the most water abundant parts of south Asia, viz. eastern India, Bangladesh and Nepal *terai*. Recent research (Deb Roy and Shah, 2002) [19] has shown that groundwater development has been spatially dispersed while canal irrigation projects have created small islands of affluence leaving large catchment areas poor and deprived. It is not surprising that, while canal irrigation projects are seldom seen as regional poverty reduction interventions, providing access to groundwater irrigation through pump subsidies or public tubewell programs has been at the centre of poverty reduction programmes in south Asia. The issue is: how long can this good run continue without any mechanism for governing this colossus? What kind of governing structures and mechanisms might help? Refined understanding of the (non)existing governance structure in groundwater and further research into fine tuning this understanding in order to try and bring about a modicum of order in the functioning of this anarchic but booming economy is urgently needed. On this will depend if the booming groundwater economy will burst like a bubble, or will continue to bring about prosperity in the region. In this quest for better governance, the need to understand spatial variation within south Asia itself will be of great importance. All in all, then, we recommend a more refined and nuanced understanding of the peculiarities of Asia's groundwater socio-ecology and a resource management approach suited to its genius.

[19] Same as footnote 4

IWMI-Tata Water Policy Program

The IWMI-Tata Water Policy Program was launched in 2000 with the support of Sir Ratan Tata Trust, Mumbai. The program presents new perspectives and practical solutions derived from the wealth of research done in India on water resource management. Its objective is to help policy makers at the central, state and local levels address their water challenges – in areas such as sustainable groundwater management, water scarcity, and rural poverty – by translating research findings into practical policy recommendations.

Through this program, IWMI collaborates with a range of partners across India to identify, analyse and document relevant water-management approaches and current practices. These practices are assessed and synthesised for maximum policy impact in the series on Water Policy Research Highlights and IWMI-Tata Comments.

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IWMI-Tata WATER POLICY PROGRAM
Elecon, Anand-Sojitra Road
Vallabh Vidyanagar, 388120, Gujarat, India
Telephone: 91-2692-229311-12-13
Fax : 91-2692-229310
E-mail: iwmi-tata@cgiar.org
Website: http://www.iwmi.org/iwmi-tata

International Water Management Institute

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HEADQUARTERS
127 Sunil Mawatha, Pelawatte, Battaramulla, Sri Lanka
Mailing Address : P. O. Box 2075,Colombo,Sri Lanka
Telephone : +94 1 787404,784080 ; Fax : +94 1 786854
E mail : iwmi@cgiar.org

REGIONAL OFFICE FOR ASIA
(Bangladesh, China, Nepal and Sri Lanka)
127 Sunil Mawatha, Pelawatte, Battaramulla, Sri Lanka
Mailing Address : P. O. Box 2075,Colombo, Sri Lanka
Telephone : +94 1 787404,784080,1 ; Fax : +94 1 786854
E mail : iwmi-asia@cgiar.org

CHINA
Center for Chinese Agricultural Policy,
Chinese Academy of Sciences
Building 917,Datun Road, Anwai, Beijing,100 101, China
Telephone : +86 -10 64889440,64856535,64856837
Fax : +86 -10 64856533
E mail : j.wang@cgiar.org

NEPAL
GPO 8975 EPC 416, Kathmandu, Nepal
Telephone : +977-1 535382 (Ext. 486)
Mobile Tel : 9810 - 22573 ; Fax : +977-1 523996
E Mail : d.pant@cgiar.org

REGIONAL OFFICE FOR AFRICA
141, Cresswell Street, 0184 Silverton, Pretoria, South Africa
Mailing Address: Private Bag X813,Silverton 0127, South Africa
Telephone : +27-12 - 845 9100 ; Fax : +27-12 - 845 -9110
E Mail : iwmi-africa@cgiar.org

KENYA
C/o. ICRAF, United Nations Avenue, P. O. Box 30677, Nairobi, Kenya
Telephone : +254 - 2 - 524751,524000 ; Fax : + 254 -2 - 524001
E Mail : f.gichuki@cgiar.org

GHANA
IWMI Ghana,CSIR campus,Odei Block,
Airport Res. Area, Accra
IWMI Ghana, PMB CT 112, Cantoments, Accra, Ghana
Telehone : +233-(0) 21-784752/53/54 ; Fax : +233-(0) 21-784752
E mail : iwmi-ghana@cgiar.org

REGIONAL OFFICE FOR INDIA
C/o. ICRISAT, Patancheru, AP 502 324, India
Telephone : +91-40 -329-6161 ; Fax : +91-40 - 324-1239
E mail : iwmi-india@cgiar.org

REGIONAL OFFICE FOR PAKISTAN, CENTRAL ASIA AND MIDDLE EAST
12KM Multan Road, Chowk Thokar Niaz Baig,
Lahore 53700,Pakistan
Telephone : +92 - 42 - 5410050-53(4 lines) ; Fax : +92-42-5410054
E mail : iwmi-pak@cgiar.org

UZBEKISTAN
Apartment NO.103,Home No.6,Murtazaeva Street,
Tashkent 700000, Uzbekistan
Telephone : +998 - 71-1370445 ; Fax : +998 -71-1370317
E mail : v.hornikova@cgiar.org

REGIONAL OFFICE FOR SOUTHEAST ASIA
(Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines,Thailand,Vietnam)
P. O. Box 1025, Kasetsart University Jatujak,
Bangkok 10903,Thailand
Telephone : +66 2 561- 4433 ; Fax : +66 2 561-1230
E mail : iwmi-sea@cgiar.org