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Examining the Economics of Affordability Through Water Diaries in Coastal Bangladesh

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Monitoring affordability of drinking water services is constrained by data gaps from traditional approaches that rely on cross-sectional data from infrequent, nationally representative surveys. Estimates of income or expenditure ratios spent on accessing a main source of drinking water are poorly equipped to reflect affordability in rural contexts where poor people often resort to multiple sources of varying costs, quality and distance to cope with unreliable or absent water supplies. Here, we present findings from an 18-week water diary study that documented daily water choices and expenditures of a stratified sample of 120 households in coastal Bangladesh. This intensive, longitudinal monitoring is supported by household surveys, water infrastructure mapping, hydrogeological analysis of salinity, automated rainfall measurements and interviews with diary participants. We identify five water expenditure typologies, ranging from those who always rely on unpaid and often poor-quality sources like shallow tubewells, pond sand filters and rainwater, to those who purchase vended water for drinking and cooking all year-round, spending 3–7% of total household expenditure. These behavioral dynamics are shaped by environmental, infrastructure and cultural factors, with household wealth being a weak indicator of behavior. We conclude that affordability measures should recognize the quality of service available and chosen by users across seasons, rather than being fixated on income or expenditure ratios for a main source. Measuring the latter without considering the former impedes the design of service delivery models appropriate for providing safe and reliable water supplies, at costs that users and society are willing to bear and sustain.

Keywords: Affordability; Bangladesh; poverty; water diary; water security; salinity.

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1. Introduction

Affordability is a concept in search of consensus. The Joint Monitoring Programme (JMP) led by WHO and UNICEF has provided critical and increasingly sophisticated information over more than a decade to inform global and national policy and investment priorities, now articulated in the Sustainable Development Goal (SDG) of safely managed drinking water for everyone by 2030 (WHO/UNICEF 2017). However, data derived from nationally representative household surveys every few years, which provide necessary political legitimacy and global monitoring consistency, conform weakly to measuring daily affordability of drinking water services. This is due to the simplification in identifying a "main source" of drinking water, whereby infrastructure types are used as proxy for service quality (e.g., UNICEF/MICS 2017; DHS Program 2015). Failure to acknowledge the multiplicity of sources used by households over time in specific hydro-climatic contexts has economic implications for policy design, infrastructure choices, financial sustainability and poverty reduction for an estimated 785 million people who live without basic water services (WHO/UNICEF 2019). There are increased calls for new methods and empirical evaluations of water affordability over time, with particular focus on understanding the water security challenges of the poor and vulnerable in difficult contexts. We aim to address this knowledge gap using water diary data from households in coastal Bangladesh, where chronic groundwater salinity and idiosyncratic hydroclimatic shocks contest simple notions of affordability for 25 million coastal inhabitants living in similar conditions in South Asia (Hoque *et al.* 2019).

Economic principles have positioned water as both an economic and a social good within public policy (Rogers *et al.* 1998). The former seeks to maximize social welfare by grounding allocation decisions on users' collective demand (or willing to pay) for water services (Van der Zaag and Savenije 2006), while the latter acknowledges the wider health, social and environmental benefits of extending basic water services to all (Opschoor 2006). As such, global policy has largely focused on the supply side with significant public investments in building water supply infrastructure aligned to meeting the Millennium Development Goal (MDG) of increasing access by 2015. On the demand side, development of appropriate price and non-price tools to address cost-recovery, demand management and distributional equity have received much attention (Rogers *et al.* 2002; Savenije and van der Zaag 2002). This approach of "getting the prices right" is suitable for urban contexts with reliable piped supplies, whereby increasing block tariffs and differential rates for domestic and non-domestic consumers are often deployed to ensure that the urban poor can afford a minimum quantity of water

(Hoque and Wichelns 2013). However, in rural areas and low-income urban settlements, where persistent shortfall of public investments in water infrastructure and ineffective institutions have left millions depending on multiple sources, the affordability question is not only limited to what households pay, but also what level of service they receive in exchange of that payment and why many choose to use unpaid sources (Komarulzaman *et al.* 2019). Current measurement and monitoring of affordability does not adequately recognize nor quantify the combination of social, cultural and environmental issues that drive water use practices. Such behavioral dynamics can provide broader evidence of what is affordable, for whom, when and where, with implications for financing and sustaining universal and equitable water services by 2030.

Here, we propose a definition of affordability as: "drinking water is affordable where a safe, reliable and accessible service generates fair and regular payments from users to contribute to service sustainability while achieving adequate consumption of other basic household services and overall welfare". With any definition the devil is in the detail. Our definition goes beyond estimating expenditures for a main water source and points towards two salient but often missing features of affordability. First, attempts to monitor affordability should be linked to the service level received by users, characterized by the quality, quantity, accessibility and reliability of the water supply. The normative criteria for these indicators are guided by SDG 6.1 and the Human Right to Water (WHO/UNICEF 2017; UN 2010), although policy approaches for interpreting, regulating and monitoring drinking water can vary by country and are not discussed further here. Affordability measures should thus account for the use of multiple sources for different needs across time. Second, it should ensure that the services are equitable for users of different socio-economic profiles, so that paying for water does not affect their ability to pay for other essential goods and services. This relates to the notion of "fair" payments, which acknowledges the issue of non-discrimination by economic, political, cultural or social factors. As such, affordability standard for water payments can be zero in the context of emergencies (conflict, drought, displacement) or social deprivation in particular geographies. However, the crude assumption that people do not pay means water is unaffordable is overly deterministic. More broadly, we wish to explore non-payment behavior to understand what other factors may influence choosing to pay beyond economic considerations alone (Hutton and Andrés 2018).

The use of multiple sources for multiple uses and the effects of seasonality are well documented in the literature. Evidence from Ghana, Kenya and Zambia shows that people spent less time and money on water collection during the wet season as rainwater and seasonal streams became available, while use of improved groundwater sources increased in the dry season with corresponding increase in expenditure and time spent (Kelly *et al.* 2018). Similarly, in the Ethiopian Highlands, Tucker *et al.* (2014) found that the use of water for personal hygiene decreased perilously in the dry season, particularly among poor households, who had less labor for water collection and fewer storage and transport assets. Given that the bulk of the water is used for non-consumptive purposes, low income households may only pay for water of high microbiological quality for drinking and cooking, while using unimproved sources for washing and bathing purposes (Elliott *et al.* 2017). Despite such extensive evidence, these behavioral dynamics have been largely overlooked in global monitoring approaches either inadvertently or by design, owing to the difficulty in developing survey instruments that accommodate untold combinations of water sources (Elliott *et al.* 2019). Economists have somewhat attempted to evaluate this dynamic nature of affordability, by estimating the costs of coping with unreliable supplies or identifying willingness to pay for a portfolio of hypothetical water services (Amit and Sasidharan 2019; Gurung *et al.* 2017; Cook *et al.* 2016; Whittington *et al.* 1990).

These behavioral dynamics have implications for the financial sustainability of water services. Analysis of multi-decadal waterpoint financial records by Foster and Hope (2017) shows that revenues and expenditures of handpumps in rural Kenya mirrored rainfall events, with pay-as-you-fetch waterpoints generating higher revenues than flat fees. Payment behaviors differ markedly between rural and urban locations as revealed by evidence from over 17,000 households in 19 African countries where roughly two-thirds of urban households pay for water compared to two-thirds of rural households who do not (Mattes *et al.* 2008). A wider economic question then emerges is how to finance infrastructure calibrated to the peaks and troughs in water demand that is affordable for consumers and suppliers. The impacts of the hydro-climatic context expand beyond the seasonality concern of rainfall to consider the issue of water quality, particularly groundwater, and climatic shocks and stresses, which in turn determine the types and scale of investments required. In Bangladesh, arsenic contamination of shallow aquifers and elevated levels of salinity across varying depths pose severe scarcity for freshwater without major investments in alternative technologies such as small piped schemes with water treatments, reverse osmosis or managed aquifer recharge (Islam *et al.* 2017; Sultana *et al.* 2014). In absence of such investments, informal vendor markets emerge, selling bottled water from distant sources at high prices (Raina *et al.* 2018; Srinivasan *et al.* 2010; Kjellén 2000; Whittington *et al.* 1989).

Wealth inequalities in access to basic water services are now documented by the JMP, with evidence showing that the relatively rich-poor gap is higher in countries with low national coverage, although absolute gaps may be small (WHO/UNICEF

2017). A systematic review of coping strategies by Majuru *et al.* (2016) shows that while wealthier households deployed capital-intensive strategies, like drilling wells or increasing storage capacity, that addressed aspects of quality, quantity and convenience more comprehensively in the long-term, poorer ones catered towards more immediate quantity problems by engaging in labor and time-intensive strategies like treating and collecting water from long distances. Water is not a homogenous commodity; its economic value is shaped by the reliability of supply, quality and ease of access and is reflected not only by its cost, but the trade-offs made by the users. In densely populated urban slums, the need to wait in long queues at shared public taps may encourage women with competing needs such as paid work, childcare and cooking to choose alternative sources of lower quality or higher price (Crow and McPike 2009). Households' ability to pay also fluctuates over time owing to changes in income, water price and other competing needs (Price *et al.* 2019).

To capture this dynamic nature of affordability, we developed and implemented a water diary method, whereby participants maintain daily records of their water sources, quantity, costs and collection responsibilities, along with expenditures on food, education, health, transport, energy and miscellaneous items. Baseline data from household surveys, water infrastructure mapping and water quality tests, along with rainfall data and in-depth interviews, complemented this intensive longitudinal monitoring and provided insights into the diverse ways in which people value water, the ensuing trade-offs and distributional inequalities. The paper offers three contributions to the water economics and policy literature building from a proof-of-concept study in Kenya (Hoque and Hope 2018). First, it advances the theoretical understanding of monitoring and managing affordability from both an economic and environmental perspective using an 18-week dataset that spans seasonal change, environmental risks and a major cultural event (Eid festival). Second, it classifies the water use behaviors of the poor using interdisciplinary methods to identify expenditure groups. Third, it considers public policy responses in terms of the nature and type of interventions to promote affordability, with particular reference to vulnerable and poor people.

2. Research Design

2.1. *Study site*

The study was conducted in Polder 29, one of the 139 polders supporting a total population of 8 million (as of 2008) living on 1.2 million hectare of embanked land in coastal Bangladesh (Tuong *et al.* 2014). Polder 29 is located in Khulna district in the southwest, covering five unions (Tier-4 administrative boundary) across

Dumuria and Batiaghata upazilas (sub-district/Tier-3 administrative boundary) and comprising more than 17,000 households and 60,000 people in an area of about 80 km^2 (BBS 2011). The south-western coastal region has an average annual rainfall of 1,900 mm, about 85% of which occurs during the monsoon month of June–August (Hossain *et al.* 2014). Although the region has highly productive aquifers within the thick unconsolidated alluvial sediments, the relatively shallow aquifers are usually contaminated by high levels of salts, with isolated freshwater lenses (Hoque *et al.* 2016). Anthropogenic pressures, including over extraction of groundwater, reduced upstream river discharge and inland modification of coastal areas, are interfering with the natural hydrology and pushing the salinity front further inwards (Shammi *et al.* 2017). Sea level rise and increased frequency and intensity of cyclones, coupled with high population growth, are likely to increase exposure to these salinity risks in future.

2.2. *Baseline data*

The baseline data for this water diary study was gathered in 2018 through household surveys, water infrastructure mapping and water quality tests. The methodological details of these exercises are detailed in a recently published paper under the same research grant (refer to Hoque *et al.* 2019) and summarized in Table 1. Ethical approval for the study was granted from Oxford University's Central University Research Ethics Committee (SOGE 18A-6, November 2017). Researchers and enumerators ensured that all respondents participated voluntarily through informed consent, and data with personal identifiers were stored in secured platforms. Local enumerators familiar with the social, environmental and political context were trained and monitored by the lead author (University of Oxford) with local government engagement in the study design through local stakeholder networks managed by collaborators from the Bangladesh University of Engineering and Technology (BUET).

2.3. *Water diary*

Diary design

The diary design was guided by a proof-of-concept study of four weeks conducted in Kenya in April 2017 (Hoque and Hope 2018) and adapted to the local context based on knowledge from the survey and the lead author's previous studies in coastal Bangladesh (Hoque *et al.* 2017). The water diaries were designed to capture daily data on the types of water sources, location of source, quantity collected, cost of water/transport and collection responsibilities, along with records of households' financial expenditures on pre-defined categories (Fig. 1). Given the

Table 1. Research Methods to Obtain Baseline Data for the Water Diary Study

Method	Purpose	Data Collection	Data Analysis
Household survey	To collect quantitative data on various indicators of multidimensional poverty and drinking/domestic water services	A sample of 2,103 households selected through stratified random sampling and surveyed by 15 enumerators using an electronic form	IBM SPSS 25 used to calculate wealth indices through principal component analysis of 10 selected variables
Water infrastructure audit	To map the locations, installation dates, technical specifications, ownership, maintenance and usage patterns of all tubewells and pond sand filters	Phase 1: 2,805 (all) tubewells in the middle and southern part of the polder and 19 pond sand filters Phase 2: 354 (sample) tubewells in the northern part	ArcMap 10.6 used to map locations of all waterpoints, differentiated by depth and functionality
Water quality	To test the salinity levels of water from all tubewells and pond sand filters included in the audit	Electrical conductivity (EC) measured *in situ* using field kit CLEAN CON30 Tester, 0–20.00 mS/cm, with further tests in the laboratory using Ohaus ST300C-G Portable Conductivity Meter, 0–199.9 mS/cm.	Inverse distance weighted (IDW) interpolation conducted in ArcMap 10.6 to illustrate the spatial variation in groundwater salinity in the shallow (1st) and main (2nd) aquifers using EC values of 2033 tubewells (depth <100 m) and 732 tubewells (depth >100 m), respectively

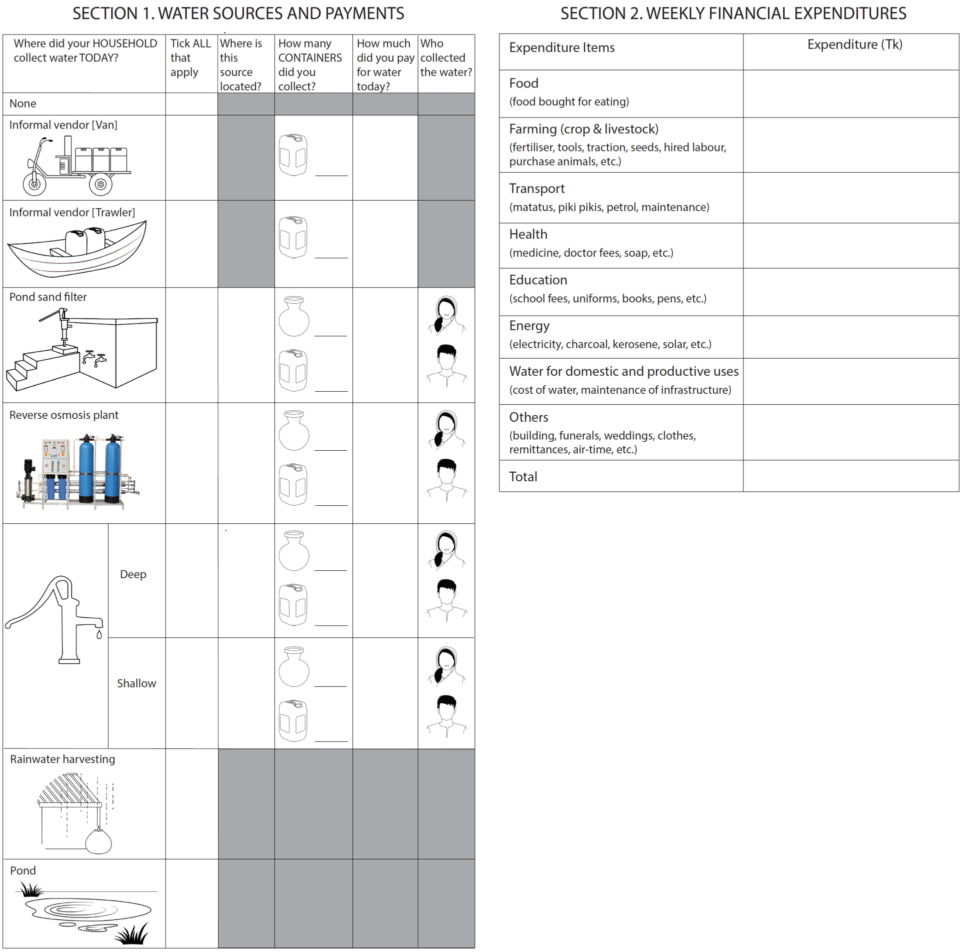


Figure 1. Water Diary Design

low level of educational attainment, we designed a simple structured diary with pictorial aids that required minimal written entries from participants.

Sampling strategy

The water diaries involved 120 households, the selection of which was guided by the baseline data from the household survey (Table 2). Analysis of survey data showed that households across the northern part of the polder were relatively water secure compared to those in the south, where high levels of salinity in groundwater forced people to rely on multiple alternative sources with varied quality and cost implications. For the water diaries, we focused on these water-stressed areas, thus,

Table 2. Characteristics of the 120 Water Diary Households Based on Survey Data

Household Size	Average — 4.3; Standard Deviation — 1.6
Wealth distribution	32% Extreme poor 39% Poor 22% Middle 7% Rich
Percentage of households involved in a given livelihood activity	58% Agriculture 41% Casual labor 32% Small business 12% Salaried jobs
Religion	62% Muslim; 38% Hindu
Tubewell ownership	38% own a private tubewell
Homestead pond	70% own/have access to a family pond within their homestead area
Storage container	18% have a storage container of 200-L or more capacity

restricting our sampling frame to 691 households across nine mouzas (Tier-5 administrative boundary) in the southern part. We divided these households into six categories based on their calculated "wealth status" and reported "concerns for water", with "water is costly" and "water is unsafe to drink" considered as proxy indicators of affordability and quality, respectively. We randomly selected 25 households from each of the four main categories (Poor + costly, Poor + unsafe, Non-poor + costly, Non-poor + unsafe) and 10 households to each of the two other categories. An additional 30 households, five from each category, were selected for the back-up list.

Training and implementation

Training households to complete the diaries and motivating them to participate in a year-long study was a crucial aspect of this study. From each of the selected households, an adult male and female (usually the household head and his spouse) were invited to attend a two-hour training session. It was important to invite two people to ensure consent and cooperation among household members, and avoid challenges related to illiteracy. If any of the pre-selected households were unavailable or unwilling to attend the training, we selected another household from a back-up list. We conducted the trainings in small groups of 10 households (20 participants), trying to ensure that households of similar wealth status and education level were trained together, so that all participants could feel comfortable within cultural norms. Households were given hands-on training on how to complete the diaries, followed by a one-week pilot study.

The main study commenced on 28 April 2018 and was completed after 52 weeks. Two enumerators visited the households every week to collect the completed diaries and discuss any noteworthy issues that may have affected water use or expenditure behavior during the week. The data was then submitted through ONA and regularly monitored by the lead author. Each household was given a non-cash remuneration worth Tk. 500 (USD 6) per month, mainly in the form of basic household food items like rice and cooking oil. We refrained from handing out cash during the study period as this would affect households' water use and expenditure patterns that we were trying to monitor. We believe that the compensation, constant engagement by the enumerators and the trust established with the study communities through previous research enabled us to successfully complete the study without any dropouts, although there were missing submissions for some households on particular weeks. Here, we present data from the first 18 weeks of the study.

Follow-up interviews

We inspected the water diary data regularly to monitor changes in behavior. After three months from the start, we purposively selected 10 households and talked to the responsible participant over phone to better understand the underlying drivers of their recorded behavior and clarify any queries regarding the data. This was followed by in-person interviews of another 15 households at the nine-month mark, ensuring quality control as well as getting qualitative insights into behavioral dynamics that cannot captured through other quantitative assessments.

Rainfall data

We installed an automated weather station [Oregon Scientific WMR300A Ultra-Precision Professional Weather System] in the polder to collect rainfall data at five-minute intervals. The data were downloaded by the local field team and stored for analysis.

3. Results

3.1. *Groundwater salinity and infrastructure development*

Hydrogeological analysis of the polder revealed spatial variation in salinity levels influencing water use behaviors. In the north and central parts of the polder, salinity in the shallow (< 100 m) and deep (> 100 m) aquifers was usually below 1,500 μS/cm and increased gradually towards the southern part of the polder where suitable deep aquifers were not found (Fig. 2). Availability of freshwater aquifers determined

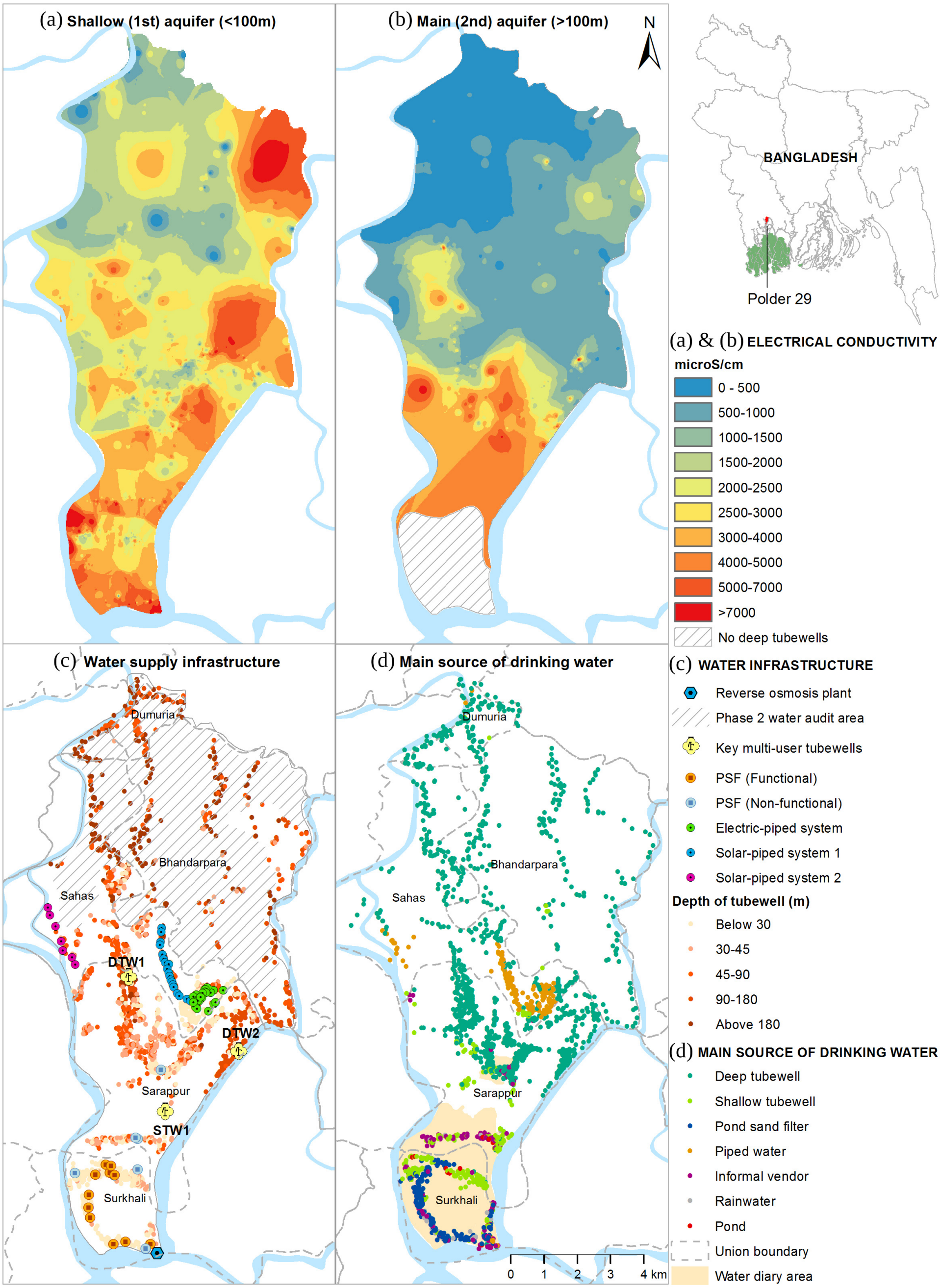


Figure 2. Groundwater Salinity, Water Supply Infrastructure and Main Sources of Drinking Water in Polder 29

Table 3. Costs and Service Levels Observed in Polder 29 in Relation to Distance from Freshwater Aquifers

Aquifer Availability	Water Supply Infrastructure	Capital Investments	Source of Funds	Household Recurring Costs	Service Level
Locally	Deep tubewells	Tk. 80,000 (USD 1,000)	Local government with 7% paid by users	Ad hoc maintenance costs	– Available when needed – Low salinity – Within or near premises
	Shallow tubewells	Tk. 20,000 (USD 250)	Privately funded by household		
Within 1-2 km	Electric-powered piped scheme	Tk. 1,000,000 (USD 12,500)	International donor, with 3% collective user contribution	Tk. 30 (USD 0.37) per month	– 1–2 hours a day – 15 households per tap – Near premises
	Solar-powered piped scheme	Tk. 7,00,000 (USD 8,750)	Local government	None, ad hoc repair costs often borne by local elites	– During daylight hours – No restriction on quantity, but pressure drops for taps at far end
Within 3-5 km	Pond sand filter	Tk. 80,000 (USD 1,000)	International donor, with 5% collective user contribution	None, except for voluntary contributions for replacing sand filter	– Quality depends on pond/filter maintenance – Turbidity increases during dry season
	Informal vendors	Cost of van or trawler; cost of containers	Private entrepreneur	Tk. 20–30 per 30-L container (USD 8–10 per m^3)	– Delivered to home/nearby main road – Order need to be placed beforehand
	Reverse osmosis plant	Tk. 1,000,000 (USD 12,500)	Private entrepreneur	Tk. 15 per 30-L container (USD 6.25 per m^3)	– Collected from source or transported by van (Tk. 5 extra) – Supply disrupted during power outages
	Rainwater harvesting	– Tk. 18,000 (USD 225) for 2,000 L storage tank – Homemade 50-L earthen pots	Privately funded by household	None, except for cleaning/rehabilitating pipes/roof before rainy season	– Depends on storage capacity – No salinity, but variable microbial contamination

the types and scale of investments required to provide drinking water services and consequently the costs borne by households (Table 3 and Fig. 2).

In areas with favorable hydrogeology, installation of deep tubewells was usually sufficient to have continuous access to a potable water source within or nearby one's premises. Our water audit data shows that in the past decade, the number of deep tubewells increased from 190 to 746, of which 73% were financed by the government with minor capital contributions from users. There were no operational costs, except for ad hoc maintenance and repair costs. For areas within 1–2 km of a suitable aquifer, small-scale piped water schemes were established, with capital and operation expenditures largely depending on the technical specifications of the systems. There were three piped-water schemes, one being financed by international donors and transferred to the community for operation and maintenance, and the other two installed by the government. As a limited amount of water was supplied at a scheduled time each day, households used the piped source mainly for drinking water, and sometimes cooking, and relied on private shallow tubewells for other domestic purposes.

In the southern part, high levels of salinity in the shallow aquifers, with some measurements greater than 3,000 μS/cm at depths below 100 m, and lack of suitable deeper aquifers, have forced people to rely on surface water for decades. In addition, the impact of flooding and erosion of polder banks have led to the loss of freshwater ponds, which has increased new infrastructure interventions and led to shifts in water use behavior over the past decade. Households in these areas, which include all our water diary participants, depend on multiple sources, including private shallow tubewells, pond sand filters, rainwater and informal vendors. In the past decade, the number of shallow tubewells across the 10 southern mouzas increased from 144 to 606, 94% of these were privately funded. Households mainly used these for domestic purposes, with only 15% reportedly being used for drinking. Rainwater harvesting was widely practiced and served as an important source of drinking water during the monsoon and post-monsoon seasons.

The water audit recorded 19 pond sand filters in the area, of which 11 were functional and served around 100–500 households each. All functional ones were installed in 2014–15, with capital expenditures financed by international donors. Maintenance involved changing the sand filters twice a year and regularly cleaning the sand beds. These were usually managed and financed by the pond owners with voluntary labor or cash contributions by users. User perception of taste and smell varied, with some pond sand filters being preferred over others.

> *"Zia's PSF is closer to my house, but the water has a foul odor. The pond is relatively smaller and the filtration layers were not*

> *designed properly. That's why I like Kartik's PSF; for a little extra cost, van drivers bring a few pitchers of water for me."*

More than half of the households in the southern area purchased water from informal vendors for varying durations throughout the year, and one-third used it as their main source of drinking water. These vendors sourced water from deep tubewells located 3–5 km further north [DTW1 and DTW2, Fig. 2(c)] and delivered it via vans (pedalled or motorized tricycles) or boats. The price of water ranged from Tk. 20–30 per 30-L (USD 8–10 per m^3), depending on remoteness of the household. In early 2018, a local entrepreneur installed a reverse osmosis plant and sold desalinated groundwater at Tk. 5 per 10-L (USD 6.25 per m^3), charging an additional Tk. 5 for home delivery.

3.2. *Temporal dynamics of water sources and expenditures*

Figure 2(d) shows the main sources of drinking water, although most households reported using two to three sources over the previous year. These are compared with water sources used for cooking, washing and bathing in Fig. 3, showing the high dependence on surface water for non-consumptive uses. The household survey data, however, presents a cross-sectional snapshot of water use behavior, the dynamics of which are revealed by the water diary.

Figure 4(a) shows the overall variations in weekly water expenditures of the 120 diary households in comparison to total expenditures over the 18-week period. Except for the spike during Eid-ul-Fitr, the largest Muslim festival, the mean total expenditures ranged between Tk. 2,000 and 2,500 (USD 25-31). Water expenditures, on the other hand, steadily declined from a median of Tk. 60 (USD 0.75) during the dry season to Tk. 0 during periods of heavy rain. While these costs

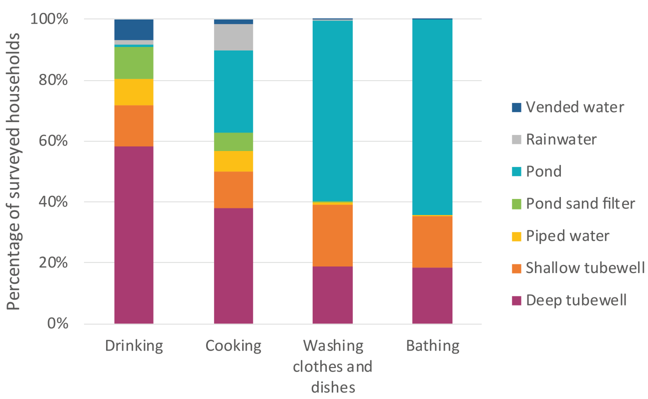
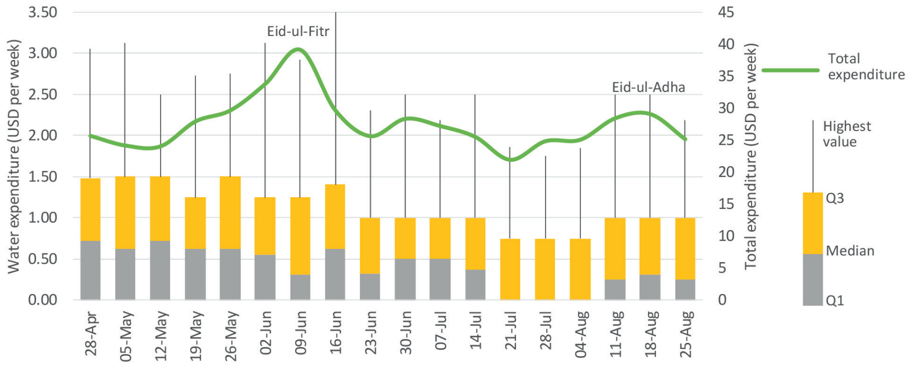
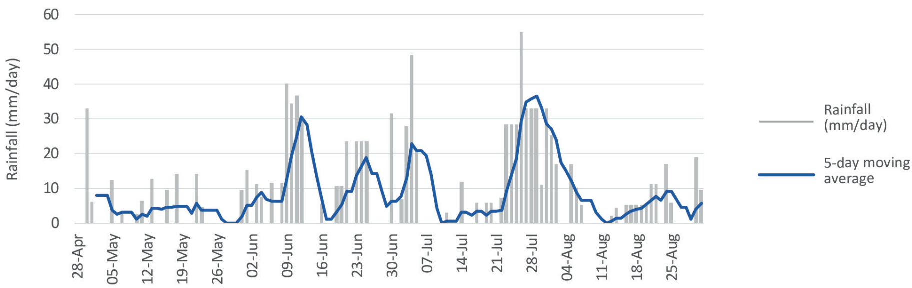


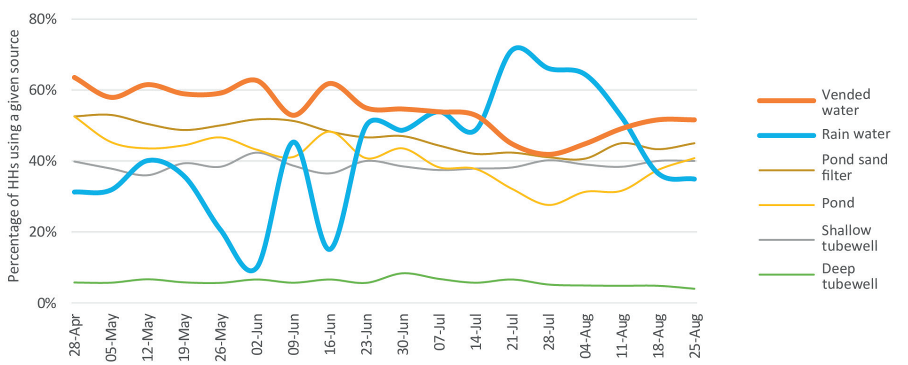
Figure 3. Main Sources of Water Used for Drinking and Domestic Purposes in Polder 29



(a) Weekly variations in water and total household expenditure



(b) Rainfall in polder 29



(c) Sources of water used by households for drinking and cooking

Figure 4. Household Water Expenditures in Relation to Total Expenditures, Rainfall and Sources used during the 18-Week Study Period

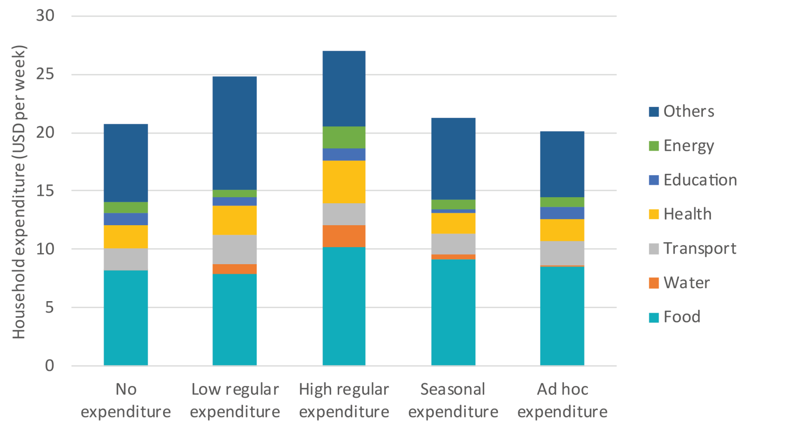
mainly included the price of vended water, about 16% of the households also spent an average of Tk. 4 per container for transporting pond water. The changes in expenditures also correspond to the variations in sources [Fig. 4(c)], with use of rainwater spiking and vended water dipping during the three weeks following 21st of July. It should be noted that Fig. 4(c) includes sources used for both drinking and cooking, and percentages reflect whether households have collected water from a given source at least once on that particular week.

3.3. *User profiles and behavioral clusters*

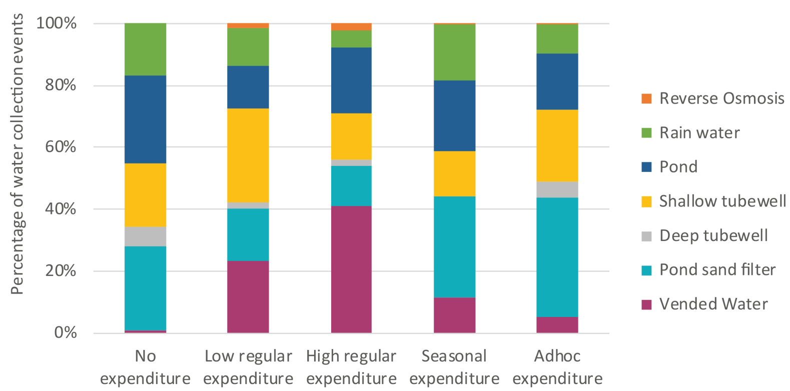
Households participating in the water diary had an average weekly expenditure of USD 28, of which 39% (USD 8.5) was spent on food, 11% (USD 2.4) on health, 9% (Tk. 2) on transport, 4% (USD 0.9) on education, 4% (USD 1) on energy, 2% on drinking water (USD 0.6) on water and 31% (USD 8.7) on miscellaneous items. Based on analysis of the weekly water expenditure, we identified five expenditure typologies — (1) "**no expenditure"**, whereby households mostly depended on pond sand filters, shallow tubewells and rainwater; (2) "**low regular expenditure"** households that purchased 20–60 L of vended water per week and spent about 2% of their total expenditures on water; (3) "**high regular expenditure"** households that purchased more than 100 L of vended water per week, corresponding to 5% of their total expenditures; (4) "**seasonal expenditure"** households that purchased vended water regularly during the dry season and subsequently switched to rainwater; and (5) "**ad hoc expenditure"** households that showed no discernible patterns purchased few containers of vended water when needed, for example, during special occasions. Figure 5 shows all the different sources of water accessed during the study period by household typology, along with the itemized household expenditures.

Applying the water expenditure classifications to food expenditure illustrates an order of magnitude relative difference and no consistent clustering (Fig. 6). The average food expenditure varies from 20% to 40% compared to 0–6% for drinking water. Of note, we find the "no expenditure", "low" or "ad hoc" water expenditure groups in a similar boundary range of food expenditure as the "high" expenditure group for drinking water. The common clustering for food expenditure may reflect the non-substitutability of these purchased items compared to drinking water where households can store rainwater or use other free alternatives. This further reflects that water is a composite good and user demands are likely to be differentiated by its quality, accessibility and costs.

While our sample size is not large enough to allow disaggregated statistical analysis on these expenditure typologies, descriptive data hint that wealth,



(a) Weekly household expenditures



(b) Water sources by expenditure typology

Figure 5. Water Sources* and Household Weekly Expenditures by Water Expenditure Typologies

Note: *No. of times a given source was accessed as a proportion of all water collection events (that is, total number of sources ticked each day by each household *number of days *no. of households in each typology).

infrastructure and groundwater quality influence these behavioral clusters (Table 4). For the "no expenditure" group, the relative number of non-poor households is lower than all other groups. They are less likely to have an improved water supply (26% having tubewell versus 87% having pond) and with greater distance to vended options (marketplace) have limited alternatives but to rely on local and poor-quality drinking water. However, the total household expenditures indicate this group spends a similar average amount to all other groups (Fig. 6).

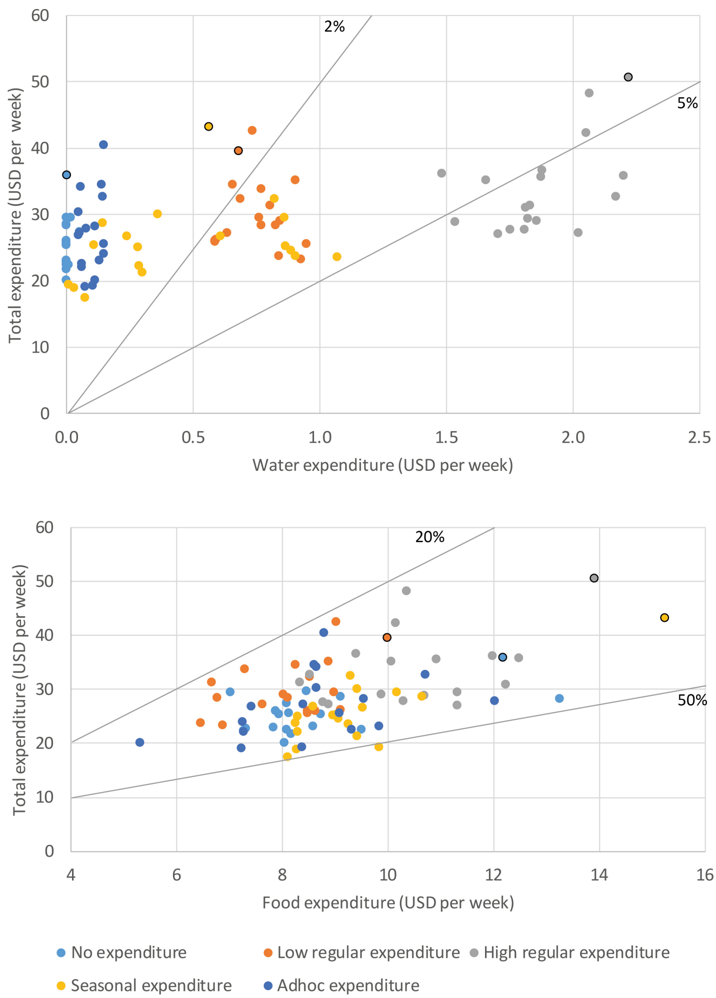


Figure 6. Water and Food Expenditures as a Proportion of Total Household Expenditures by Expenditure Typology (Each Dot represents the 5% Trimmed Mean Value of all Households in a Given Typology in a Given Week; Dots with Black Outline represent the Week of Eid-ul-Fitr)

More modest health expenditure features too but may be biased by people choosing not to treat illnesses; however, it points to a combination of physical isolation and social preferences not adequately explained by economic reasons alone for water affordability. In contrast, the "high expenditure" group are characterized by high numbers of non-poor (43%) living in high saline areas (100%), higher ownership of their own tubewell (42%) compared to an unimproved private pond (20%), and higher expenditure than all other groups, including investment in a basket of services including water, health and energy.

Table 4. Characteristics of Households by Expenditure Typologies

	Expenditure Typology				
	No Expenditure	Low Regular Expenditure	High Regular Expenditure	Seasonal Expenditure	Ad Hoc Expenditure
% of households ($n = 120$)	19%	25%	20%	20%	16%
Water expenditure (USD per week)					
% of total weekly expenditure spent on water (5% trimmed mean)	0.0%	3.5%	7.7%	2.1%	0.4%
Mean	0	0.7	1.9	0.5	0.2
Median	0	0.7	1.7	0.2	0
Std. Deviation	0.1	0.4	1.2	0.7	0.3
Minimum	0	0	0	0	0
Maximum	1.4	2.4	10.1	7.6	1.9
Location and water supply infrastructure					
Within 0.5 km of salinity hotspot	87%	93%	100%	96%	89%
Within 0.5 km of functional pond sand filter	57%	47%	38%	79%	68%
Own shallow/deep tubewell	26%	57%	42%	25%	32%
Private pond within premises	87%	67%	50%	58%	95%
Within 0.5 km of market place	9%	40%	29%	46%	21%
Wealth distribution					
Extreme poor ($n = 38$)	43%	20%	33%	37%	29%
Poor ($n = 47$)	43%	47%	25%	32%	46%
Middle ($n = 26$)	13%	23%	25%	21%	25%
Rich ($n = 9$)	0%	10%	17%	11%	0%

While these findings should not be over-interpreted, they suggest affordability behavior is not simply determined by relative wealth alone and the important ancillary factors of environmental context, broader expenditure preferences and differential access to other drinking water supplies of varying quality. For instance, despite being extremely poor, all four participating households from Jaliakhali mouza (southeast of the polder) exhibited high regular expenditure. River erosion and flooding over the past decades caused massive loss of land, forcing people to live on the embankment without any freshwater ponds or tubewells in the vicinity.

> *"My husband is partially paralyzed and hence, unemployed since the last five years. I work as a wage labour during the sowing and*

> *harvesting seasons and spend the rest of the year catching fish larvae from the river. But whether we can eat or not, we have to purchase water both for drinking and cooking. When we do not have any cash in hand, I walk all the way to Zia's PSF and fetch a couple of pitchers" — High regular expenditure typology, extreme poor household*

The fluctuating nature of rural income makes it a better predicator of expenditure compared to overall wealth status, particularly for those who depend on casual employment. This, in turn, affected the quality of drinking water one could afford, with further implications for health.

> *"Our daughter gets sick if she drinks the PSF water; so we purchase vended water from time to time. But for the past few weeks, there was no work in the village, we couldn't purchase water. Sometimes when we cannot go to the PSF or if it is not working, we drink pond water, after boiling or treating with alum." — Ad hoc expenditure typology, poor household*

Habits and individual preferences also drive inter- and intra-household differences in choice of sources, particularly for rainwater and desalinated water. Rainwater harvesting was widely practiced; while most households used 50-L earthen pots (locally known as "motkas"), about 14% had 200-L plastic drums and 3% had large 1,000–2,000-L storage tanks. Whether the rainwater was used for both drinking and cooking or for cooking only varied depended on how well individuals tolerated it. While some cited it as their most preferred source, others complained about coughs, bloating or diarrhoea resulting from drinking rainwater. About 20% of the diary households did not harvest rainwater at all.

> *"We normally drink rainwater in the monsoon and go to Kalar kol [STW1] during the dry season. But my son, who currently studies in Gopalganj [nearby district], cannot drink the water from any of these sources. So whenever he comes to visit, we buy water from Sarappur [DTW2]." — Ad hoc expenditure typology, poor household*

Similarly, although the desalinated water was comparatively cheaper than vended water and nearer for those at the southern end, many households refrained from using it. While some drank it and disliked the "sweet" and "caustic" taste, others never tried it due to the general scepticism about its quality. One participant explained, "*The vended water [from DTW2] is as natural as coconut water, but this [desalinated] water is treated with chemicals.*"

About 90% of the water collectors were women, usually fetching water twice during the day — once in the morning for cooking and later in the afternoon for drinking. As "no expenditure households" usually depended on pond sand filters, ponds and shallow tubewells, the women of these households walked longer distances and bore greater physical burden, compared to those in the low/high expenditure typologies that had vended water delivered to their doorstep. In fact, 67%, 73% and 50% of households in the no, seasonal and ad hoc expenditure typologies reported incidences of quarrels with neighbors or verbal abuse during water collection, in contrast to 8% and 0% of households in the low and high expenditure typologies. Similarly, illness and physical ability of the women in the household, in turn, affected the choice of source and water expenditure.

> *"My wife suffers from hypertension and heart problem and cannot go to fetch water herself. So we started to purchase water from DTW2, about two containers a week. We also hire a van to fetch water from the PSF, and the driver charges Tk. 20 per trip regardless of the number of containers. This is because the road connection is not good. Water is life, and we have to fetch water at any cost. Once the rains start, we won't need to spend as much." — Seasonal expenditure typology, middle class household*

4. Discussion

Global and national monitoring of affordability is in a predicament due to a lack of consensus on what it should encompass and a dearth of data to measure it. Our proposed definition departs from the narrow policy framing of designing the right price and non-price tools, dominant in the urban water sector, to a broader understanding of user behavior in relation to the spatio-temporal variation of sources used for drinking and domestic purposes. This reveals the diverse ways in which people value water for different uses compared to other basic goods and services protected by the human right, which, in turn, has implications for policy and infrastructure interventions.

4.1. *Social, economic and environmental aspects of affordability*

The complex water use behavior of the poor, as revealed by our empirical evidence, contributes to a nuanced understanding of affordability from social, economic and environmental perspectives. First, monetary measurements of affordability should be calibrated to the service levels accessed, as higher expenditures do not necessarily reflect better services. Paying for water is not a norm in rural Bangladesh, and many developing countries, and often a proxy for infrastructure or resource scarcity. Although the proportion of total household expenditure spent on water might be below 5% for most of our study households, it should be noted that these payments are only providing a limited quantity of drinking water, not the high service levels that urban residents in developed countries receive for comparatively lower costs. On the other hand, those incurring no costs might seem to be doing well from an affordability perspective, but do not even have access to basic services in practice (cf. Hutton and Andrés 2018). These findings resonate with the wider literature across Asia and Africa, where unreliable or absent public water provision cause certain households to pay high prices for small quantities of "packaged water" or bulk delivery through tanker trucks while others resort to easily accessible and free surface water sources (Price *et al.* 2019; Kelly *et al.* 2018; Raina *et al.* 2018). Moreover, these costs only reflect the direct recurrent financial costs and do not account for the opportunity costs of time spent, health risks and other aversion behaviors like treating water at home. Capital investments in drilling tubewells, purchasing storage tanks and contributions for infrastructure repair are also not included. Previous studies that included these components, estimated coping costs to be as high as 10–12% of household cash income (Gurung *et al.* 2017; Cook *et al.* 2016).

Second, reasons for non-consumption of paid (or better) sources often go beyond income constraints, and depend on a range of environmental and cultural factors, which, in turn, influence how people value the different attributes of water (that is, quality, cost and accessibility). The fact that five out of six households in our study sample purchase vended water either regularly or infrequently shows that people recognize the benefits of better quality but often choose to use other local sources of lower quality and costs. During the monsoon season, the marginal value of consuming vended water declines when availability of rainwater makes the high costs of vended water not worth the difference in quality. Such seasonal shifts are well documented in the literature, and raises health concerns particularly in contexts where people switch from low-risk to high-risk sources (Thomson *et al.* 2019; Pearson *et al.* 2016; Tucker *et al.* 2014). While surface water is hardly used for drinking purposes in rural Bangladesh, ponds have a special significance in rural culture and are preferred for cooking, washing and bathing. As noted by Kränzlin (2000), the high iron content in tubewell water stains clothes and dishes, with rice and lentils losing their texture, taste and color when cooked with this water. Thus, besides purchasing vended water for drinking, some also paid for transporting water from community ponds.

Poor households facing multiple demands on limited financial resources weigh the utility derived from different water sources against other essential needs. While water expenditures varied across typologies, food expenditures showed no general patterns, again highlighting the trade-offs in financial expenditures, access time and health risks. As rehearsed in the literature, this internalization of (potential) negative externalities of poor quality drinking water is not an uncommon strategy for rural households (Thomson *et al.* 2019). The economic implication is that drinking water is not a "normal" good where higher income results in higher consumption. The market structure of drinking water provision differs to food markets where public provision of multiple water sources, often at low or no cost, is not matched by private provision of food staples, which elicits a remarkably similar expenditure pattern across all households regardless of wealth or location. Other than the "regular high expenditure" group, most households spend less than 2% on drinking water. However, unlike food expenditure, cultural or environmental changes lead to peaks and troughs in behavior.

Third, the inconsistent market demand for an "improved service", as triggered by the weather, groundwater quality, festivals or other cultural norms, poses questions on the design and delivery of drinking water infrastructure, in terms of management responsibilities and recovery of operation, maintenance and capital depreciation costs. For instance, despite the lower cost and proximity of the reverse osmosis plant, many preferred the usual vended water from the deep tubewell, due to negative perceptions of the former's water quality. The demand for vended water was also highly seasonal and the quantity purchased per week fluctuated even among low and high regular expenditure typologies. Our evidence also suggests that user acceptance and sustainability of water supply infrastructure is partly driven by the extent of scarcity. The pond sand filters in Surkhali union, for instance, seemed to be well-maintained as they were installed in private ponds and served as lifelines for all. However, those installed in community ponds in Sarappur union were all non-functional after a few years, as easier access to alternative sources (including vended water) led to poor user demand and lack of maintenance.

4.2. *Policy lessons to improve water affordability*

While the above behavioral dynamics reveal the challenges of conceptualizing and monitoring affordability, the bigger question is how to translate these findings into policy responses to provide safe and affordable water services for the poor. Here, we present three recommendations.

First, the public policy axes linking policy design, independent regulation and service delivery need to be strengthened to promote institutional coordination. In Bangladesh, current national policy assimilates a regulatory role to monitor and measure performance leading to a conflict of interest in the collection and reporting of relevant and high-quality data. The reliance on occasional, high-quality national surveys provide incomplete and misleading information as this study has illustrated. The absence of "regulating up" is married by a lack of "regulating down". Service delivery at the operational level is informal and uncoordinated with limited accountability for the quality of services provided or their affordability. The significant acceleration in self-supply through private investments in shallow tubewells of uncertain water quality is a particular concern given high levels of salinity in the study area and the millions at risk from arsenic nationally (Hoque *et al.* 2019; Jamil *et al.* 2019). While drinking water access has risen to the meet the MDGs, there is evidence that the service targets for the SDGs, including affordability, will result in large relative reductions in national progress. The planning horizon to address these challenges is narrowing which promotes the need to invest in more coordinated institutional structures to ensure policy goals are achieved and sustained. This should not overlook the provision, monitoring and coordination of drinking water services for facilities such as schools, clinics and hospitals.

Second, financial sustainability will be greater by pooling public and private resources, including user payments. The emergence of widespread, private investments in shallow tubewells has implications for affordability and financial sustainability. The demand for more convenient water supplies reveals a significant source of private funds which might be pooled with government and donor investments if interests in service delivery can be aligned. Given evidence that water users will pay for higher-quality vended water, there is an opportunity to rethink the financial architecture of the scale and nature of water supply investments. The high population density of the coastal region may provide an economic case for centrally managed piped water systems, which would also help address the risks of increasing salinity in the long-term. Again, institutional investments and regulatory oversight will be required given the unsatisfactory performance of several pilot, piped water schemes in rural Bangladesh where operational oversight was limited or absent (World Bank 2016, 2018).

Third, environmental risks determine differential investment needs to ensure more equitable outcomes. The spatial heterogeneity in groundwater salinity in our study polder show that affordability is generally a concern in difficult hydroclimatic contexts, which require relatively complex infrastructure with higher capital and operational costs. Rainfall variability and water demand also present an important control for the design and demand for rural water services. Environmental scarcity influences demand profiles and water payment behaviors which regular monitoring can quantify and predict over time. Institutional coordination which regulates the roles and responsibilities of water sector stakeholders will promote a more equitable and sustainable approach. By monitoring and reporting independently to government and the public, the investment case will be more transparent and may attract new forms of performance-based funding as emerging evidence is witnessing in rural Africa (McNicholl *et al.* 2019).

5. Conclusion

Providing access to safely managed drinking water services to the unserved pockets of rural population in hydro-geologically difficult contexts is one of the key SDG challenges. Measures of water security derived from aggregate statistics mask the socio-spatial inequalities in access to safe and affordable water, particularly in contexts where investments in water supply infrastructure are not commensurate to the severity of scarcity. In the case of polder 29, snapshot data on the main sources and payments, would have indicated that rural households do not pay for water as tubewells, pond sand filters and rainwater do not have any regular operational costs. Detailed evidence derived from the water diaries, however, show the dynamics of user payments and the trade-offs between costs, quality and accessibility, which are in turn mediated by income flows, seasonality, groundwater quality, habits and cultural norms. Households in water-stressed regions incur significant water expenditures for relatively poor services, indicating that future interventions for improved services may be partly sustained through user payments. However, choice of technology, pricing and payment modes, and management responsibilities should be sensitive to social and cultural values and safeguard the interests of the poor and vulnerable. Monitoring and measuring affordable services is a hybrid challenge of achieving institutional coordination, independent regulation and financial sustainability. The least-cost logic of the MDG era is no longer fit for purpose to deliver and sustain the SDG services' ambition. Creating value rather than reducing costs is implicit in the water payment behaviors reported in this study. The public policy challenge is to design and test new institutional models that create and sustain value at scale to balance affordable and safe drinking water for all at a price society and users can bear.

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References

Amit, RK and S Sasidharan (2019). Measuring affordability of access to clean water: A coping cost approach. *Resources, Conservation and Recycling*, 141, 410–417, https://doi.org/10.1016/j.resconrec.2018.11.003.

BBS (2011). *Preliminary Report on Household Income and Expenditure Survey 2010*. Dhaka: Bangladesh Bureau of Statistics, Ministry of Planning.

Cook, J, P Kimuyu and D Whittington (2016). The costs of coping with poor water supply in rural Kenya. *Water Resources Research*, 52(2), 841–859, http://dx.doi.org/10.1002/2015WR017468.

Crow, B and J McPike (2009). How the drudgery of getting water shapes women's lives in low-income urban communities. *Gender, Technology and Development*, 13(1), 43–68, http://dx.doi.org/10.1177/097185240901300103.

DHS Program (2015). Questionnaires: Household, Woman's and Man's. *Phase 7 (2013–2018).* USAID.

Elliott, M, MC MacDonald, T Chan, A Kearton, KF Shields, JK Bartram and WL Hadwen (2017). Multiple household water sources and their use in remote communities with evidence from Pacific Island Countries. *Water Resources Research*, 53(11), 9106–9117, https://doi.org/10.1002/2017wr021047.

Elliott, M, T Foster, MC MacDonald, AR Harris, KJ Schwab and WL Hadwen (2019). Addressing how multiple household water sources and uses build water resilience and support sustainable development. *npj Clean Water*, 2(6), https://doi.org/10.1038/s41545-019-0031-4.

Foster, T and R Hope (2017). Evaluating waterpoint sustainability and access implications of revenue collection approaches in rural Kenya. *Water Resources Research*, 53(2), 1473–1490.

Gurung, Y, J Zhao, K Kumar, X Wu, B Suwal and D Whittington (2017). The costs of delay in infrastructure investments: A comparison of 2001 and 2014 household water supply coping costs in the Kathmandu Valley, Nepal. *Water Resources Research*, 53(8), 7078–7102, https://doi.org/10.1002/2016WR019529.

Hoque, SF and D Wichelns (2013). State-of-the-art review: Designing urban water tariffs to recover costs and promote wise use. *International Journal of Water Resources Development*, 29(3), 472–491, http://dx.doi.org/10.1080/07900627.2013.828255.

Hoque, M, P Scheelbeek, P Vineis, A Khan, K Ahmed and A Butler (2016). Drinking water vulnerability to climate change and alternatives for adaptation in coastal South and South East Asia. *Climatic Change*, 136(2), 247–263.

Hoque, SF, CH Quinn and S Sallu (2017). Resilience, political ecology, and wellbeing: An interdisciplinary approach to understanding social-ecological change in coastal Bangladesh. *Ecology and Society*, 22(2), 45, https://doi.org/10.5751/ES-09422-220245.

Hoque, SF and R Hope (2018). The water diary method — proof-of-concept and policy implications for monitoring water use behaviour in rural Kenya. *Water Policy*, 20(4), 725–743, http://dx.doi.org/10.2166/wp.2018.179.

Hoque, SF, R Hope, ST Arif, T Akhter, M Naz and M Salehin (2019). A social-ecological analysis of drinking water risks in coastal Bangladesh. *Science of The Total Environment*, 679, 23–34, https://doi.org/10.1016/j.scitotenv.2019.04.359.

Hossain, MS, K Roy and DK Datta (2014). Spatial and temporal variability of rainfall over the south-west coast of Bangladesh. *Climate*, 2(2), 28–46.

Hutton, G and L Andrés (2018). Counting the costs and benefits of equitable WASH service provision. In *Equality in Water and Sanitation Services*, O Cumming and T Slaymaker (eds.), Oxford, UK: Routledge.

Islam, MA, MA Akber and PK Ghosh (2017). Water quality of small-scale desalination plants in southwest coastal Bangladesh. *Water Science and Technology: Water Supply*, 18(5), 1606–1616.

Jamil, NB, H Feng, KM Ahmed, I Choudhury, P Barnwal and A van Geen (2019). Effectiveness of different approaches to arsenic mitigation over 18 years in Araihazar, Bangladesh: Implications for National Policy. *Environmental Science & Technology*, 53(10), 5596–5604, http://dx.doi.org/10.1021/acs.est.9b01375.

Kelly, E, KF Shields, R Cronk, K Lee, N Behnke, T Klug and J Bartram (2018). Seasonality, water use and community management of water systems in rural settings: Qualitative evidence from Ghana, Kenya, and Zambia. *Science of The Total Environment*, 628–629, 715–721, https://doi.org/10.1016/j.scitotenv.2018.02.045.

Kjellén, M (2000). Complementary water systems in Dar es Salaam, Tanzania: The case of water vending. *International Journal of Water Resources Development*, 16(1), 143–154.

Komarulzaman, A, ED Jong and J Smits (2019). Hidden water affordability problems revealed in developing countries. *Journal of Water Resources Planning and Management*, 145(4), 05019006, https://doi.org/10.1061/(ASCE)WR.1943-5452.0001051.

Kränzlin, I (2000). Pond management in rural Bangladesh: Problems and possibilities in the context of the water supply crisis. *Natural Resources Forum*, 24(3), 211–223.

Majuru, B, M Suhrcke and P Hunter (2016). How do households respond to unreliable water supplies? A systematic review. *International Journal of Environmental Research and Public Health*, 13(12), 1222.

Mattes, R, M Bratton, YD Davids and C Africa (2008). Afrobarometer: Round IV 2008 [merged 20 country dataset]. Cape Town, South Africa: DataFirst.

McNicholl, D, R Hope, A Money, A Lane, A Armstrong, N van der Wilk, M Dupuis, A Harvey, C Nyaga, S Womble, D Favre, J Allen, J Katuva., T Barbotte, E Buhungiro, P Thomson and J Koehler (2019). Performance-based Funding for Reliable Rural Water Services in Africa. Working Paper 1. Uptime consortium.

Opschoor, JH (2006). Water and merit goods. *International Environmental Agreements: Politics, Law and Economics*, 6(4), 423–428.

Pearson, AL, A Zwickle, J Namanya, A Rzotkiewicz and E Mwita (2016). Seasonal shifts in primary water source type: A comparison of largely pastoral communities in Uganda and Tanzania. *International Journal of Environmental Research and Public Health*, 13(2), 169, http://dx.doi.org/10.3390/ijerph13020169.

Price, H, E Adams and RS Quilliam (2019). The difference a day can make: The temporal dynamics of drinking water access and quality in urban slums. *Science of the Total Environment*, 671, 818–826, https://doi.org/10.1016/j.scitotenv.2019.03.355.

Raina, A, Y Gurung and B Suwal (2018). Equity impacts of informal private water markets: Case of Kathmandu Valley. *Water Policy*, https://doi.org/10.2166/wp.2018.138.

Rogers, P, R Bhatia and A Huber (1998). *Water as a Social and Economic Good: How to Put the Principle into Practice*. Stockholm: Global Water Partnership.

Rogers, P, R De Silva and R Bhatia (2002). Water is an economic good: How to use prices to promote equity, efficiency, and sustainability. *Water Policy*, 4(1), 1–17.

Savenije, HHG and P van der Zaag (2002). Water as an economic good and demand management paradigms with pitfalls. *Water International*, 27(1), 98–104, https://doi.org/10.1080/02508060208686982.

Shammi, M, MM Rahman, MA Islam, M Bodrud-Doza, A Zahid, Y Akter, S Quaiyum and M Kurasaki (2017). Spatio-temporal assessment and trend analysis of surface water salinity in the coastal region of Bangladesh. *Environmental Science and Pollution Research*, 24(16), 14273–14290.

Srinivasan, V, SM Gorelick and L Goulder (2010). Factors determining informal tanker water markets in Chennai, India. *Water International*, 35(3), 254–269, https://doi.org/10.1080/02508060.2010.487931.

Sultana, S, K Ahmed, S Mahtab-Ul-Alam, M Hasan, A Tuinhof, S Ghosh, M Rahman, P Ravenscroft and Y Zheng (2014). Low-cost aquifer storage and recovery: Implications for improving drinking water access for rural communities in coastal Bangladesh. *Journal of Hydrologic Engineering*, 20(3), B5014007.

Thomson, P, D Bradley, A Katilu, J Katuva, M Lanzoni, J Koehler and R Hope (2019). Rainfall and groundwater use in rural Kenya. *Science of the Total Environment*, 649, 722–730, https://doi.org/10.1016/j.scitotenv.2018.08.330.

Tucker, J, A MacDonald, L Coulter and RC Calow (2014). Household water use, poverty and seasonality: Wealth effects, labour constraints, and minimal consumption in Ethiopia. *Water Resources and Rural Development*, 3, 27–47, https://doi.org/10.1016/j.wrr.2014.04.001.

Tuong, TP, E Humphreys, ZH Khan, A Nelson, M Mondal, M-C Buisson and P George (2014). *Unlocking the Production Potential of the Polders of the Coastal Zone of Bangladesh through Water Management Investment and Reform* [Online]. CGIAR Challenge Program on Water and Food, http://r4d.dfid.gov.uk/pdf/outputs/WaterfoodCP/CPWF-Ganges-basin-messages-final.pdf [Accessed 20 November 2014].

UN (2010). Resolution adopted by the General Assembly on 28 July 2010 — The human right to safe drinking water and sanitation. *A/RES/64/292*. Geneva, Switzerland: Office of the United Nations High Commissioner for Human Rights (OHCHR).

UNICEF/MICS (2017). Multiple Indicator Cluster Surveys (MICS). *Round 6*. UNICEF.

Van der Zaag, P and HH Savenije (2006). *Water as an Economic Good: The Value of Pricing and the Failure of Markets*. UNESCO-IHE.

Whittington, D, DT Lauria, DA Okun and X Mu (1989). Water vending activities in developing countries — A case of Ukunda, Kenya. *International Journal of*

Water Resources Development, 5(3), 158–168, https://doi.org/10.1080/07900628908722429.

Whittington, D, J Briscoe, X Mu and W Barron (1990). Estimating the willingness to pay for water services in developing countries: A case study of the use of contingent valuation surveys in southern Haiti. *Economic Development and Cultural Change*, 38(2), 293–311.

WHO/UNICEF (2017). Progress on drinking water, sanitation and hygiene — 2017 update and SDG baseline. Geneva, Switzerland: World Health Organization (WHO) and the United Nations Children's Fund (UNICEF) Joint Monitoring Programme (JMP).

World Bank (2016). *Private Sector Provision of Water and Sanitation Services in Rural Areas and Small Towns: The Role of the Public Sector.* Washington DC: Water and Sanitation Programme (WSP) of the World Bank.

World Bank (2018). *Implementation Completion and Results (ICR) Report for Bangladesh Rural Water Supply and Sanitation Project*. Dhaka, Bangladesh: The World Bank.

WHO/UNICEF (2019). Progress on household drinking water, sanitation and hygiene 2000–2017. Special focus on inequalities. New York, USA: World Health Organization (WHO) and the United Nations Children's Fund (UNICEF) Joint Monitoring Programme (JMP).