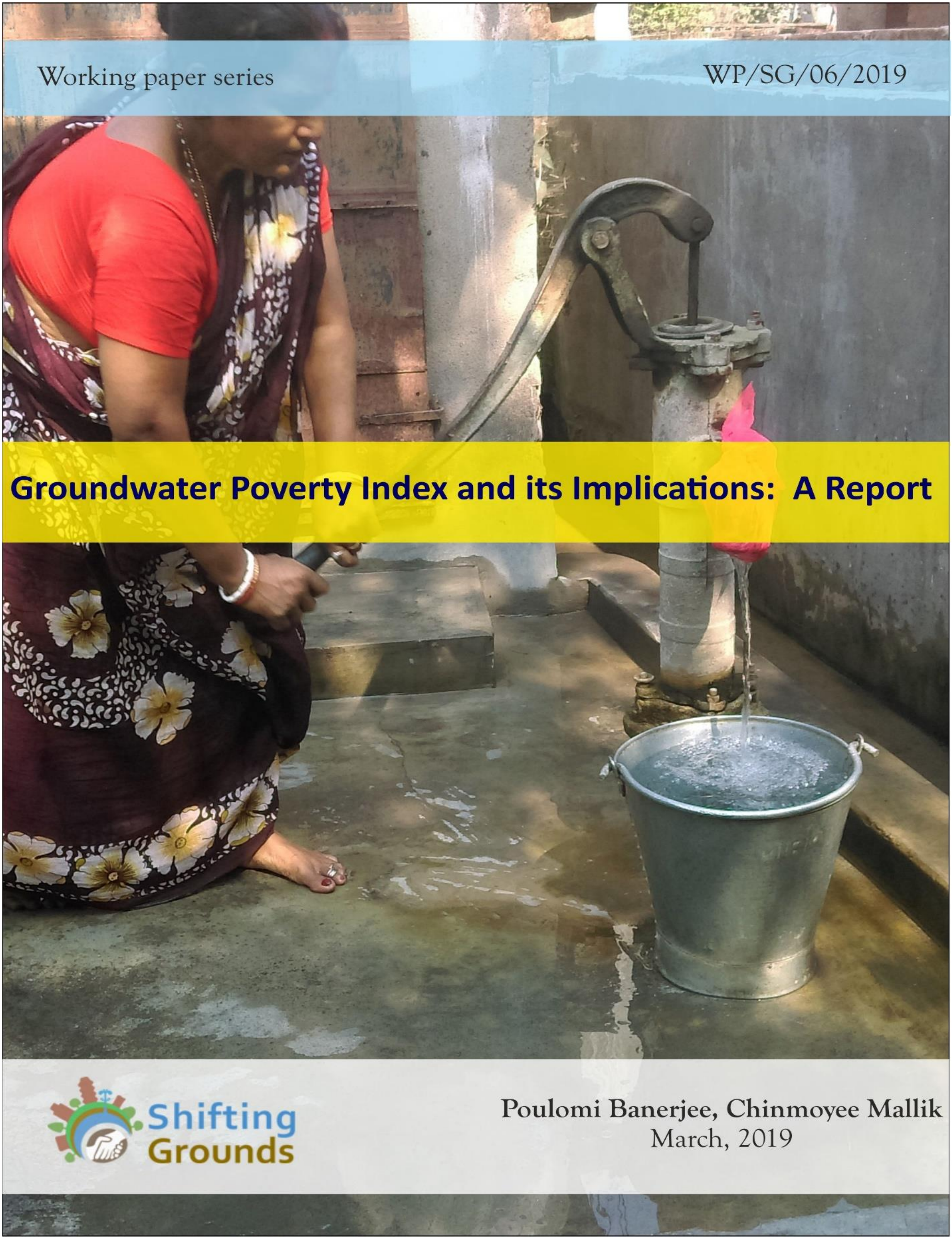
Working paper series WP/SG/06/2019

Groundwater Poverty Index and its Implications: A Report



Shifting Grounds

Poulomi Banerjee, Chinmoyee Mallik

March, 2019

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1 Introduction

The peri-urban has long been considered as an analytical construct where complex socio-environmental processes interact at multiple scales. The interaction creates opportunities for development often at the cost of its most crucial resource; groundwater (Steinberg, 2013). As the city penetrates deep into the rural sphere, it indiscriminately appropriate resources like land and water (Friedmann, 2011), transferring them to serve urban interests (Janakarajan, 2004; Nelliyat,2008; Packialakshmi et al., 2011; Prakash and Singh, 2015; Mehta and Karpouzoglou, 2015).

Highly complex and informal property regimes of peri-urban areas coupled up with the elusive nature of groundwater resources (Steinberg 2013) has allowed "non-control" of the states. This "non-control" 'gives rise to overexploitation, competitive deepening, conflict of authorities and eventual degradation of the resource' (Akpabio and Udom, 2018) and sometimes large financial losses (Jankarajan and Moench,2002; Ranganathan et al, 2009; Mehta and Karpouzoglou, 2015).The risk is more acute for a flat deltaic urban tract with low natural hydraulic gradients, sensitive to pumping.

Groundwater and peri-urban scholarships are quite explicit about the above mentioned challenges, reasoning out groundwater stresses function of faulty regulatory framework and mismanagement (Swyngedouw, 1999;Mehta and Karpouzoglou, 2015; Mukherjee and Chakraborty, 2016; Ranganathan and Balazs, 2015;Akpabio and Udom, 2018). They have identified unique biophysical and socio-economic processes and flows resulting into transformations of the groundwaterscape (Swyngedouw; Akpabio and Udom, 2018). What becomes critical is to derive tools to translate the complex interaction of processes into workable action components. To understand the multidimensional aspects of groundwater poverty at different scales in order to come up with more holistic management strategies at different levels.

As Juran et al. 2017 argues "it is maintained that populations with access to water at a sufficient quality and quantity and in a relatively less burdensome configuration are better equipped to satisfy health needs, attend work more frequently, exploit water for livelihood purposes, develop human capital, and transfer the opportunity costs of meeting water needs to more economically and socially productive outlets". Identification and measurement of groundwater poverty is thus crucial for households and communities to come out from the trap of socio-environmental vulnerabilities.

Quantitative measurement of such complex associations and interaction of variables in even complex space like peri-urban is challenging but critical as it can translate diverse contradictory variables into one single platform understandable by community and policy makers. This is more so when there has been growing response from the government to recognize such spaces, communities and their basic needs. Past research has focused on the use of poverty indices to provide such quantitative assessments. Index methods such as the Integrated indexing provide a useful starting point. The study reported here, adapts an integrated index tool with specific water poverty and vulnerability indices (e.g. Barua et al., 2012; cf. Hermans et al., 2005; Sullivan & Meigh, 2003) to asses groundwater poverty. This index-based integration should result in a systematic assessment of various variables that are known to influence the linkages between groundwater, poverty and vulnerability of peri-urban water users.

The report provides analysis of the groundwater poverty index for four periurban villages: Two villages in the vicinity of Kolkata and Khulna respectively. The overall objective is to measure the pathways of groundwater poverty at different scales and across these four villages. It combines measures of resource availability with measures of people's ability to access water (WHO/UNICEF 2000; Sullivan, 2002; Molle & Molinga.,2003).The development of such an index should enable decision makers to target crosscutting issues in an integrated way, by identifying and tracking the physical, economic and social drivers which link water and poverty at a village level (Sullivan, 2002;Juran et al. 2017). The research questions addressed in this report are:

1. To what extent physical availability, access to drinking and irrigational sources, awareness and capacity to use and store causes variations in groundwater poverty across households?
2. To analyse whether social differentiation in terms of caste, class and religion significantly influence these factors and the overall groundwater status of the households?
3. What are the areas of priority for negotiation and interventions in order to improve the groundwater status of the households?

2 Methodology and Data Collection

Groundwater Poverty has been identified as complex interaction across biophysical, social and institutional factors. The concept takes its root from the work of Sullivan, 2002; Ahmad, 2003; Falkenmark, 2009 and Juran et al. 2017. The term 'groundwater poverty' acknowledges associations among socio-economic status, quality and quantity of groundwater resources, and human development broadly defined (See Juran et al . 2017).

The traditional Water Poverty Index comprises of five components (Resources, Access, Capacity, Use, Environment).

The Ground water poverty index (GWPI) is computed using Principal Component Analysis (PCA) method. PCA is a statistical method for obtaining weighted linear combination of a large number of variables resulting into a smaller number of 'dimensions' that are mutually uncorrelated. Mathematically, it means beginning with 'n' number of correlated variables where PCA creates fewer number of uncorrelated 'dimensions' which are the weighted linear combinations of the initial n number of variables. If $X_1, X_2, ... X_n$ are the variables, then the principal components would be as follows:

$$PC_1 = a_{11}.X_1 + a_{12}.X_2 + a_{13}.X_3 + ...a_{1n}.Xn$$

$$PC_n = a_{m1}.X_1 + a_{m2}.X_2 + a_{m3}.X_3 + ...a_{mn}.Xn$$

where a_{mn} represents the weight for the m^{th} principal component and the n^{th} variable (see Vyas & Kumaranayake, 2006). The first principal component is considered as it captures the highest variance present in the selected dataset.

In the present study, PCA has been computed several times to create the subcomponent level dimensions initially. For example, to obtain the "storage & capacity" subcomponent, PCA is undertaken twice: first to obtain the 'asset index' which is a variable within the said subcomponent; second, to combine the selected variable to obtain the said subcomponent (see Table 1). Some of the variables were dropped from the analysis due to poor quality and data redundancy. The sub-component level dimensions are re-entered into the PCA model for final aggregation into the GWPI. The component level as well as subcomponent level weightages and the selection of variables is tabulated below in table 1:

Table 2.1: Components and subcomponents for GWPI

Components	Subcomponents	Weightage at Subcomponent level PCA	Weightage at GWPI level PCA
Resource: Physical availability of both surface and groundwater, taking into account variability and quality as well as the total amount of water.	1) Number of Months (in Last 1 Year) Main Water Source Sufficient to Meet Household's Drinking, Cooking, Bathing and Cleaning Needs 2) Quality of Household's Drinking and Cooking Water (Before Treatment)	.739 .739	.799
Access: access to water for human use, including distance to a safe source, time needed for collection per household and other significant factors. Access also includes water for irrigating crops or industrial uses.	1. Total Pumping Hours per unit of operated area All Crops 2. % Gross Irrigated Area	.753 .753	.242
Use: different uses of water , including domestic , agricultural and industrial.	Per capita water collected (Ltr per capital)	Original variable taken	-.092
Capacity effectiveness of people's ability to manage water. Capacity is interpreted in the sense of income to allow purchase of improved water,and education and health, which interact with income and indicate a capacity to lobby for and manage a water supply.	1) Highest Level of Education among Household Members 2) Can household head read newspaper? 3) Highest level of schooling that female children in the household are likely achieve 4) Asset Index (PCA with source of drinking water, construction material, toilet, kitchen)	.739 .660 .423 .619	.138
Environment: evaluation of environmental integrity related to water and of ecosystem goods and services from aquatic habitats in the area.	Quality of Household's Non-Potable Water Source	Original variable taken	.835

The report is a part of larger project where household data were collected from a joint survey conducted in four villages of Bodai, Tihuria, Matamdanga and Hogaladanga. Stratified random sampling technique was used with household as the unit of measurement. Sample size for each of the villages is determined by using below formula1 –

[1] Cochran W. G. (1963). Sampling techniques. New York: John Wiley & Sons.

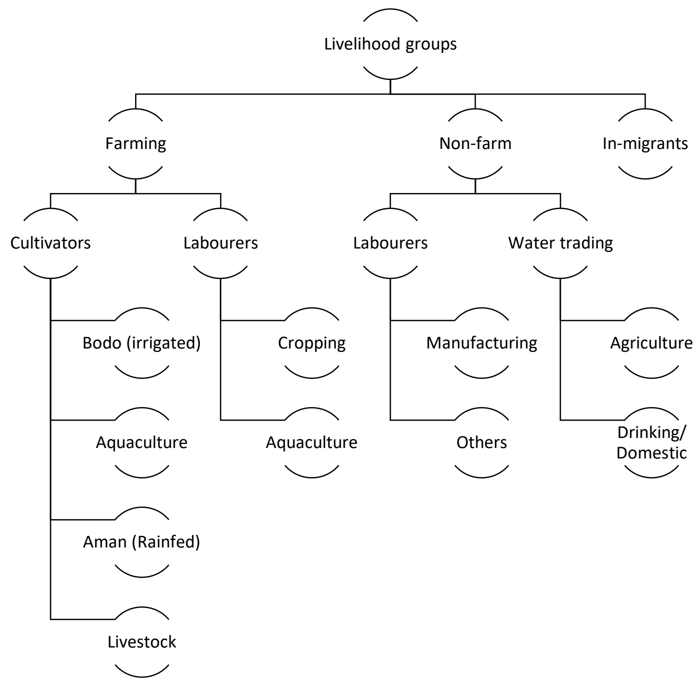
$$n = \frac{N}{1 + Ne^2}$$

Where, n – is the sample size N – is the population size e – is the level of precision (95%; e = 0.08). Major sources of livelihoods in the village as well as migration status of the households have taken as the criteria for stratification. Sample size has been kept to the exact proportion of all identified groups in actual total population. However, attempt have been made to keep the sample size representative enough across these strata to maintain the statistical robustness for comparison between these groups. Table 2 shows the number of sample households in each study villages. Figure 1 shows the sample design.

Table 2.2: Sample Size in the Study Villages

	Tihuria	Bodai	Hogaladanga	Matamdanga
Total Households	563	641	461	421
Samples taken	128	130	100	93

Figure 2.1: Sample Design



In order to determine the villages and the sampling framework Rapid Rural Appraisals, Key Person Interviews, and Group Discussions were conducted at different stages of the project execution. Local Partners namely; The Researcher, from Kolkata and JJS from Khulna supported the household survey. Series of Mango Tree meetings and Negotiated Approach workshops with multiple stakeholders in each of the study locations helped in consolidating the issues to be surveyed. Blogs, workshop reports and informal discussion reports prepared by PhD scholars and other academic and non-academic partners, as shared in the project website would provide further understanding of the critical issues in the study villages. The detailed sampling framework and survey design is mentioned in the working paper titled "Thematic paper on Urbanization and Groundwater use: Socio-economic system mapping" published in December 2017 (http://saciwaters.org/shiftinggrounds). Following section provides a brief introduction to the study villlages.

3. Case Studies

Before going into results and discussion this section will discuss the four case studies in brief. All the four villages are heterogeneous in nature, although the degree of periurbanization processes varies. Resource accessibility is a factor of class, caste and religion.

Bodai is one of the most industrialized villages of North 24 Pargana with more than 500 small scale manufacturing units dotting the landscape. Public deep tube well with a catchment of 120.25 acres provides irrigation to 150 beneficiaries, though the percentage irrigated area shows a declining trend for the past 10 years. Irrigation water market operates outside the legal ambit between upstream and tail farmers. Tube well operator is politically most powerful man and plays a significant role in the water distribution system of the irrigation well. Drinking and domestic water supply that is provided by the panchayat to 4 clusters seldom meets the requirements. Drinking water market with few registered plants and more illegal private vendors ensures the supply. Excessive pumping by the industries, farmers, private water filtration plants has resulted in fast depletion of the groundwater aquifer. Bodai has lost its shallow aquifer layer between 150ft and 180ft.Evidences of increase in pumping hours and depth of the bores from 60ft to 900ft indicates a strenuous aquifer.

Tihuria of S 24 Pargana is a part of east Kolkata wetland and has been product of its modernization drive and unabated quest for water. City's lateral spread is seen in construction of metro about 7 km from the village. Transport network not only caused a real estate boom, but influenced 500 years old surface water-based irrigation system. Land acquisitions and transfer have been largely outside the framework of Protection Act. Encroachments of the surface water channels locally called Suti Khals', altered the farming system, giving rise to two distinct groundwater-based livelihood groups, shallow paddy farmers of Tihuria and aquaculturist of Shaheberabad. Increase in population, particularly influx from the city increases the heterogeneity of the village, putting additional pressure to the local village council to supply basic needs like drinking and domestic water. The panchayat managed tube wells and common taps often fall short resulting in significant increase of packaged drinking water. The village has 7 private illegal water filtration plants that supply water in unsealed 20-liter jar costing around INR 25.

Hogaladanga falls under Jalma Union and Bhatiaghata Upazila of Khulna metropolitan area. The village has been a favored destination of migrant population since 2005. Traces of urbanization in terms of industrial expansion is less pronounced while private appropriation of resources is significantly high. Drinking and domestic water supply is managed by Department of Public Health (DPH) through 3 deep tube wells. Unlike peri-urban Kolkata where informal water vending is more prevalent, household level private deep tube wells ensure potable water supply. Household survey reported depleting groundwater status essentially attributing it to the intensive tube well irrigation in the larger area catchment. Falling groundwater level has often compelled the poor to rely on common access resources like ponds and open wells.

Matamdanga falls under Attra-Gilatola Union of Phultala Upazila in peri urban Khulna. Unlike Hogladanga, the village has experienced haphazard industrialization, public appropriation of land and water resources. Matamdanga host a cantonment area appropriating huge groundwater resources. Dependence on private shallow and deep wells are extensive with insignificant dependence on open water sources. Insufficiency of the drinking water is miss appropriately faced by the peri-urban poor, while the rich or the upper class manages to accesses private water sources. Unlike villages of peri-urban Kolkata the irrigation in both the villages of Khulna is privately owned. Shallow tube wells with diesel pump-sets forms the major irrigation sources for boro cultivation. Aquaculture that forms significant livelihood source for Matamdanaga is dependent on private shallow diesel run tubewell.

4 Results and Discussions

Among the four villages studied, Bodai appears to be most groundwater rich followed by Matamdanga, Hogaladanga and Tihuria (Fig 2 & Table 3). ANOVA however suggests that while the two villages on the peri-urban Kolkata side are different in terms of ground water poverty, the Bangladeshi counterparts are not significantly different. Based on Tukey HSD Post Hoc Tests[2], Matamdanga and Hogaladanga constitute a single subset. This actually confirms to the ground realities as observed through visual observations, interviews and group discussions.

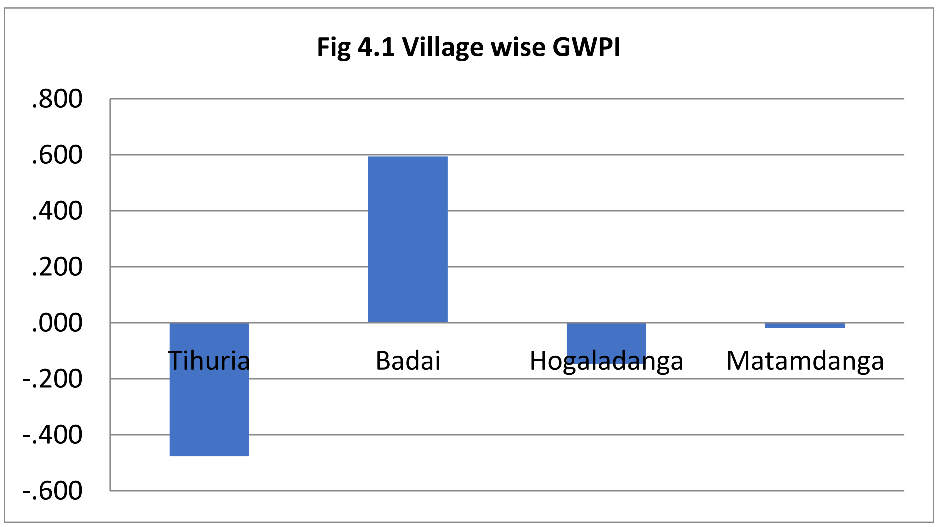


Table 4.1 ANOVA: Village wise GWPI

Village		N	Mean GWPI	Subset for alpha = 0.05*		
				1	2	3
Tukey Ba,b	Tihuria	128	-.4761087	-.4761087		
	Hogaladanga	100	.5945963		-.1469155	
	Matamdanga	93	-.1469155		-.0178931	
	Badai	130	-.0178931			.5945963

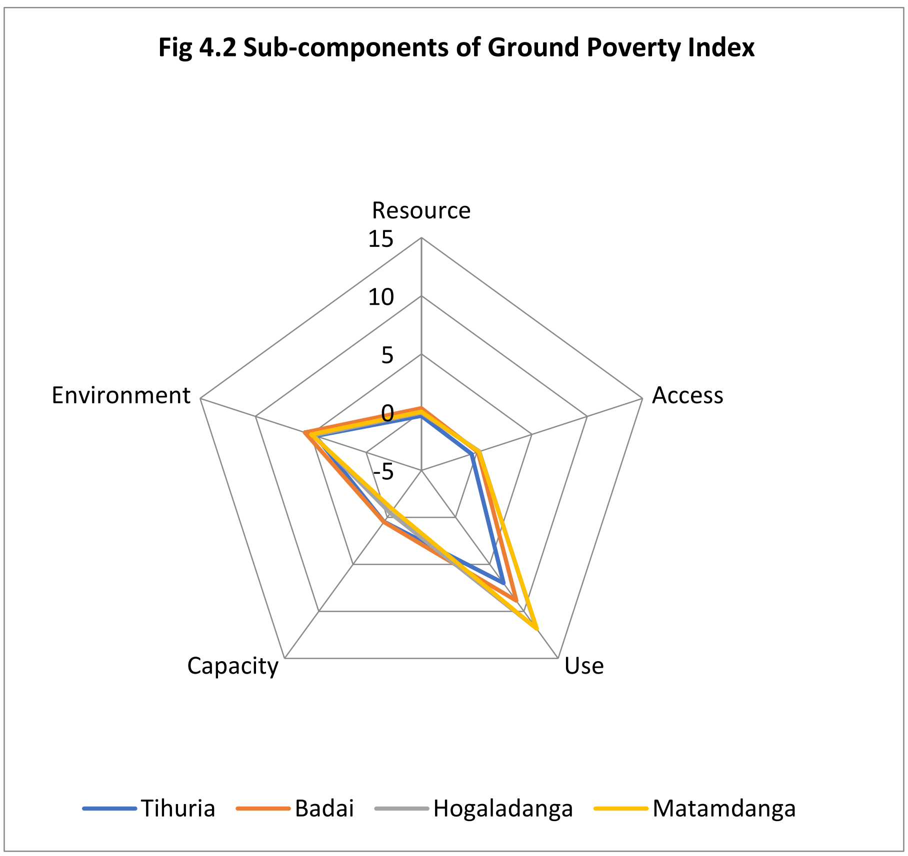
[2] A post hoc test is done to check whether the mean values of the selected variables are significantly different. ANOVA along with a post hoc test is selected when the comparison is between more than two elements.

If we look into each of the sub-component the above description holds true. Sub-component wise comparison of the four villages depicted in figure 3 shows that all of them fairs well in terms of use, ie, per capita water collected. It is highest in Matamdanga, followed by Hogaladanga, Bodai with lowest in Tihuria. Group discussions and observations provides possible answer to this pattern. The villages of peri-urban Khulna access to private deep and shallow tubewells is high and there is significant difference between the two. In Hogaladanga informal sharing of water from private deep tube wells have been reported. Besides dependence on common water sources like open wells, ponds and small streams are more in both Hogaladanga and Matamdanga. In the peri-urban villages of Kolkata per capita water collection is a function to the distance of the common public water source and number of private water vendors. Though in Bodai number of public stand-posts or deep tube wells are more, greater presence of private informal ROs in Tihuria has significantly increased per capita water collection. After use, environment measured in terms of perceived quality of non-potable water is significantly high across all the four study villages with highest in Bodai and lowest in Tihuria respectively. Bodai has been essentially dependent on public deep tubewells of more than 900ft deep. These deep tube wells are the only source for both drinking and domestic as the village has lost the shallow aquifers. In some of the clusters within the village collective sharing and informal distribution through plastic pipelines have ensured the access to such deep tube wells to the larger households. For Tihuria on the other hand non-potable water sources are shallow tube wells whether public or private. Low lying areas of Tihuria often gets inundated during rainy reasons contaminating the shallow aquifers. Besides the presence of arsenic is relatively in Tihuria. Lack of maintenance of the public sources is critical and significantly applies to all the four villages affecting the water quality.

Resource measured in terms of sufficiency of drinking and domestic water and potable water quality, and access shown by total pumping hours per unit of operated area of all crops and percentage of gross irrigated area reveals interesting insights. Both these components are very critical indicators of water poverty, yet all the four villages have depicted a poor resource and access status. Bodai has reported to have relative sufficiency in potable and non-potable water supply for large number months while it is significantly insufficient for Tihuria. Similar trend can be seen for potable water quality for peri-urban Kolkata. Peri-urban Khulna while on the other hand does not exhibit any significant variations. The pattern resonates the peri-urban attributes of the villages and the groundwater usage to a large extent. The shallow and deep tube wells maintained by Public Health Engineering Department (PHE) and local administration (Panchayat, union) have been the main source for drinking, cooking and other domestic use. For all the four cases the source is groundwater with exception in Tihuria, where surface and groundwater is mixed, stored in the panchayat overhead tanks and gets distributed through common points. Insufficiency in these public sources for longer period of time not only tells about the acute water crisis but poor governance particularly coverage and maintenance. The aforesaid argument holds true for Tihuria where there are only three active PHE water distribution points. These are essentially concentrated in one of the clusters in the village occupied by more influential households. The supply is erratic, comes thrice a day (between morning 7 am -9 am, 11 am to 12 pm and 3 pm -5 pm) as observed by the long que. Interviews reported poor water quality with yellow colour and foul odour in Tihuria.

Access measured in terms of pumping hours and area irrigated shows a different trend with Matamdanga and Hogaladanga surpassing peri-urban Kolkata. Irrigation is groundwater dependent in all the four villages. Weightage at sub-component level reveals the significance of groundwater irrigation in the overall poverty status. Irrigation is more decentralized with private access to shallow tube wells in Khulna while Bodai has a centralized public deep tubewell system. Presence of water market is a common in Hogaladanga and Matamdanga ensuring small farmers access to groundwater. Rental market for pumps has made groundwater based paddy cultivation significant in Tihuria. Water distribution in Bodai is more politically motivated and market is governed by few large farmers. However total pumping hours per crop has increased in all the four cases with marginal increase in the irrigated area. This implies the stress in the groundwater level.

Capacity measured in terms of household's education level and assets ownerships played critically in the groundwater poverty although less significantly compared to other four components. Bodai and Tihuria scored relatively high compared to Hogaladanga and Matomdanaga. This points out to the influence of the city of Kolkata to such peri-urban villages. The urbanization processes and Kolkata's spread has a colonial history. Tihuria was an important trade centre and played critically in meeting city's demand for land and water. Left party movement brought significant changes in the socio-cultural life of people of Tihuria. Village had primary and secondary schools and health centres. People are more aware of their rights. Bodai on the other is a highly industrialized village where majority of the Hindu population involved into service sector. Asset ownership calculated in terms of drinking water source, settlement types, presence of toilets etc reflects the class. Greater is the asset ownership lower is the groundwater poverty.



Four components and clusters of sub-components as discussed in the previous section narrates the village wise groundwater poverty level. Household level analysis will show variability of groundwater poverty level along the caste and religion axes. Caste has always been a critical vector structuring the complex and fractured waterscape of south Asia. Disparity by caste is significantly seen in the villages of peri-urban Kolkata while it is largely absent in Khulna. Tihuria has presence of two major social groups, the Scheduled Caste (SCs) or Dalits and Other Backward Caste (OBCs). General caste (GCs) forms a very small section of the total population. While Bodai is more heterogeneous in nature with larger proportion of general or upper caste households. Table 4 shows caste based discrimination and groundwater poverty status in Bodai and Tihuria. 'Others' belonging to the upper social ladder report to be significantly better-off in terms of ground water status followed by the OBCs and SCs in both the villages. This confirms to the larger literature of caste and water where age-old social hierarchy of hindu society has historically positioned Dalits or SCs at the lowest level to access water or any other basic services. Tihuria although had majority of the dalit population, age old subjugation has influenced the way water has been access in both the villages.

Table 4.2 ANOVA: Caste wise GWPI					
Household's Caste	Mean GWPI	N	Subset for alpha = 0.05*		
			1	2	3
SC	-.4448690	128	-.4448690		
Others	.6045177	299		.1419224	
OBC	.1419224	24			.6045177

Significant differences exist religion wise across all the four villages as depicted in table 5 and 6. Religion wise mean difference at 1% significance level across all the four cases together indicates that the observed difference is real and not 'by-chance'. The table 5 further suggests that the Muslim community is significantly better-off compared to the Hindu community both the countries taken together. But, at a disaggregated level, the trends are interesting. As table 6 depicts groundwater poverty is significantly higher for the Muslims in case of peri-urban Kolkata compared to the Hindu counterparts while there is no statistical difference between the two communities in Khulna. In terms of Resource, the Muslims in the Bodai and Tihuria are significantly more ground water secure compared to the Hindu community while there is no statistical difference between the two communities in peri-urban Khulna. In terms of access there is a pattern observed: Muslims are better in peri-urban Kolkata while the Hindus are better in peri-urban Khulna. In terms of Use and Environment, Muslims in Bodai and Tihuria are better-off compared to the Hindus (at 10% level of significance) and there is no statistically significant difference between them in Hogaladanga and Matamdanga. In terms of Capacity, while in India there is no difference, in Bangladesh the Hindus are better than the Muslims.

Table 4.3 Mean Difference: Religion-wise GWPI			
	N	Mean	Sig.
Hindu	217	-.1953514	.000
Muslim	234	.1811592	

Table 4.4 Religion wise cross country comparison

Components	Group	India				Bangladesh			
		N	Mean	Sig.	Mean Difference	N	Mean	Sig.	Mean Difference
Ground Water Poverty Index	Hindu	151	-.3118576	.000	-.90481188	66	.0712008	.129	.23698713
	Muslim	107	.5929543			127	-.1657863		
Resource	Hindu	151	-.2114712	.000	-.51226201	66	.2172154	.013	.33208693
	Muslim	107	.3007909			127	-.1148716		
Access	Hindu	151	-.4016667	.000	-.56403176	66	.1630901	.411	-.09293090
	Muslim	107	.1623651			127	.2560210		
Use	Hindu	128	7.0594	.035	-2.11258	65	12.0665	.721	.37850
	Muslim	71	9.1720			116	11.6880		
Capacity	Hindu	151	.4919174	.831	.02442866	66	-.4082798	.001	.35828993
	Muslim	107	.4674887			127	-.7665697		
Environment	Hindu	151	4.7020	.000	-.84007	66	4.8939	.599	.08292
	Muslim	107	5.5421			127	4.8110		

.000 measures 1% significance level

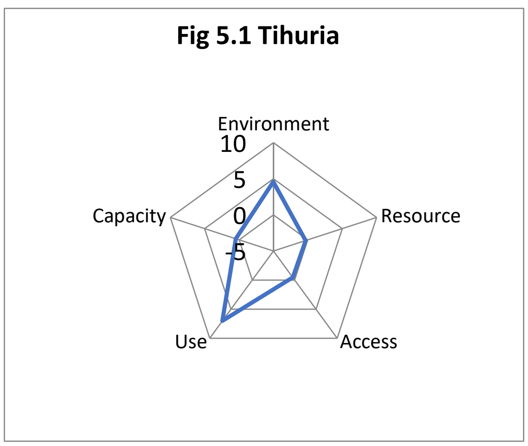
5 Potential Area of Contribution to Negotiation

The discussion so far gives a detailed account of physical availability, household's access to domestic and irrigational sources, and several socio-economic vectors affecting their groundwater status. One of the critical elements of the study was not only to assess household's groundwater poverty level but capacitate them to negotiate with the local authorities. The aim has been to identify the critical challenges and bring them on to the negotiation table with the local government. The index analysis was designed to be used as a tool to identify such critical areas of priority and interventions beneficial for both local government and community. The weightages in PCA was thought to help in identifying the potential area of prioritization, planning and interventions. As a mode of engagement and dialogue the project adopted Negotiated Approach to bring farmers, local government (panchayat and union government members), parastatal bodies to engage in the dialogue process. Initially the approach was planned to be tested in all the four villages however, limited fund and politico-economic feasibility restricted its implementation to Tihuria and Hogaladanga respectively. The project therefore has tried to establish the link between socio-economic index analysis and Negotiation. Such linkage needs longer timeframe and protracted association with the village, it nevertheless has helped in identifying potential areas of negotiation and long-term engagement.

Tihuria one of the peri-urban villages of Kolkata where Negotiated Approach was implemented, has demonstrated insufficiency in drinking water sources, poor quality of potable and non-potable water(Figure 4). Poor condition of the public water source is very well visible in the village as well as reported by the community in several mango tree meetings all through the project period. Concentration of PHE water sources are highly skewed with clusters or 'paras' of no public water distribution points. Many remained dysfunctional due to poor maintenance with others reported to have arsenic.

Access as measured by increase pumping hours and percentage groundwater irrigation points out to the critical usage of groundwater in the village. Traditionally the village practiced waste water paddy and aquaculture. Acquisition, encroachments of the wastewater canals forced many farmers to shift to shallow tube well based paddy cultivation. Boom in the private investments in shallow tubewells and mechanized diesel and electric pumps increases the percentage irrigation area taking it beyond the boundary of the waste water canal command area. Tihuria saw mushrooming of local, informal pump irrigation service market where electric run pump costs around INR 20/hr while diesel pump, INR 60 /hr. It helped the small farmers to access groundwater from pump owners to cultivate both paddy and fishes and thus increased percentage irrigated area. Increase pumping hours on the other hand indicates longer time to water crops or fill aquaculture ponds. This in turn indicates strenuous aquifer condition of the village.

From the index, as revealed by the component and sub-component score in table 1, resource, access and environment got highest priorities. Insufficiency of the public sources, drinking water quality, reclamation of the waste water canal were taken as potential areas for dialogue, engagement and interventions in Tihuria. 'The Researcher', organization working with the community in the village periodically shared the community's demand with PhD and post doc researchers and disseminated research results in several NA workshops. Discussions with community, researchers and local partner helped in identifying two groups; namely shallow tube well based paddy cultivators aquaculturist, as potential group for negotiation and dialogue. Disproportionate power structure and contradictory interests forced the community mobilizer to work out around groundwater quality as a common point of interest for community and local government.

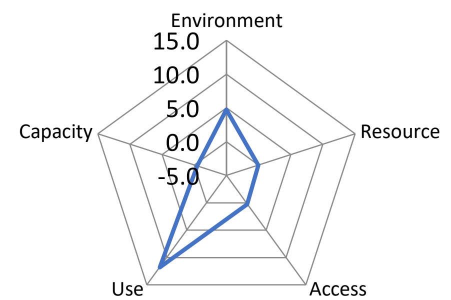


Thus in Tihuria water quality of the drinking and domestic water sources was prioritized as issue of urgent intervention. Community was mobilized and trained to better understand the water quality particularly Arsenic. 40 samples were collected from domestic tube wells and arsenic map of the village was prepared and shared with panchayat members, the local PHE official, experts, as well as the members of the Village Water and Sanitation Committee. The engagement led to upscaling of the effort to 7 more villages within the Tihuria Gram Panchayat. This was followed by a health camp in Tihuria with a Community Medicine Doctor to check possible arsenic affected households.

Articulating community demand for improvement in the public water delivery system as part of resource mobilization was considered yet another issue of engagement and negotiation. Through several mango tree meetings and Negotiated Approach workshops community members were identified to form a Negotiation group to articulate their demands like installation of more number of tube wells or community taps in Tihuria.

Hogaladanga was considered as a potential village for Negotiation in peri-urban Khulna. The PCA results at the village level depicts the similar pattern where insufficiency and groundwater quality got maximum weightages (Figure 5). Dialogue and engagement to address the critical issue of insufficiency was taken on a priority basis. The village has three active Department of Public Health Engineering (DPHE) deep tube wells catering to 237 households. Low installation cost has led installation of private tube wells only to encounter the critical challenges of iron and salinity. The women often had to travel outside the village and wait for longer hours to collect water. The rate of drawdown has been high where several private tube wells at shallow depth have failed. Discussion also brought issues like canal encroachment, water logging, and waste disposal by city corporation which might not have a direct linkage to groundwater but reflects the larger environmental concerns and water quality problems of Hogaladanga. The local partner organization was JJS involved in negotiation between community and government at different levels.

Fig 5.2 Hogaldanga



Discussion with the community in several mango tree meetings and negotiated approach workshops with local authorities resulted in the formulation of 'Small Scale Participatory Water Management Plan'. A social map indicating existing tube wells, canals and surface water bodies were prepared by the community and shared with DPHE as first step towards engagement and negotiation. Problem areas thus were jointly identified while the demands for increase in number of public drinking and domestic water sources were together ratified. The dialogue and negotiation resulted in definitive action in the village. For instance DPHE commits to install a test tube well of 1500 ft deep in Hogaladanga village, in recognition to the declining water tables and the need for sufficient safe public drinking water supply points. This informs the importance of economic analysis and negotiations resulting into plans and interventions. Engagement, dialogue and Negotiation helped the community not only identified their problems but also articulate their demands in the language better understand by the authorities and service providers. The impact of such engagement could be seen in the formation of a peri-urban water forum of communities, representatives of all related government authorities and civil society to work on the issue even after the project completion.

6 Conclusion

GWPI is an effective instrument for measuring groundwater poverty and moving towards a clearer understanding of waterscape complexities. To those ends, the GWPI can be considered diagnostic (saying what is wrong), prescriptive (saying what should be done), evaluative (assessing intervention outcomes or intervention 'success' against predetermined goals) and pragmatic. It has helped the researchers and the community to identify critical issues around groundwater, capacitate them to negotiate with authorities at different scales. The index showed groundwater poverty rankings across households and villages. Such ratings and village level comparison cutting across countries helped not only in micro-planning but macro understanding of the groundwater challenges in peri-urban delta context. Comparison of components and sub-components across social groups delve further into the complexity of access and capacity in peri-urban space. Aforesaid analysis has made Bodai the most groundwater rich followed by Matamdanga, Hogaladanga and Tihuria. Environment measured in terms of quality water sources and per capita water collected played significantly in affecting the groundwater poverty status of the village. Issues around water quality also has been taken as entry point activities for community engagement, dialogue and negotiation. Resources in terms of availability played an important role of the dialogue process. Breaking the components village wise gives a similar trend.

GWPI thus throws light on potential area of prioritization, planning and execution in groundwater management. Poor water quality, insufficiency in public supply, and poor coverage as depicted by environment and resource components reflects urgent interventions. Maintenance is a challenge and requires long term engagement among community and authorities. Negotiated approach took up some of the important issues emerged from the index in Tihuria and Hogaladanga. The arsenic mapping of Tihuria and Participatory peri-urban participatory plan of Hogaladanga reflects such initiatives. Some of the issues like waste dumping and canal encroachment have been actively taken up by the peri-urban water forum in Hogaladanga although not directly came out of index but has a potential linkage to one the significant component; water quality. The sustenance of the engagement and potential areas of dialogue and negotiation has been ensured through constitution of peri-urban forum in Hogaladanga. Similar initiates in Bodai, Tihuria and Matamdanga could open up opportunities of engagement on issues like illegal water vending, waste water irrigation, education and awareness building.

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Shifting Grounds: Institutional transformation, enhancing knowledge and capacity to manage groundwater security in peri-urban Ganges delta systems

The project aims to build knowledge and capacity among local actors to support a transformation process in peri-urban delta communities in Bangladesh and India for a pro-poor, sustainable and equitable management of groundwater resources across caste/class and gender. This will be based on an improved understanding of the dynamic interplay between local livelihoods, the groundwater resource base, formal and informal institutions and links with nearby urban centres in Khulna and Kolkata. These two cities provide a good basis for an institutional comparison, being part of the same Ganges delta system, yet located in different countries.

Funded by the Netherlands Organisation for Scientific Research (NWO), the Shifting Grounds project is executed by a group of academicians, researchers and civil society organisations. Delft University of Technology (TU Delft) leads the consortium and SaciWATERs is the regional coordinator for the project. Other project partners are Jagrata Juba Shangha (JJS), The Researcher, Bangladesh University of Engineering and Technology (BUET) and Both ENDS.

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