



# Pump-Priming Payments for Sustainable Water Services in Rural Africa

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**Summary.** — Locally managed handpumps provide water services to around 200 million people in rural Africa. Handpump failures often result in extended service disruption leading to high but avoidable financial, health, and development costs. Using unique observational data from monitoring handpump usage in rural Kenya, we evaluate how dramatic improvements in maintenance services influence payment preferences across institutional, operational, and geographic factors. Public goods theory is applied to examine new institutional forms of handpump management. Results reveal steps to enhance rural water supply sustainability by pooling maintenance and financial risks at scale supported by advances in monitoring and payment technologies.

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*Key words* — drinking water security, handpumps, public goods, payment behavior, Africa, Kenya

## 1. INTRODUCTION

An enduring puzzle in achieving progress toward universal and reliable water service delivery in Africa is overcoming barriers to sustainable water user payments for community-managed handpumps (Harvey & Reed, 2004). The nonfunctioning of one third of the handpumps in rural Africa (RWSN, 2009) has resulted in an uncertain return on the USD 1.2–1.5 billion of infrastructure investments in the last two decades (Baumann, 2009). Increasing water service coverage has failed to translate into a guarantee of reliable service delivery (Hope & Rouse, 2013; Therkildsen, 1988; Thompson *et al.*, 2001). The long repair times that contribute to high handpump failure rates in rural Africa are essentially associated with weak payment systems (Foster, 2013; Harvey, 2007; RWSN, 2009). Community management of water services has been widely identified as a dominant but failing model in rural water service delivery in Africa (Bannerjee & Morella, 2011; Hope, 2014) with growing evidence that improved payment systems promote handpump sustainability (Foster, 2013). Increasing opportunities to exploit the new, inclusive, and low-cost mobile infrastructure offer new but untested approaches to accelerate and maintain reliable water services for the 273 million rural Africans without improved water coverage (Hope, Foster, & Thomson, 2012; WHO/UNICEF, 2014). The policy implications are relevant to the post-2015 debate on the Sustainable Development Goals (SDGs) and may increase momentum for universal and sustainable water services within the framework of the Human Right to Water and Sanitation (UNGA, 2010).

In this paper, three major barriers to achieving regular rural water user payments to promote financial sustainability are identified and empirically examined. First, *institutional barriers* indicate that the organizational structure of the user group influences the regular collection of user fees from all handpump users. Second, due to *geographic barriers*, handpump density in certain areas can negatively impact payment behavior. Third, *operational barriers* frequently cause handpumps to remain unrepaired for an extended period, discouraging users from paying, as the source is considered unreliable. This constitutes a vicious cycle with the risk of long-term failure in service delivery.

The paper makes novel contributions to the literature by (a) drawing on unique hourly data on observed handpump usage

over a 12-month period, (b) relating water use estimates to current and future payment preferences, and (c) applying public goods theory to community water management structures to examine new approaches to overcome financial sustainability barriers. In conclusion, an output-based payment framework is outlined as a potentially replicable approach to support the Government of Kenya's and the global drive to universal and reliable water services.

## 2. CONTEXT

### (a) *The rural water challenge*

Since the latter years of the Decade of International Drinking Water Supply and Sanitation, 1981–90, community management of rural water supply has been advocated by international organizations, governmental and nongovernmental alike (Briscoe & de Ferranti, 1988; Carter, Tyrell, & Howsam, 1999; Churchill *et al.*, 1987; Harvey & Reed, 2004; Jiménez & Pérez-Foguet, 2010; Therkildsen, 1988; Whittington *et al.*, 2008). The empowerment of communities is based on the principles of participation, decision-making, control, ownership, and cost-sharing (Briscoe & de Ferranti, 1988; Lockwood, 2004). However, despite the positive characteristics of community management, operations and maintenance have barely improved (Blaikie, 2006; Lockwood, 2004). Failure is largely blamed on poor planning and service delivery (Carter, Harvey, & Casey, 2010; Carter *et al.*, 1999;

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The World Bank Water Demand Research Team, 1993), limited community financing (Carter *et al.*, 2010; Harvey, 2007; Harvey & Reed, 2004; Skinner, 2009) and shortcomings in the institutional design of management models (Sara & Katz, 2010; Whittington *et al.*, 2008). Consequently, rural water supplies are in danger of falling into a spiral of decline in the post-construction phase (Rouse, 2013). Adoption of simplified infrastructure asset management principles can increase cost-effectiveness and reduce interruptions in service (Boulenouar & Schweitzer, 2015). While maintaining the community-based model, new approaches are therefore required which acknowledge the communities' inability to maintain their water supply without support in the long term (Harvey & Reed, 2004; Lockwood, 2004).

(b) *Deconstructing the rural water challenge*

(i) *Institutional choices*

Institutions, "the humanly devised constraints that structure political, economic and social interaction" (North, 1991, p. 97), evolve over time and are adapted to specific human needs. This study focuses on those institutions that have been created for the management of groundwater resources, and specifically for managing handpumps in rural areas. Due to its delineation of management systems along the lines of rivalry of consumption and exclusion, the theory of public goods, building on Samuelson (1964), is chosen for analyzing the institutional design at community level. Two versions of the theory are applied – Ostrom's (1990) understanding of common pool resources (CPRs) and Buchanan's (1965) definition of club goods. While the nonexcludable and rivalrous CPR is a "natural or man-made resource system that is sufficiently large as to make it costly... to exclude potential beneficiaries from obtaining benefits from its use" (Ostrom, 1990, p. 30), the excludable and nonrivalrous club good determines a membership margin at "the size of the most desirable cost and consumption arrangement" (Buchanan, 1965, p. 2). Ostrom (1990) defines principles for robust common pool resource institutions, requiring clear institutional rules and solution mechanisms. Buchanan's (1965) criteria for the management of club goods expand on the public-private spectrum and emphasize consumption/ownership/membership arrangements. Consumption-sharing models, tariffs, and membership levels are determined by the local communities according to their particular requirements to prevent "congestion".

If adapted to handpump management, the institutional design is a response to varying group preferences with implications for payment behavior: Some groups prefer higher payments at household level to be able to limit abstraction levels by reducing the number of users (with the tendency of organizing themselves as "handpump clubs" with a more exclusive membership); others prefer lower individual payments but with higher membership numbers to ensure that enough money is available to pay for maintenance bills (acting more as common pool resource groups). Agrawal and Gibson suggest that communities must be examined "by focusing on the multiple interests and actors within communities, on how these actors influence decision-making, and on the internal and external institutions that shape the decision-making process" (1999, p. 629). It is beyond the scope of this research to analyze these aspects, as the focus is on the group's collaborative decision-making on willingness-to-pay. However, it is acknowledged that the institutional structure of user groups may change in response to internal power relations or external factors, such as population growth or increasing aridity. The latter may reinforce a potential tendency toward excludability,

which some groups pursue to counteract congestion and over-abstraction. Only by understanding the institutional design of rural user groups can payment models be adapted to local needs.

(ii) *Geographic challenges and infrastructure decisions*

A problem specific to sub-Saharan Africa is that low population density encourages broad spatial distribution between handpumps and the clustering of systems around existing infrastructure (Harvey & Reed, 2004). This implies high opportunity costs for users, often women, who have to walk long distances to the next-best pump alternative when their usual pump breaks (Van Houweling, Hall, Diop, Davis, & Seiss, 2012). As the most urgent demand tends to occur in areas of widely scattered pumps, geography appears to have an important impact on payment behavior. Another geographical aspect is the distance of handpumps to spare parts outlets, which impacts the reliability of service delivery (Harvey & Reed, 2006). Similarly, Foster (2013) found that distance from the district/county capital city is significantly associated with nonfunctionality of handpumps in a study covering 25,000 pumps across three countries in sub-Saharan Africa.

(iii) *Demand and service level*

Since the Dublin Principles of 1992 (ICWE, 1992), the demand-responsive approach has provided the template for most rural water supply services. It focuses on both financial and managerial sustainability through participatory planning, informed choices, community management, and cost recovery or cost-sharing arrangements (Sara & Katz, 2010). It involves households in the choice of technological and institutional arrangements, while requiring them to pay for the service (Whittington *et al.*, 2008). According to this approach, communities rather than donors or governments make informed choices about the preferred service level, which is reflected in their willingness-to-pay. They also decide on service delivery mechanisms, operation and maintenance of services as well as the management of and accounting for funds and the degree to which the private sector is involved (Deverill, Bibby, Wedgwood, & Smout, 2001; Lockwood, 2004; The World Bank Water Demand Research Team, 1993). To best serve the users' preferences, economic and social constraints are considered in the user group's institutional design. These comprise informal constraints, including sanctions, taboos and codes of conduct, as well as formal rules (North, 1991), including property rights.

However, in practice the success of the demand-responsive approach can be thwarted through lack of acceptability, feasibility, or the limited capacity of communities to sustain the chosen option (Harvey & Reed, 2004; Skinner, 2003). The failure of communities to speedily repair their handpumps results in longer term nonfunctionality causing discontent among water users, who then look for alternatives and refrain from paying fees – a process that leads to a downward spiral in water services (Cross & Morel, 2005). To counter such a downward development, supra-communal management options should be considered for rural water services recognizing the critical importance of the interface between a community-based model and the local community it is meant to serve (Blaikie, 2006). Bannerjee and Morella (2011) demonstrate that central, regional, or local governments play a dominant role in all aspects of energy, road, and water infrastructure provision across Africa. However, it is only in the area of providing and maintaining water services where local communities are given a leading role – precisely the area

where [Bannerjee and Morella \(2011\)](#) identify most challenges. Alternatives such as private rural water service providers are promoted by [Kleemeier and Narkevic \(2010\)](#), who argue for private firms or individuals to receive long-term government-let contracts to design, build or rehabilitate, operate, and maintain water supplies within a defined geographical area.

### 3. STUDY SITE AND METHODOLOGY

#### (a) *Study site*

The study site comprises the Kyuso District, Kenya, (38° 10'E, 0° 35'S; 660–880 m elevation; 2,446 km<sup>2</sup>) located 267 km east of Nairobi with a population of 26,848 households ([Government of Kenya, 2009](#)). The population is almost entirely rural (99%) with 62% living in absolute poverty – one of the highest rates in Kenya ([KIHBS, 2006](#)). Frequent droughts exacerbate the area's poverty by adversely affecting the farmers' major source of income from crop yields and live-stock ([Office of the Prime Minister, 2009](#)). The mean annual temperature ranges between 26 °C and 34 °C. The bi-modal rainfall pattern, with long rains from March to May and short, heavier rains from October to December, drives hand-pump usage patterns with pumps more heavily used in the dry season. An estimated 70% of households rely on unimproved sources, such as ponds and rivers ([Office of the Prime Minister, 2009](#)), which have negative health implications. Of the remainder, 30% use wells or boreholes, which include 66 Afridev handpumps installed over the last 20 years (see [Figure 1](#)).

As part of Oxford University's "Smart Handpumps Project" these 66 pumps have been equipped with mobile-enabled transmitters reporting hourly pump usage to a central server via SMS ([Thomson, Hope, & Foster, 2012a](#)). About half the pumps are "actively managed" and send data automatically to the server. The others are "silent" with usage data being recorded for later analysis, while disruptions are monitored by users through crowd-sourcing ([Thomson, Hope, & Foster, 2012b](#)). Following water user committee (WUC) approval, robust stickers were attached to the silent pumps, providing contact information for users to call in case of breakdowns. When a handpump failure is noted, a mechanic is dispatched immediately to assess and fix the problem. Consistent with [Marks and Davis' \(2012\)](#) finding that reliable and regular access to the water source (a piped system in their case) significantly enhances community members' sense of ownership, this service was provided for free on the assumption that a good service had to be demonstrated in order to establish the maintenance model was viable and build trust that a faster repair service was feasible. This study examines the willingness-to-pay preferences of rural water users after experiencing the service for a 1-year trial period. The automated monitoring technology provides unprecedented information on handpump usage thus creating the basis for institutional and financial progress in rural water supply.

During 2013, the year of the study, handpumps broke two times per year on average; however, the range was between zero and 11, which led to a high variation in repair cost ranging from USD 54 to USD 649 per pump per year with an average repair cost of USD 62 ([Oxford/RFL, 2014](#)).

The unpredictability of pump failures and the variation in cost indicate that pooling payments across the District may afford the users higher security against water risks. Therefore, a supra-communal management structure was proposed by

the "Smart Handpumps Project" to explore a mobile payment platform that could build on high (73%) use of mobile money services in Kyuso District ([Oxford/RFL, 2014](#)). In such a scheme all members would contribute monthly cash payments to be deposited into a designated mobile payments (M-PESA) account by the water user committee treasurer. SMS messages would subsequently inform users that their fees have been received and deposited into the account, thus creating greater transparency and accountability for the user group. If pooled, even costly repairs can be covered following an insurance-based approach.

During handpump downtimes in the dry season, 77% of households report using a nonpump alternative drinking water source, whereas 64% use such sources during the wet season, which may cause seasonal shifts in pump revenue. Two major alternative sources in the area are Kiambere water pipeline and Ngomeni rock catchment, which provide piped water through kiosks (USD 0.02/20 liters) for people living in the limited service area.

#### (b) *Methodology*

##### (i) *Sampling framework and hypotheses*

Four factors are hypothesized to be major influences on demand for a certain service level of rural water supply: hand-pump service reliability, handpump density, water use, and water quality. The first three factors form the basis of the sampling framework and the analysis in this paper. Water quality is not examined here but is a goal of further research in the site. The institutional framework depicts an organization of users whose preferences determine payment level and mode in order to achieve a certain service level supply ([Figure 2](#)). The institutional design of the water user group is a key factor in achieving regular rural water user payments as it constitutes a link between the individual user and the supra-communal management structure in terms of personal involvement in the user group and willingness-to-pay.

The following four hypotheses are tested in this study to analyze the barriers to rural water user payments.

##### (1) Institutional design and management

The institutional design of the user group – with a tendency to either a "handpump club" or a common pool resource group – is, *inter alia*, an expression of its preferences, and it influences payment behavior. Therefore applying public goods theory to communal management of handpumps provides a useful framework of analysis. Buchanan's theory of clubs (1965) is concerned with the highest attainable utility for the individual with respect to the optimum size of groups. Too large a number of handpump users may implicate long queuing for water or cause over-abstraction, which represents a form of congestion in Buchanan's terminology, as the consumption of the sustainable quantity of the good may be exceeded. Some user groups are therefore expected to opt for an institutional design with higher levels of excludability, although this requires higher payment levels by individual users. Thus, user groups are characterized by different levels of physical, financial, and social excludability. Hence, we hypothesize that the institutional design of the user group affects willingness-to-pay levels (H<sub>1</sub>).

As water abstraction levels are an expression of demand – with higher levels being more likely to lead to "congestion" – this study suggests that the organizational structure of the user group and the associated willingness-to-pay are linked to handpump usage. It is tested whether handpump user groups with a high water demand are prone to opt for more exclusive management arrangements (H<sub>2</sub>).

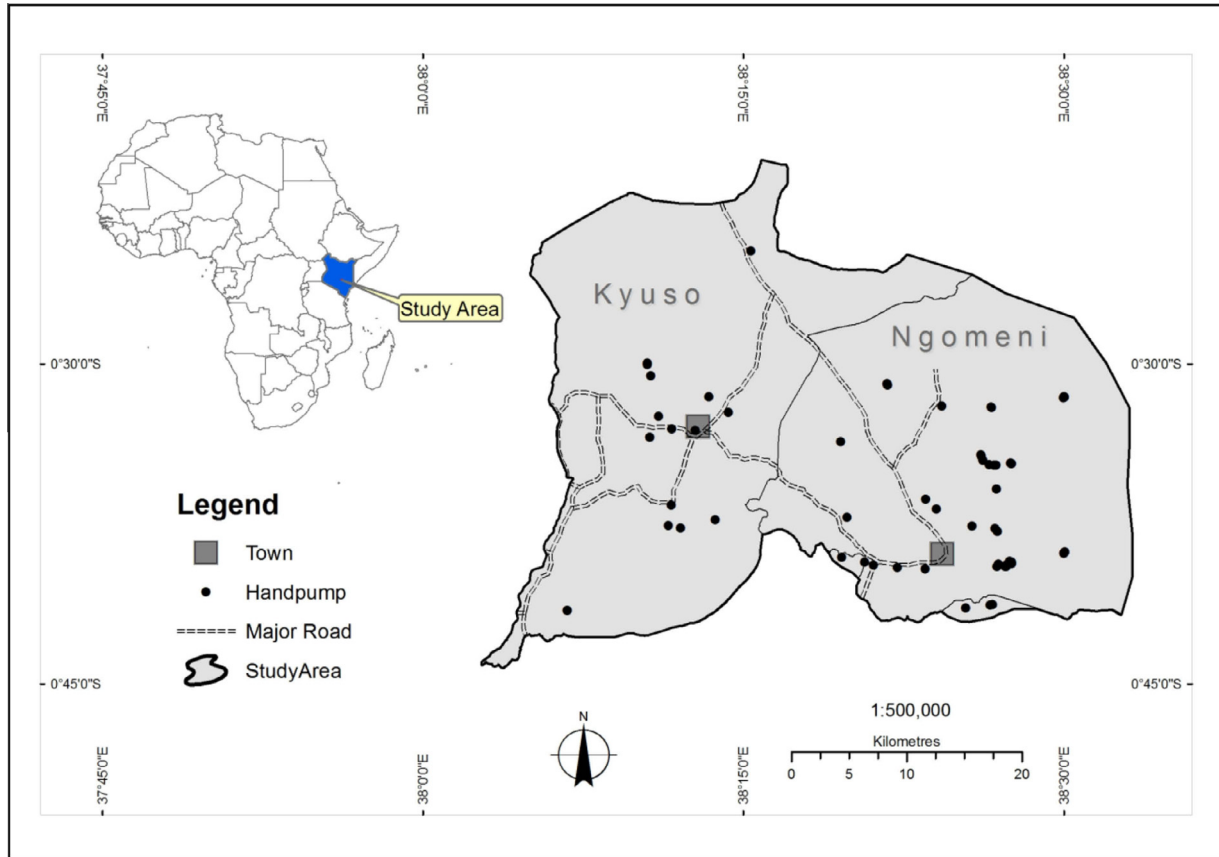


Figure 1. Map of study area.

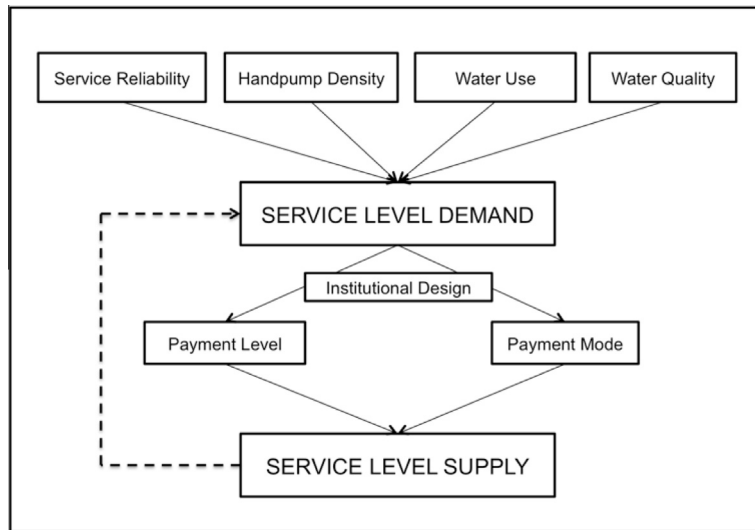


Figure 2. Framework of analysis.

(2) Handpump density

A household's willingness-to-pay depends on existing alternatives (The World Bank Water Demand Research Team, 1993), as people attribute a high value to the time spent on collecting water (Whittington, Mu, & Roche, 1990). Briscoe (1996) argues that opportunity costs are substantially higher, all other things being equal, in arid, high-demand areas. Moreover, he points out that the existence of opportunity costs can

give rise to conflicts among users, unless institutional mechanisms exist which recognize these costs. The influence of existing alternative handpump sources on willingness-to-pay is therefore tested with the third hypothesis: Payment levels are related to handpump density; higher payments occur at more isolated pumps (H<sub>3</sub>).

Thus, the sampling framework included three classes of handpump density: single pumps, pairs, and clusters. Single

pumps have no alternative pump closer than 1.5 km; pairs have one alternative pump closer than 1.5 km and at times share management arrangements; clusters have three or more pumps within a radius of 1.5 km. This definition was derived from two pumps with the longest distance between them (1.3 km) but shared management.

### (3) Maintenance service reliability

According to Narayan, “a service can be considered reliable when it has a high probability of being available in the quality, quantity, and at the time required. Since attaining reliability has a financial cost, the standard acceptable to users will vary depending on the particular context” (1993, p. 33). Thus reliability of the maintenance service and financial sustainability are interdependent (The World Bank Water Demand Research Team, 1993). This insight leads to the fourth hypothesis that payments are contingent on service delivery ( $H_4$ ).

### (ii) Ethics statement

Ethical permission was granted from Oxford University’s Central University Research Ethics Committee and the National Council of Science and Technology, Kenya, based on the following consent procedure. All respondents were adults (over 18 years of age) who provided oral consent to voluntarily participate. Oral consent is the local, socio-cultural norm and accepted practice. At the beginning of each focus group discussion (FGD), the following criteria were confirmed: (a) the respondents’ membership of the handpump user group, (b) summary of the project purpose with government support, (c) project contact name and mobile number, (d) voluntary exercise, and (e) anonymity.

### (iii) Data collection

Data collection comprised three linked components led by Oxford University’s Smart Handpumps Project: (1) a baseline survey in 2012, (2) handpump monitoring using mobile transmitters (January to December 2013), (3) focus group discussions in June/July and November/December 2013. Oxford/RFL (2014) provides details on the first two components which are briefly discussed here to contextualize the findings from the third component, which affords new knowledge and insights linking water use with payment behaviors.

#### (1) Baseline survey

In July 2012, after training and piloting the instrument, a team of five experienced enumerators (four women, one man) administered a revised baseline survey in either the local language Kikamba (54%) or Kiswahili (46%), according to the respondent’s preference. A random sample (32%) of the universe of handpumps was selected and interviews were conducted with any person who drew water for their household on the day of sampling ( $n = 118$ ) (Hope, 2014; Oxford/RFL, 2014). The majority of sampled respondents were female (64%) with an average age of 41 years. The informants represented households with an average of 5.3 members.

Before the handpump maintenance trial started in January 2013, 56% of users paid for water in some way with the majority of payments (80%) coordinated by the water user committee. Payment for water has traditionally been collected as monthly fees (31.5%), when the pumps break (26.6%), per 20-liter jerrycan (19.3%), as membership fees (16.7%) or by livestock usage (8.9%) (Oxford/RFL, 2014). However, only 24% of users had sufficient funds saved when the pump broke. For the other groups, on average 18 days were required to raise funds, with a range of 1–180 days. The average time from pump breakage to repair was 27 days (Oxford/RFL, 2014).

#### (2) Handpump monitoring

As described above, the water data transmitters installed in all 66 handpumps either send or record hourly information on handpump usage and associated volumetric use (Thomson *et al.*, 2012a), depending on which arm of the study they are in. These data are used for correlation with willingness-to-pay levels and institutional design.

#### (3) Focus group discussions

To inclusively and reflexively explore community preferences to institutional barriers and opportunities, focus group discussions (FGD) were administered by two Kikamba native speakers supported by the lead author. A total of 63 field days were spent in 66 handpump communities in the periods June/July and November/December 2013. Enumerators co-developed, piloted, and refined the discussion framework subject to the composition (gender, size, location) of the focus groups. In doing so, they adhered to a structured process of (a) pre-planning discussion purpose and delivery (lead and rapporteur), (b) community liaison to timetable the meeting, (c) community discussion, and (d) debrief and write-up on the same day (see Table 1).

In the first phase 32 of the 66 handpumps were systematically sampled according to the following criteria: density category, experience of service and level of usage. In round two the remaining 34 handpumps were sampled. Follow-up focus groups were conducted at the community pumps. In the first round groups were divided by gender. This methodology was chosen because women might be reluctant to state their own preferences in the presence of men (The World Bank Water Demand Research Team, 1993). The follow-up was conducted in mixed groups because groups had met in the interim to discuss the proposals. Participants ranged in age from 20 to 80 years and represented both users with and without mobile phones. FGD methods included mapping the water user community with alternative sources, a seasonal calendar, and a timeline on handpump maintenance (Narayanamy, 2009).

A group willingness-to-pay activity was designed to identify how much each water user group would be willing to pay for a continuation of the existing maintenance service at the conclusion of the free maintenance trial in December 2013. No maintenance service standard was guaranteed as the aim was to understand individual community preferences based on their experience of the service. Community experiences varied from no maintenance response, as 30% of handpumps did not fail in 2013, through to communities having had their handpump repaired on at least one occasion. A willingness-to-pay design was chosen as a means to initiate community debate on payments collectively. Without rehearsing the extensive literature critiquing willingness-to-pay studies conducted with individuals (Hensher, Shore, & Train, 2005; Merrett, 2002) or collectively (Wiser, 2007), well-established biases (strategic, protest vote, anchor) and limitations (temporal invariance, intra-household dynamics, social dynamics, computation) are acknowledged. Davis’ study (2004) on the effects of the mode of data elicitation on results obtained in demand-assessment research demonstrates that the explanatory power is highest in a combination of focus groups and subsequent self-administered questionnaires, which she attributes largely to additional time for contemplation. We acknowledge this finding, however, as in our case group decision-making was the objective for a standard payment level per user group, we replaced the questionnaires by follow-up focus groups leaving time for each group to reach

Table 1. *Composition of focus groups and number of interviewees*

Handpump user group	Total number of participants/interviewees	Number of female participants	Number of male participants
Total (users)	1692	639	291
Median	15	8	4
Mean	26	10	5
Min	1	1	0
Max	157	41	20

Table 2. *Factors of excludability*

Exclusion type	Percent of pumps (%)	Description
Physical excludability		
1. Lock	77	Keys are only available to group members and are kept at a nearby house
2. Fence	59	Symbolic demarcation; Fence helps keep livestock out
3. Pump attendant	14	Pump attendant is employed to keep the keys and collect money. Alternatively, group members rotate to fill the position
Financial excludability		
4. Membership joining fee	29	Membership joining fees since the installation of the pump are charged (payable in installments) (average USD 35)
5. Nonmember fee	46	Fee collected for single use by nonmembers (usually USD 0.06/20 liters)
6. Regular payment	23	Monthly and weekly options are used (average USD 0.98/month)
7. Fines	52	Warranted for late fee payment or missing WUC or user group meetings (between USD 0.06/offence and USD 1.15/offence)
Social excludability		
8. Labor contributions	64	Contributions include fixing fences or labor on a community crop scheme
9. Regular meetings	53	33% meet once a week, 18% once a month, 9% twice a month and 6% only when the pump is broken; the remainder with infrequency or not at all
10. Usage rules	74	Rules include schedules and limits for pump use, especially during dry periods

consensus. Thus, we selected a flexible and comprehensible approach whose results were to inform the wider institutional analysis; however, we do not claim nor wish to advance the methodology. The research team did not suggest minimum payment nor did it prescribe a payment system (from equality to a sole benefactor) but supported the group discussion with a view to engage quieter members actively but respectfully in an inclusive discussion.

The members of the water user committee attending focus group discussions were interviewed separately regarding the current management of their committee, thus informing the discussion on excludability. Additional interviews with user group members provided insight into relevant group dynamics.

Both qualitative and quantitative methods were used to analyze the data gathered in focus group discussions and interviews with 639 participants in June/July and November/December 2013 as well as the 2012 baseline survey. Data were analyzed in three steps: firstly, the quantitative willingness-to-pay was analyzed according to the themes developed in the sampling framework. The statistical program SPSS, version 22, was used for the statistical tests. Secondly, focus group transcripts were coded according to themes, which added narrative to the quantitative findings (Miles & Huberman, 1994). The analysis of excludability through a ranking system determined management types as common pool resources, club goods, or privately managed pumps.

#### 4. INSTITUTIONAL DESIGN AND RURAL WATER USER PAYMENTS

##### (a) *Levels of excludability of handpump user groups*

The institutional design of handpump user groups may constitute a major obstacle to securing regular rural water user payments. To test the hypothesis that the level of excludability in the institutional design has an impact on willingness-to-pay ( $H_1$ ), the data were classified into three different categories of excludability – physical, financial, and social (Table 2). Pumps may combine several types, thereby further increasing their exclusivity. By counting the number of exclusion types in place at each pump (assuming all exclusion types are equal, which is a simplification), a value for exclusivity was determined for each, which allowed for their division into two groups: more exclusive pumps (exclusivity levels six to ten) and less exclusive pumps (exclusivity levels up to five). Drawing on public goods theory, these two levels of exclusivity show a tendency toward the institutional type of club goods (Buchanan, 1965) or common pool resources (Ostrom, 1990) respectively. The water user committee plays an important role in administering rules and regulations that define the exclusivity of the group. Purely private pumps, which are the property of and are managed by a single household, constitute the third category.

The average membership size of exclusive groups (27 members) is 43% smaller than that of more inclusive groups (47

members). As one member usually represents a household (average 5.3 people), the difference is over 100 people.

Buchanan’s (1965) delineation of the highest attainable utility for the individual within clubs is reflected in several user groups’ endeavor to maintain an optimum size. Excludability is meant to prevent queuing, wear on the pump, over-abstraction, and potential rationing of the resource (occurring at 28% of the pumps in the dry months). While experiencing long, time-consuming queues, pumps with more than 100 members can offer lower membership fees. This implies that there is a trade-off between an individual’s benefits, especially in the dry season, and their cost over the whole year. When one pump (MIS-059) became too congested, users increased the fee to USD 1.15 per month in 2007, which paid for an attendant to enforce excludability. This led to a reduction in group size by 40% as people sought alternative sources.

(b) *Effects of excludability on rural water user payments*

The application of public goods theory to the institutional design of user groups reveals that the more exclusive handpump clubs show a 43% higher average willingness-to-pay per member per month (USD 1.03) than more inclusive groups classified as common pool resource groups (USD 0.72). The finding is significant ( $t = 2.12$ ;  $df = 57$ ;  $p < 0.05$ ), which supports hypothesis H<sub>1</sub> that a more exclusive form of management is related to higher user payment levels (see Figure 3 and Table 3).

Excludability is a response to water supply risks and trade-offs between sustainable abstraction, aquifer variability, handpump reliability and varying social demands. It is there-

fore an important feature of the institutional design of certain handpump groups. Too small or too large a membership limits group stability as demand can become insufficient or excessive (Carley, 1991). Through restricting membership, the good becomes less rivalrous. At the point of equilibrium between benefit and cost, an individual’s preferences are best met, which contributes to the group’s stability and the handpump’s sustainability.

Hence, the institutional design of the user group determines the operationalization of water user committee-administered payments. More exclusive groups tend to impose tighter financial regulations to generate the required revenue for the pump. They do not only achieve this through higher membership fees, which correspond with club members’ 43% higher willingness-to-pay for a more reliable water source, but also through nonmembership fees, joining fees and fines. Abstraction quantity and geographical distribution influence the decision-making process. On the other hand, some pump groups charge a lower fee while having more members to achieve the same overall revenue. Finally, some households prefer to own their pumps – 16% of the pumps studied are privately managed. These owners demonstrate a high willingness-to-pay. “I will pay whatever it takes to ensure [the pump] is repaired” (pump NGO-065, June 22, 2013). This is usually achieved by selling livestock. The implication of this finding is that studies regarding pump ownership should acknowledge the different institutional designs and the formation of handpump clubs. Although in their research on sense of ownership Marks and Davis (2012) refer to forms of participation during water supply planning and construction, we

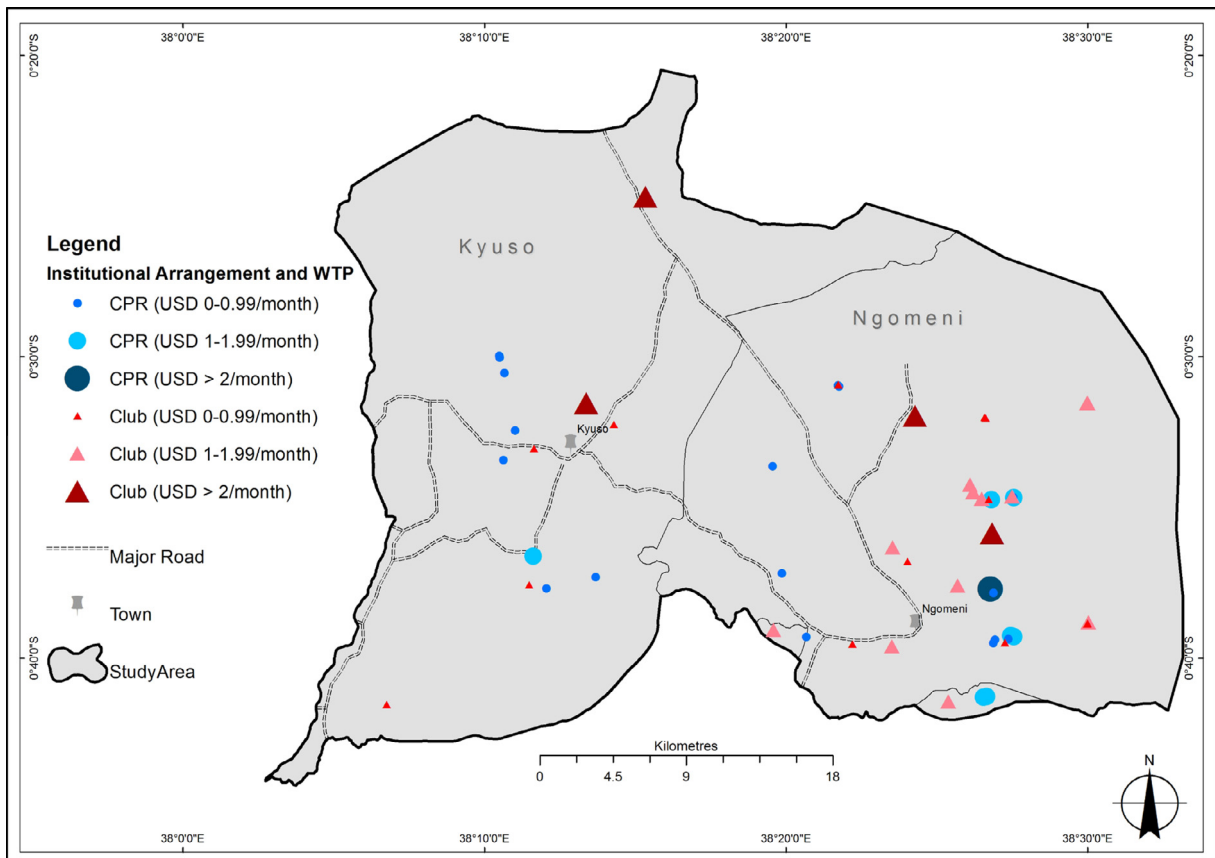


Figure 3. Institutional arrangement and willingness-to-pay (household/month) as agreed by each handpump user group.

Table 3. *Factors influencing willingness-to-pay levels at user household and user group levels*

Treatment category		Household willingness-to-pay per month (USD) Mean (st.dev)	Group willingness-to-pay per month (USD) Mean (st.dev)
Management	CPR ( $n = 26$ )	0.72 (0.47)	22.52 (34.43)
	Club ( $n = 32$ )	1.03 (0.69)	23.80 (29.18)
	Private ( $n = 8$ )	1.20 (1.91)	1.43 (2.05)
Handpump density*	Single ( $n = 18$ )	1.12 (0.78)	40.79 (51.04)
	Pair ( $n = 14$ )	0.79 (0.49)	22.03 (6.75)
	Cluster ( $n = 27$ )	0.76 (0.52)	11.28 (7.90)
Use*	Domestic ( $n = 7$ )	0.61 (0.40)	35.76 (56.31)
	Productive ( $n = 8$ )	1.58 (1.10)	48.69 (54.19)
	Both uses ( $n = 44$ )	0.79 (0.41)	16.08 (10.03)
Estimated quantity*	Low ( $n = 10$ )	1.15 (0.63)	31.65 (47.76)
	Medium ( $n = 28$ )	0.91 (0.75)	15.09 (13.13)
	High ( $n = 13$ )	0.66 (0.30)	36.91 (44.25)
Serviced*	Yes ( $n = 41$ )	0.92 (0.68)	24.98 (36.74)
	No ( $n = 18$ )	0.79 (0.47)	17.95 (12.17)

\* Only considering community pumps (CPRs and clubs;  $n = 59$ ), excluding private pumps.

found the same factors to be relevant in the post-construction phase. User group decisions on stricter enforcement mechanisms – from membership joining fees, regular payments, and labor contributions through to higher household contributions to maintenance costs in case of impending congestion – also strengthen the sense of ownership among group members, which links the club good approach to the sense-of-ownership discussion. Whereas Marks and Davis (2012) emphasize the intensity of individual factors, we draw on a number of measures reinforcing each other to make an aggregate impact.

This study suggests a distinction between membership clubs and common pool resource groups, the consequences of which have yet to be considered. While membership clubs may have a positive impact on the financial sustainability of handpumps, exclusion may have repercussions for the communities. The benefits of CPR management models must therefore not be disregarded. Ostrom (1990) demonstrates that if self-organizing principles are adopted, an institution may be relatively robust. This applies to common pool resources as well as club goods; however, the lower excludability of CPR groups may help to reduce the potential for community conflict, which exclusion might provoke. While no such conflicts were observed in the communities, it is acknowledged that handpump clubs can exacerbate financial and social inequality – through wealth, kinship, or other factors. These potential social repercussions as well as the implications for the Human Right to Water and Sanitation (UNGA, 2010), require further investigation. At the same time progressive realization of universal drinking water services requires financial sustainability. Handpumps managed as club goods contribute to progressing, and critically maintaining, universal services consistent with property rights regimes for piped water systems in urban Africa, such as kiosks, which are not open access but provide the poor with a lower cost and generally safer water supply than other alternatives (Kjellén & McGranhan, 2006).

### (c) Institutional design and handpump usage

The handpump user groups that have a tighter organizational structure appear to be those with a higher demand for

water. Club handpumps have a 57% higher usage level than CPR handpumps. Figure 4 shows the increasing usage levels with increasing exclusivity levels (sixfold increase). This suggests that club handpumps need a more exclusive management structure in order to prevent over-abstraction and queuing at sources where demand is relatively high ( $H_2$ ). The user group safeguards the desired degree of exclusiveness primarily through adaptation of payment levels.

Not only the abstraction quantity per user group but also the intended use is relevant. Productively used water shows high willingness-to-pay levels (USD 1.58 per user per month *versus* USD 0.61 per user per month for domestic-use pumps), supporting the water-pays-for-water hypothesis, which implies that using water for income-generating activities has a greater perceived value than purely domestic uses. Pumps with both productive and domestic use have 2.3 times the weekly mean output compared to solely domestic-use pumps (900 liters per day *versus* 400 liters per day). The productive use of water also confounds estimates of demand based on population data and assumptions on personal use patterns. Having objective handpump usage data enables the spatial mapping of demand for water (see Figure 5). Given the reality of limited resources and inevitable trade-offs, this information can provide an objective basis for investments in water infrastructure, be that the installation of more handpumps or determining the best place to upgrade to a powered pump and tank or the transition to a piped water scheme.

When willingness-to-pay is compared to measured usage, the following pattern emerges: high-use pumps, above 36,000 liters per month (75th percentile and above), have the highest mean group willingness-to-pay of USD 37 per month; low-use pumps, with abstractions below 6,000 liters per month (25th percentile), show a willingness-to-pay of USD 32 per month; medium-use pumps, between 6,000 and 36,000 liters per month (up to 75th percentile), have the lowest willingness-to-pay per user group at USD 15 per month. This relationship is nonmonotonic, and thus cannot simply be explained by looking at the demand for water at a pump in isolation. The geographical distribution of pumps, in particular a pump's location in relationship to other pumps must be considered.



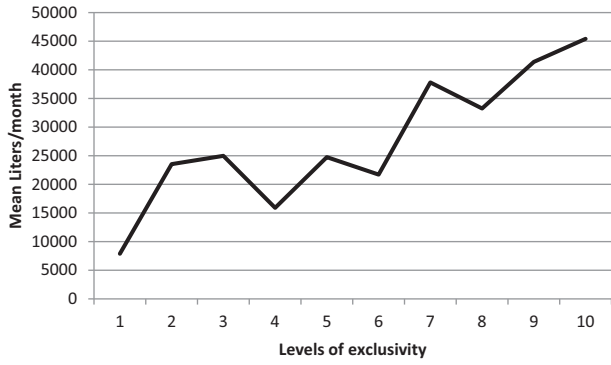


Figure 4. Abstraction versus exclusivity.

### 5. HANDPUMP DENSITY AND RURAL WATER USER PAYMENTS

Geographic factors also influence rural water user payments. Population density does not generally vary across all three groups; however the geographic distribution of pumps does. The existence of alternative sources is likely to reduce the willingness of users to pay for operation and maintenance of a certain pump since they can easily switch to another one. Thus handpump density has implications for operational management and investment planning. In Kyuso there are 17 single pumps, eight pairs, and four clusters (eight pumps on average per cluster) according to definition (see Section 3(b)).

The research has shown that isolation of pumps influences the institutional design of user groups. The average group size

for single pumps is 43 household members, for pairs 32 household members. Considering community handpumps, the willingness-to-pay level of households at single pumps is 42% higher than that of pairs; moreover, it is 47% higher for singles than for clusters. This tendency is consolidated at group level. At user group level singles have an 85% higher willingness-to-pay than pairs, and a 2.6 times higher willingness-to-pay than clusters. The relationship is significant ( $F = 5.355; df = 2; p < 0.01$ ), which supports the hypothesis that payments are related to handpump density ( $H_3$ ). This also explains why medium-use pumps (between 6,000 and 36,000 liters per month) showed a lower willingness-to-pay at the group level than high-use or low-use pumps. In Kyuso, medium-use pumps are disproportionately those in clusters.

Considering opportunity cost, users generally tend to prefer paying higher fees to walking greater distances to alternative handpumps (Hulton, 2012; Sorenson, Morssink, Abril, & Campos, 2011). This fact is highlighted by Narayan (1993), who shows that the presence of alternatives is the major cause for pump users not to invest in a well as they lack incentives. Thus handpump clustering is at best inefficient, and at worst a counter-productive planning decision (see Figure 6).

### 6. SERVICE DELIVERY AND RURAL WATER USER PAYMENTS

Poor service levels appear to be the most important barrier to sustaining water user payments. Increased reliability, enabled through mobile monitoring, constitutes a critical component of demand as it affects other preferences. For this pur-

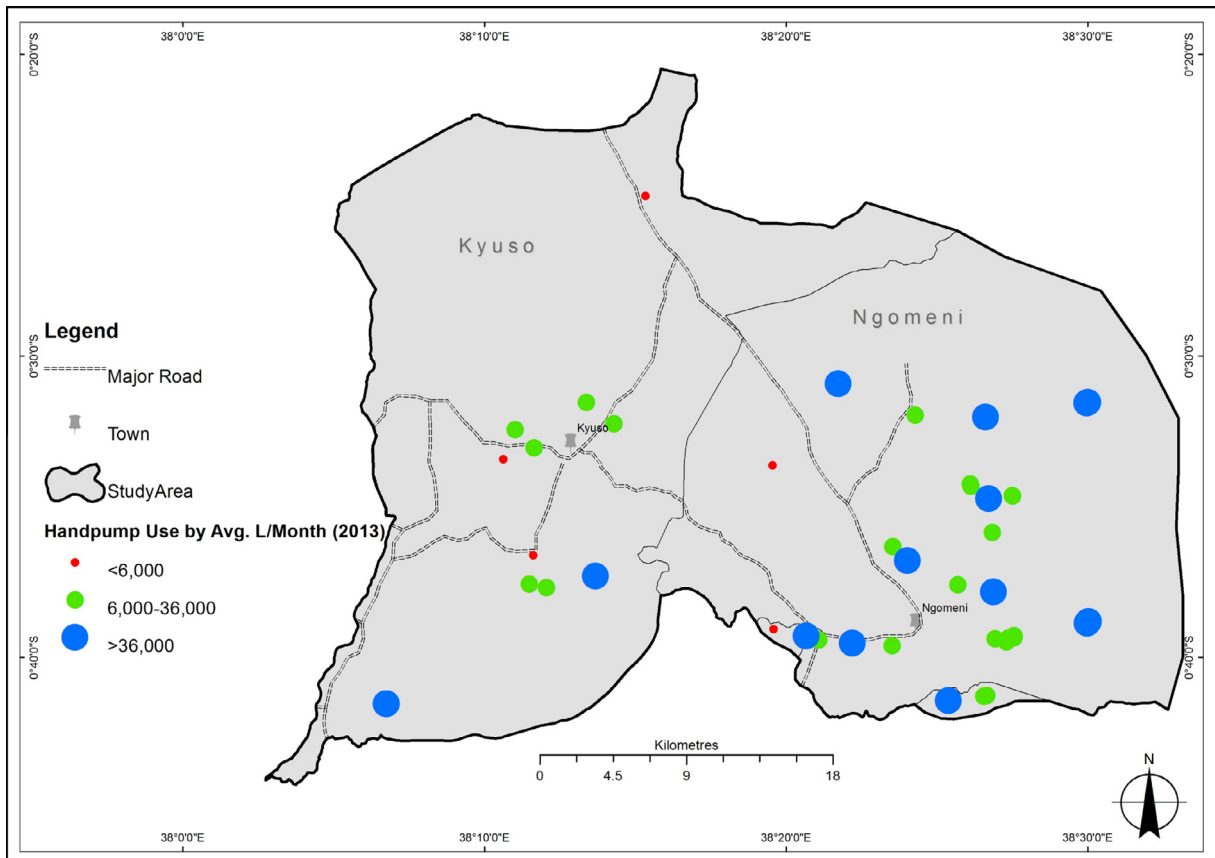


Figure 5. Handpump usage by average liters per month, 2013.

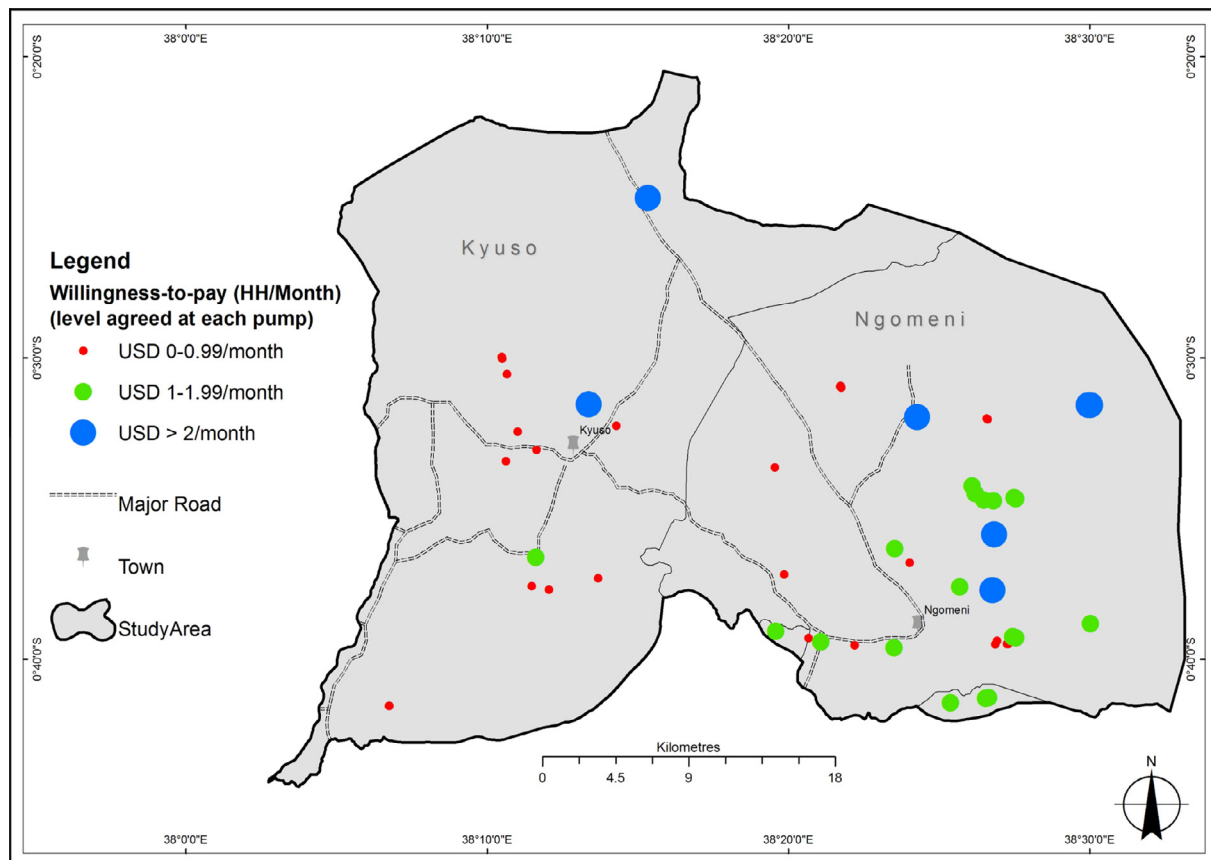


Figure 6. Willingness-to-pay (household/month) as agreed by each handpump user group.

pose, monthly payment levels per household of the time before the service started were compared with willingness-to-pay levels after the users had experienced the service ( $n = 46$ ) – including those private pumps that would join the payment model. The increase is fivefold from USD 0.2 to USD 1 per household per month (Table 4). This can be related to the fact that the new level of service produced a tenfold decrease in handpump downtime from 27 to 2.6 days on average over the 1-year study period (Oxford/RFL, 2014), which represents an order of magnitude improvement found to be critical in the baseline survey (Hope, 2014). Moreover, the number of handpump groups intending to contribute monthly – rather than making post-breakdown payments – increased threefold (Table 4).

The findings suggest that payments are contingent on service delivery, thus supporting hypothesis H<sub>4</sub>. The aspects of service delivery that were most valued by the water users were the speed of service (77%), the quality of the service (54%), and the knowledge that the service is guaranteed (31%). The focus group participants also endorsed mobile payments as an acceptable payment mode, especially as mobile payments are already used for remittances by at least one member in each focus group. The average willingness-to-pay for a mobile-enabled service at all 66 pumps is USD 0.92 per household; the average monthly group willingness-to-pay is USD 21 per month across all pumps. Of the sample of 66 handpumps, 70% required at least one repair in 2013, with 63% of broken handpumps requiring more than one repair. The average cost of each repair was USD 62 (Oxford/RFL, 2014). If the stated willingness-to-pay of all pump user groups reflected the actual future payment collected, this would raise sufficient revenue to

have covered all repair costs in 2013; however, if communities chose not to pool revenue, 43% of communities would not have met their individual costs (Oxford/RFL, 2014). Equal monthly payments and equal cost-sharing are therefore deemed universally important. With the given level of acceptance and use of mobile phones in Kyuso, a mobile-enabled service delivery model is socially acceptable and familiar as well as practical and efficient.

The benefit of higher revenues can lead to a cycle of improved pump maintenance triggering higher returns for users (Figure 7). The spiral of decline and discontent among users leading to nonpayment and long-term pump nonfunctionality can be reversed through an effective maintenance system that facilitates demand for higher service levels (The World Bank Water Demand Research Team, 1993), which is expressed by greater willingness-to-pay. Translating this willingness-to-pay into actual payments requires strong institutions with enforcement mechanisms. Madrigal, Alpizar, and Schlüter (2011) point to the significance of a set of working rules enforced by the local communities. At the same time, satisfying user preferences reinforces institutional stability (Olson, 1965; Ostrom, 2010). Even beyond willingness-to-pay, a study by Ali, Fjeldstad, and Sjørnsen (2014) finds that satisfaction with public service provision supports a tax-compliant attitude among Kenyans and other sub-Saharan Africans, which may indicate that willingness-to-pay will eventually translate into payments recognizing the new service level. Altogether, the measures discussed above have profound implications for the operational and institutional challenges of community management of handpumps.

7. OPERATIONALIZING AND INSTITUTIONALIZING RURAL WATER SERVICES AND USER PAYMENTS

(a) *Harnessing mobile technology for monitoring and payment*

Mobile monitoring and mobile payments have the potential to improve traditional payment systems with benefits for both service provider and water user. For the former, it provides an effective monitoring system that “would be alert to all credible problems and notify maintenance responses in a timely and constant manner” (Thomson *et al.*, 2012b, p. 283), thus not only enabling fast repairs but also contractual oversight. For the latter, benefits include a more transparent financial system and a higher level of water security through regular repairs (Hutchings *et al.*, 2012). While mobile monitoring facilitates a hitherto impossible alignment of service delivery with user level demand through monitoring functionality and abstraction, mobile payments facilitate direct financial flows back to the maintenance service provider (Figure 7). Mobile technology could therefore act as a conduit for reliable information and financial flows, thus achieving the central objective of strengthening handpump sustainability while increasing financial transparency and security. The service provider may achieve a better understanding of the financial capacity of water user groups while users can monitor their management committees through feedback loops, which would counter potential mismanagement of handpump finances. Without strict group level enforcement measures, the entire group may lose interest in fee collection (Harvey & Reed, 2004).

Mobile technology is not a panacea for Kenya’s and other countries’ rural water supply problems. There are numerous obstacles impeding the successful delivery of a mobile-enabled service, including the lack of signal and electricity for recharging mobile phones, together with operational problems of crowd-sourcing. However, these technical challenges are surmountable with coverage and subscription levels continuously increasing. Technology is an enabler that creates the opportunity for novel management models, which were not previously possible; yet it will not train and equip mechanics, enforce agreed payment levels, or conduct a spare parts inventory check. Overall, success is contingent upon the willingness of the people to participate. “Getting the human side of things right... [is] much harder than making the technology work” (Daraja, 2012). Nevertheless, this study has shown that, by aligning rural water supply systems to the service level demand formed through socio-economic preferences and translated into the institutional design of user groups, the financial sustainability of community handpumps may be improved. Mobile technology is a useful tool for aligning supply and demand – but only if the institutional structure at the community and supra-communal level are sufficiently robust to nurture and exploit its full potential.

(b) *Developing an output-based payment framework*

Overcoming the barriers to rural water user payments is an essential step in the global drive toward achieving the water targets of the sustainable development agenda. An output-based payment model represents a new framework for donor and government behavior in Kenya and other African countries (Figure 8) within the wider initiatives on result-based payment approaches (DFID, 2014; Hope, 2014). The cycle of improved service delivery presented above constitutes the first building block at the sub-national level where finances flow from communities whose payments are clustered to a performance-based maintenance service provider, who in

Table 4. *Service delivery and willingness-to-pay*

Handpumps repaired under new model (n = 46)	Before treatment		After treatment		Increase in pre-paying handpumps	Increase in payment level
	% handpumps pre-paying		% handpumps to pre-pay			
	Yes	No	Yes	No		
	29%	71%	91%	9%		
	Mean household monthly payment (st.dev)		Mean household monthly payment (st.dev)			
	USD 0.2 (0.49)		USD 1 (0.99)		318%	500%

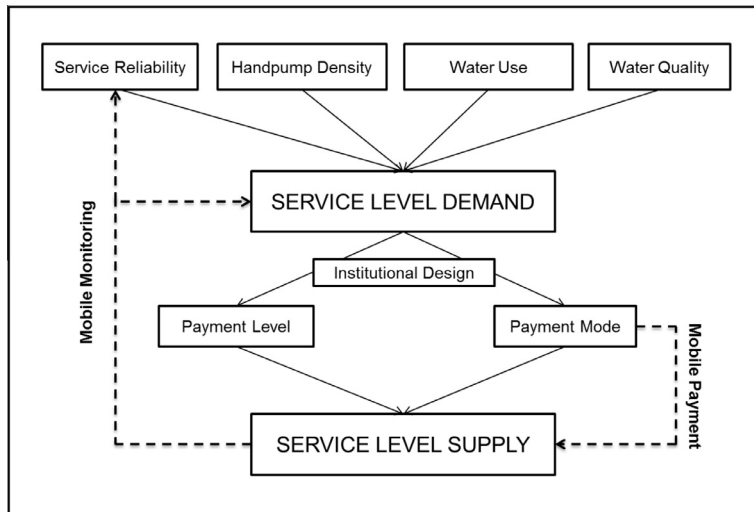


Figure 7. Cycle of improved service delivery.

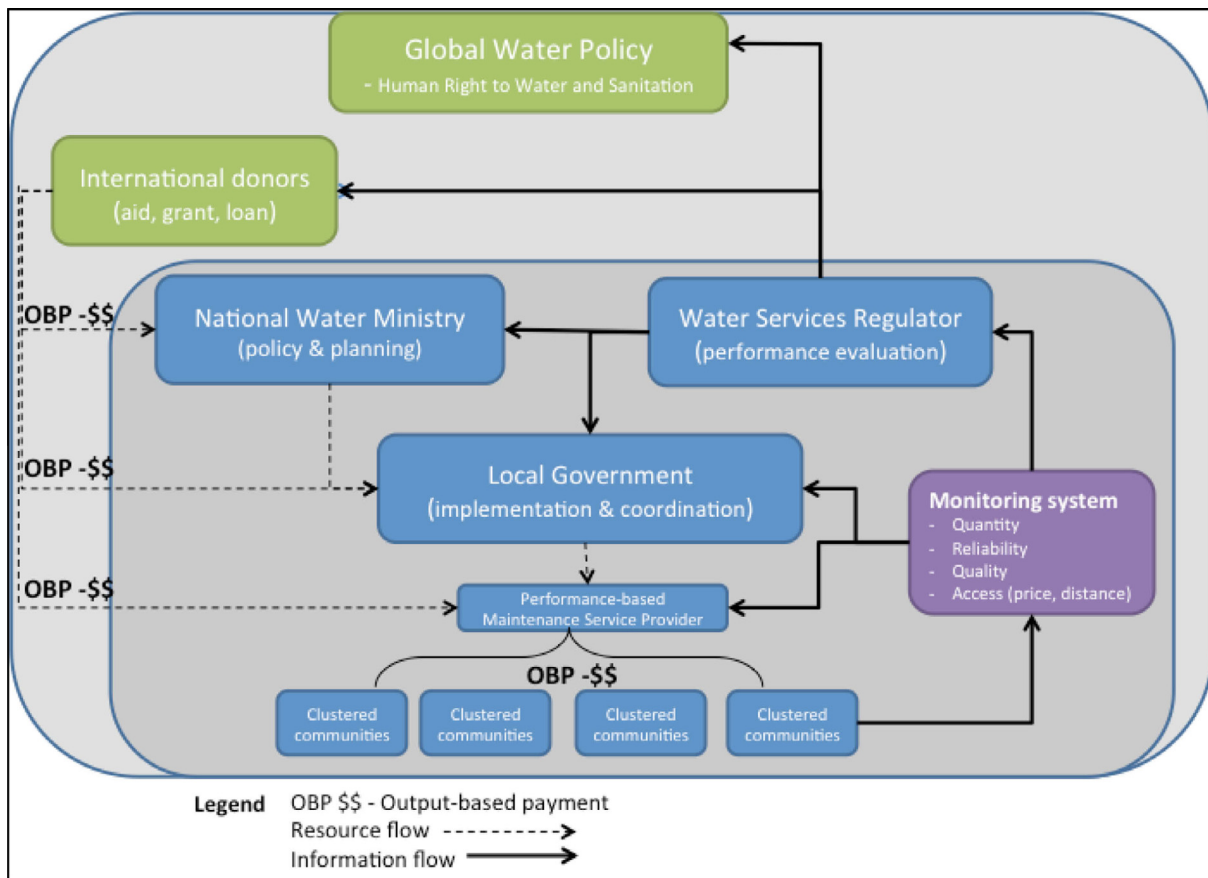


Figure 8. An output-based payment model of rural water services (Oxford/RFL, 2014).

turn is monitored and regulated by local and national governments. The national rural water regulation system documents existing and new investments by environmental, technical, and operational indicators, thus providing a valuable resource for monitoring and regulating investment behavior and outcomes at scale. The sub-national level can provide regular information on performance and user payments, lending itself to the

model of a results-based financing mechanism that supports the provision of basic public services. This can be facilitated by delegating the delivery of outputs, such as a functioning maintenance service, to a third party in exchange for the payment of a subsidy upon delivery of specific outputs. It can thus address a potential funding gap between the cost of service delivery and the beneficiaries' ability and willingness to pay

the full amount of user fees for the service (GPOBA, 2014; IDA, 2009). Hence this system can continuously inform national government goals and priorities while supporting global water policy approaches.

## 8. STUDY LIMITATIONS

Five limitations are identified in this study. First, the study site is in one District in rural Kenya with a unique hydro-climatic, geological, social, and political landscape; no claim is made to generalize the findings though there is confidence in internal validity. Second, the free maintenance service may have biased upwardly informant responses, particularly on payment levels, toward the end of the study given the successful performance of the technology. As noted, there are significant methodological concerns with willingness-to-pay studies (see e.g. Davis, 2004). Aware of the issues, we have attempted to be conservative in the estimates and associated implications. We could not address all the broader scope socio-cultural factors affecting willingness-to-pay of users. Third, insufficient resources were available to conduct analysis of environmental variation (hydrogeology, recharge, water quality) or technical components (installation quality, depth of well), which may confound some of the results. Future work aims to include natural and human-related contamination to understand the extent to which this key variable affects water payment behaviors. Fourth, the research team worked closely with but independently from the Government of Kenya District Water Office and staff. While government support was instrumental in the research, we acknowledge such collaboration may have affected community behavior despite enforcing strict ethical and human informant measures on confidentiality and anonymity. Fifth, the data on handpump usage are presented as an estimated value for volumetric abstraction over a given period. This is based on calibrations of handle movements against observed flow prior to the start of the study (Thomson *et al.*, 2012a). The same calibration coefficients were used for all pumps throughout the study, so slight differences in pump dynamics between pumps and across time will not have been captured. We acknowledge the associated inaccuracies in this approach, but highlight the novel insights this technique allows in understanding factors contributing to sustainable rural water service delivery.

## 9. CONCLUSION

This study identifies three major findings to prime rural water user payments in Africa. First, a reliable and fast maintenance service is key to sustaining rural water user payments. Second, these payments are subject to demand, which is related to the spatial distribution of handpumps. Hence, clustering should be avoided for financially sustainable services and new handpump installations determined by verifiable metrics. Third, the management of community handpumps takes several forms along the public-private spectrum. Almost half

of the handpumps self-organize in clubs and choose a semi-privatized model with a higher payment structure.

The empirical findings suggest that there are two linked and potentially competing arguments: First, sustainable water services require new approaches to tackle the widely documented failure beyond infrastructure construction and the associated limitations of current monitoring practices. Second, the universal water access argument requires approaches that are sustainable. Historically, the latter has been applied at the expense of the former with major waste of resources (Baumann, 2009). We provide new insights to advance theory on improving sustainable water services for the rural poor through the club good model. However, the legacy and limited accountability of external interventions by donors and government can undermine the model as illustrated by clustering handpumps, which may neither be cost-effective nor deliver sustainable services. If sustainability is not achieved through the efforts of functioning institutions, the human right to safe drinking water is generally infringed, not only for those who do not have access yet. Acknowledging the requirement of progressive realization is therefore realistic as well as beneficial to a growing number of sub-Saharan Africans, if steps are taken by communities and governments alike toward the full realization of the human right, using the “maximum available resources” and “ensuring that the right can be realized for present and future generations” (UNGA, 2013).

Understanding operational, geographic, and institutional barriers of rural water user payments contributes to developing an innovative, output-based payment model for rural water services in Africa. The real test will be if users support the introduction of a new payment system, which acknowledges the higher value for money that the new maintenance service system creates. This research indicates that such reforms are supported by the communities if reliable services are delivered. The findings offer pathways toward the suggested water targets of the post-2015 sustainable development agenda promoting, *inter alia*, universal and sustainable access to safe drinking water and raising service standards, as well as robust and effective water governance with more effective institutions and administrative systems (UN Water, 2014). It demonstrates the need for continuous monitoring of rural water services, as well as suggesting strategies for achieving this. Water service performance data are key to defining a baseline and measuring progress toward sustainable services at the local level, for operationalizing a maintenance service provider model at the supra-communal level and testing an output-based payment model at the national and international levels. The Government of Kenya’s Water Services Regulatory Board (WASREB) acknowledges the importance of such performance data “enabling WASREB to ensure that satisfactory performance levels are achieved and maintained, and enhancing transparency and accountability within the rural sector” (WASREB, 2014, p. 79). Thus, the data can support and monitor national policy goals that promote progress toward universal access and more reliable improved water services for the rural poor.

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