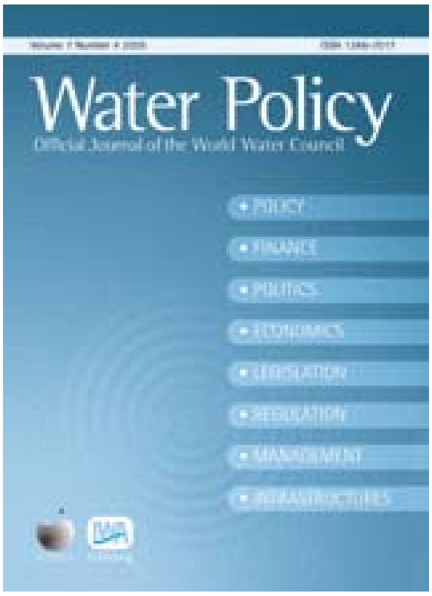
Water Policy
Official Journal of the World Water Council
POLICY
FINANCE
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MANAGEMENT
INFRASTRUCTURES

Water Policy 17 (2015) 664–678

Is community water management the community's choice? Implications for water and development policy in Africa

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Abstract

The global drive for universal drinking water security has faltered in rural Africa. Community management of handpumps, which provide water to over 200 million rural people, is the prevailing but increasingly embattled policy choice. A choice experiment is designed to test alternative maintenance models across competing attributes of maintenance provider, maintenance level, payment mode, and payment level. A sample of 3,540 observations is modeled from 118 handpump users in rural Kenya. Results identify community management of maintenance services as the least preferred option with water user payments contingent on an order of magnitude improvement in handpump repair times. Social choice heterogeneity varies by socio-economic status and water use behaviors indicating uneven adoption profiles within communities compounded by no acceptable payment mode. Policy responses to community choices need to address these institutional challenges through new monitoring platforms and acceptable payment systems.

Keywords: Africa; Choice experiment; Human right to water; Kenya; Poverty reduction; Water policy

'*If well-drilling and handpump problems are focused (on) during the first half of the (International Decade of Drinking Water Supply and Sanitation) decade, it is probable that the operation and maintenance problems will be the ones dominating during the second half*' (Falkenmark, 1982, p. 15).

1. Introduction

Four trends present challenges to the United Nations' goal of the universal human right to reliable, safe, affordable and accessible drinking water in rural Africa (United Nations (UN), 2011). First, sub-Saharan Africa is making the slowest relative and aggregate global progress with one in three people (30%) without improved drinking water access equivalent to 35 million *more* people lacking improved water services in 2012 compared to 1990 (UNICEF/WHO, 2014).

doi: 10.2166/wp.2014.170

Second, in the same period, rural piped water coverage has increased by 1% (from 4% to 5%) making piped water networks an unlikely policy option. Third, by 2050 Africa's rural population will have increased by 47% to 0.9 billion (10^9), a higher rate of rural growth than any other region (UN, 2012). Fourth, community management of Africa's one million handpumps has been unreliable with one in three handpumps not working at any one time (Rural Water Supply Network (RWSN), 2010; Foster, 2013). With the first three trends pointing to the likelihood of continuing reliance on handpumps to access low-cost groundwater of generally good quality, this paper examines whether rural water users support the dominant policy model of community management given a choice of competing alternatives.

Community management of handpumps can be thought of as a mechanism to achieve a given policy goal at least cost. By transferring handpump ownership and operational responsibility to a community of users, the state provides the technical means by which individuals can access improved water services. Community water management emerged in the 1980s during the International Decade of Drinking Water Supply and Sanitation (Arlosoroff *et al.*, 1987; Briscoe & de Ferranti, 1988). Policy pragmatism identified rural communities with clearer incentives to maintain handpumps rather than remote and under-resourced governments. In theory, handpump users have the right incentives to manage and monitor effective service delivery tailored to local requirements for domestic and productive uses. However, over the last decade there have been increasing concerns that communities are not able to manage handpumps reliably with implications for public health and poverty reduction (Harvey & Reed, 2007; Cairncross *et al.*, 2010).

The concept of community management as a unitary, benign, effective and apolitical approach has been labeled as 'myth' by research in common pool resource management in Africa (Mamdani, 1996; Cleaver, 1999; Page, 2003; Blaikie, 2006). The decentralization of rural water supply to rural communities promoted a particular articulation of the roles and responsibilities between the state and the community. In an all-Africa infrastructure assessment, it is reported that central, regional or local governments play a dominant role in all aspects of energy, road and water infrastructure provision; it is only in the area of providing and maintaining water services that local communities have a leading role; precisely where the authors identify that most challenges occur (Banerjee & Morella, 2011, p. 112). In post-colonial Africa it is argued that there is a 'political failure to grasp the specificity of the mode of rule that needs to be democratized … an infatuation with civil society, a preoccupation that conceals the actual form of power through which rural populations are ruled' (Mamdani, 1996, pp. 288–289).

Mamdani's critique has contributed to a shift in the global policy and donor investments to align more closely to the voices and choices of the vulnerable and poor (Narayan & Walton, 2000; Sen, 2009). In the rural water sector, 'informed choices' has long been a principle of the demand responsive approach to the installation of rural water supply technologies (Narayan, 1995; Sara & Katz, 1998). The contribution of this paper is to examine rural water choices to the elusive goal of maintaining services after installation. The main research question is: 'If rural water users are given a choice between competing alternative models for handpump maintenance service provision, would they choose community management?' The results inform a discussion on the implications for water policy and development planning in rural Africa.

2. Methods

2.1. Study site

The study site comprises Kyuso and Ngomeni Districts in Kitui County, Kenya (38°10′E, 0°35′S; 660–880 m elevation; 2,446 km^2), located 267 km east of Nairobi with a population of 26,848 households (Government of Kenya (GoK), 2013) (Figure 1). The population is almost entirely rural (>99%) with two out of three households classified as 'poor' (GoK, 2006). Average rainfall in the period 1961–2006 was 774 mm (coefficient of variation (CV) = 41 mm) with increasing variation in decadal rainfall patterns during both the long rains (mean = 250 mm; March–May) and short rains (mean = 426 mm; October–December). Temperatures range from 14°C to 34°C with February and September marking periodic and severe drought events across the wider Horn of Africa (Rao *et al*., 2011). Livelihood systems are largely agro-pastoral with cattle and goat husbandry combined with low-value, rainfed agriculture (maize, beans) on small plots (<1 hectare). Households rely on over half their income from casual labor and remittances (GoK, 2012). Over half the population (54%) use unimproved water sources (stream, pond, dam). Over one-third of the population (39%) use wells or boreholes for drinking water including 66 Afridev handpumps installed over the last 20 years to help improve drinking water security.

2.2. Survey and choice experiment

In July 2012, after training and piloting a household survey, a team of five experienced enumerators (four women, one man) administered a revised survey in either the local language KiKamba (54%) or

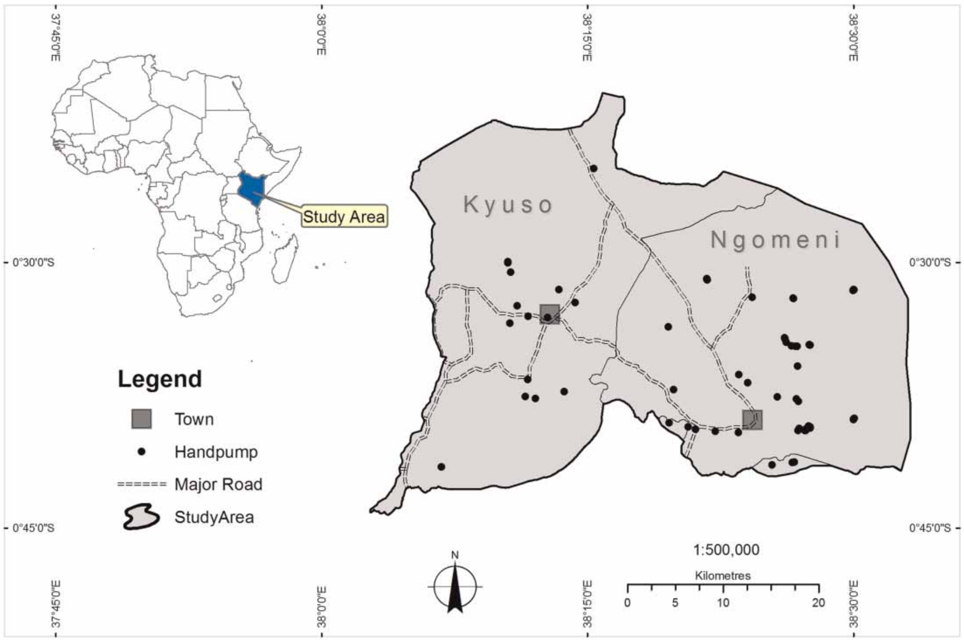

Fig. 1. Study site.

KiSwahili (46%) to 124 water users across 21 functioning handpumps (32% of total). After data cleaning, six surveys were rejected to leave a sample of 118. Descriptive analysis and the orthogonal design for the choice experiment used SPSS (version 21) with multinomial regression (choice) modeling using NGLOGIT (version 3.0).

The handpump survey comprised five sections:

(1) household composition by age, gender, education, mobile phone ownership and use, and handpump behavior (collection, frequency) for each member;
(2) handpump use including domestic and productive uses, frequency/quantity of use, treatment/storage before drinking, frequency/nature/cost of handpump failures, payment for handpump use and maintenance, management regime, alternative sources;
(3) choice experiment including a structured and common introduction to the hypothetical and voluntary nature of the exercise, careful explanation of attributes and attribute levels, answering a test ('dummy') card, and then votes taken on 10 choice cards;
(4) socio-economic status including assets and expenditure (food, school fees, health, transport, building, other);
(5) enumerator notes on length of survey, language used, respondent comprehension and data quality.

Choice experiments provide a structured method to test respondent preferences to future and uncertain scenarios (Louviere *et al.*, 2000). They explicitly identify key attributes that can be voted on by respondents in a simple but replicable voting format. They allow decision-makers to explore behavioral responses and priorities, which cannot be satisfactorily examined by analysis of observed data. A feature of the methodology is that a good or service is characterized by a collection of attributes and attribute levels (Lancaster, 1966) rather than assuming an aggregate 'whole good' approach. In the rural water sector, this differs from the wider use of contingent valuation where respondents are given a statement on 'improved water services' without clear guidance on how levels of quantity, quality, reliability or physical access might vary (Diamond & Hausman, 1994). Choice experiments provide a more explicit specification though can be biased from (a) inappropriate or overly complex design, (b) protest votes, or (c) strategic bias (Colombo *et al.*, 2006). To promote user comprehension, choice cards are presented pictorially, which has been found to aid greater participation in rural areas of Africa where literacy levels may be low (Hope, 2006; Hope *et al.*, 2009). A key component of any choice experiment is the 'status quo' option, which permits respondents to opt out.

The choice experiment tests four attributes with varying attribute levels (Figure 2):

(a) maintenance provider (community, government, private sector);
(b) maintenance level (1, 3, 5 or 7 days to repair);
(c) payment mode (cash per bucket, cash per month, mobile money transfer each month);
(d) payment level (USD 0.5[1], USD 1.1, USD 1.6).

[1] Payment options were presented in Kenya Shillings – Ksh 50, Ksh 100, Ksh 150, Ksh 200 (USD 1 = Ksh 93).

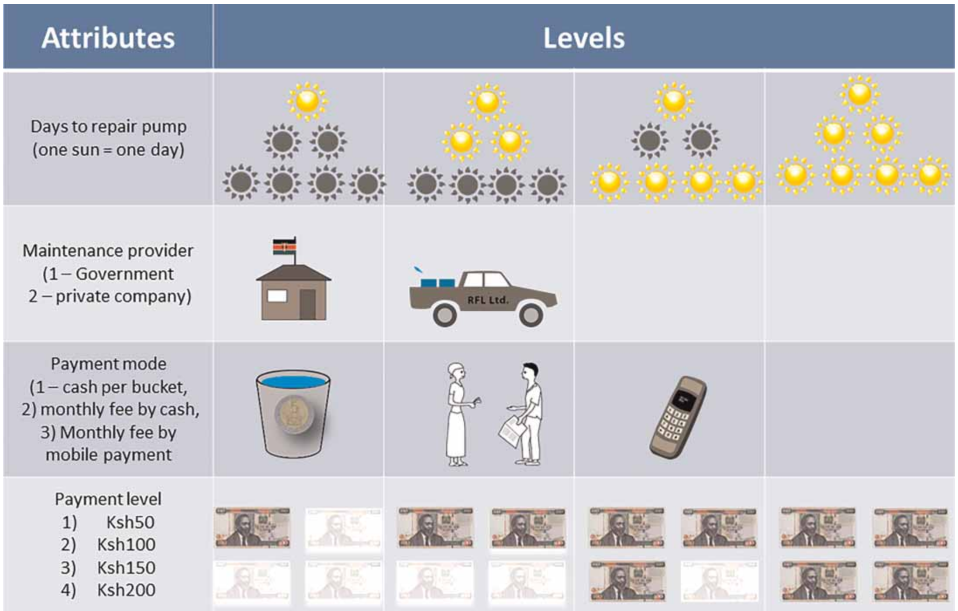

Fig. 2. Choice card design.

The attributes and attribute levels were co-designed by the research team, Kenyan water managers and exploratory visits to the communities from December 2011. In addition, the literature on handpump functionality in Africa (World Bank, 1993; Carter *et al*., 1999; Harvey & Reed, 2007; Whittington *et al*., 2009; Narkevic & Kleemeier, 2010; RWSN, 2010; Lockwood & Smits, 2011) provided further guidance supported by the largest ($n > 25{,}000$), cross-country analysis of determinants of handpump functionality in rural Africa, which concludes that 'greater efforts are needed to test and evaluate alternative models for managing handpump water supplies' (Foster, 2013). The choice experiment has an orthogonal, main effects design with 10 choice cards analyzed by each respondent comprising three choices (two hypothetical and status quo, see Figure 3). This generated 3,540 choice responses (118*10*3). The data are analyzed in two stages: (a) the main attributes (Model I) and (b) attributes interacted with socio-economic and handpump use coefficients (Model II). Less restricted models (latent class, mixed logit, etc.) were not tested as the Independence from Irrelevant Alternatives (IIA) test was rejected (Hausman & McFadden, 1984).

3. Results

3.1. Handpump water use behavior

Sampled respondents were mainly female (64%) with an average age of 41 years. The informants belonged to households with an average of 5.3 members with a child-to-adult ratio of 0.38. Median adult equivalent expenditure is USD 313 per year which is two-thirds (68%) of the global poverty line of USD 1.25 per person per day. Livelihoods were largely agro-pastoral in nature with scattered

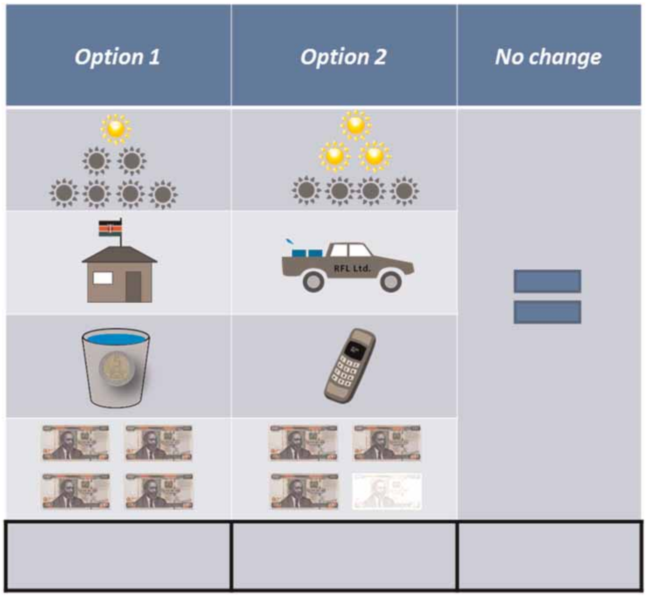

Fig. 3. Example of choice card.

settlements owning livestock (64%), pit latrine (79%) or an own-dug well (18%). The majority of households own mobile phones (85%) with an average of over two mobile phones per household. Over seven in ten households use mobile money services with the majority (95%) using the nationally dominant M-PESA platform.

Handpumps provide the majority of households with their main drinking water source (59%) and cooking, bathing and washing water (67%) throughout the year. However, the main use of handpump water for households is for livestock watering (74%). Almost nine in ten households (86%) consider the water safe to drink, though one in three claims to treat the water by either boiling or chlorination. Roughly half of households pay for water (56%) with payments managed by water committees in 80% of the sample. Water payment methods vary from monthly fees (32%), when handpump breaks (26%), by bucket (19%), membership fee (13%) or by head of livestock (9%).

The handpumps have been operational for an average of 6 years (range 0–20 years) with a median of 60 households using handpumps in the dry season and 25 households in the wet season. This translates to roughly 125–300 people using an average handpump through the year. In the previous 12 months to the survey, 18 of the 21 handpumps (86%) had experienced a failure. The average failure rate was just over two failures per year (range 0–10) with a total of 48 failures. The median repair time to fix a pump was 6 days with an average of 27 days (range 0–365 days).

Over two in five households (44%) indicated that they did not pay for water from their handpump. Of the majority that did pay, a portfolio of overlapping payment approaches existed from a one-off membership fee, a monthly user fee, to pay-as-you-go fees for drinking water containers or head of livestock. The two most common payment modes were monthly fees, which were generally USD 0.56 per month (30% of all paying households), or USD 1.1 per m^3 of water (Ksh 2 per 20 l container; 28% of all paying households). A rough attempt to approximate and smooth the various fees that households paid by month or use, by number of residents and livestock, suggests a median monthly fee of USD

0.78 per household or USD 9.3 per household per year. The opaque approach to fee collection is reflected in the financial challenges when a handpump breaks and needs repairing. It was reported that there are sometimes sufficient funds to fix the handpump (24%), but more often there are not (36%) or there are funds that cover only minor repairs (18%). Handpump failures lead to delays in raising money in 40% of cases with an average of 18 days to raise sufficient funds (median = 7 days; range 1–180 days). Unprompted concerns on handpump management identified maintenance as a key priority across a range of overlapping factors: (a) repairs are too expensive (19%), (b) repairs take too long (17%), (c) handpump breaks too often (17%), (d) too many users (10%), (e) pump too far (8%), (f) water unsafe to drink (6%) and, of lowest concern, (g) water fee too high (1%).

When handpumps fail in the dry season 77% of users turn to an alternative source compared to 64% in the wet season. For the majority of households, there is no financial cost incurred for alternative drinking water sources, though time and health costs may be borne. The main alternative drinking water sources include public wells or springs (33% dry season; 24% wet season) and surface water (24% dry season; 33% wet season). Risks identified with alternative drinking water sources include health concerns for water from rock catchments (43%), surface water (38%) and own well/spring (28%), and greater distance to collect water from other handpumps (79%), vended water (47%), public well/spring (41%), and surface water (35%).

3.2. Rural water choices

Model I results underline that rural water users predictably prefer quicker to slower handpump repairs and paying less to more money (Table 1). Of significance is that fixing handpumps in 3 days or less provides positive and significant utility. Taking 5 or more days to repair has low and non-significant utility (value) for water users. Utility values for monthly payment coefficients are equivalent for the two lower costs but diminish rapidly (53% less) at the next payment level (USD 1.6). Government and community maintenance management record negative and significant utility coefficients; private sector is also negative but not significant. Across the three tested payment modes, the mode of monthly payments results in significant and negative utility. Both paying when handpump breaks and mobile money modes are non-significant.

Model II interacts socio-economic status and handpump user behavior variables. The model reports only significant and stable variables. The model fit is significant with a notable increase in the pseudo R^2 from 0.136 to 0.259. The behavior and circumstances of respondents influence the weight and nature of choices reflecting the heterogeneous nature of the community of water users. Attribute values largely conform to Model I findings of preference for a rapid and low-cost maintenance service with two notable exceptions. First, management regime coefficients differ markedly when interacting household variables. While community management is no longer negative it remains small (0.01) and non-significant. In comparison, government or private sector maintenance service delivery has positive, large (>8.4) and significant values. Second, all payment modes appear unattractive with broadly similar, significant and negative values (<-2). Payment coefficients are broadly similar to Model I with a non-linear reduction in utility from USD 1.2 to 1.8.

Handpump user behaviors reveal four factors positively associated with the choice alternatives: (a) using older handpumps (>5 years), (b) already paying for water, (c) relying on the handpump as the main drinking water source, and (d) treating handpump water before drinking. As expected, if a household was ‘satisfied’ with current handpump services they had no interest in changes. A well-rehearsed

Table 1. Multinomial regression model.

Attributes		Model I Coeff.	Model I Std. Err.	Model II Coeff.	Model II Std. Err.
Maintenance provider	Community	−0.57*	0.22	0.01	0.34
	Private sector	−0.19	0.32	8.92*	1.13
	Government	−0.75**	0.33	8.42*	1.13
Maintenance level (days to repair)	One day	1.48*	0.26	1.57*	0.37
	Three days	1.09*	0.24	0.98*	0.32
	Five days	0.37	0.24	0.12	0.32
	Seven days	0.24	0.25	−0.08	0.32
Payment mode	When handpump breaks	0.04	0.21	−2.17*	0.49
	Monthly	−0.38***	0.21	−2.88*	0.49
	Mobile money	−0.21	0.22	−2.54*	0.49
Payment level	Ksh 50 (USD 0.5)	1.37*	0.27	1.89*	0.32
	Ksh 100 (USD 1.2)	1.39*	0.20	1.70*	0.23
	Ksh 150 (USD 1.8)	0.74*	0.12	0.92*	0.14
Constants					
Household socio-economic status	C1. Respondent over 40 years old			0.89*	0.30
	C1. More than 5 people live in household			−2.21*	0.50
	C1. Top 20% of households by expenditure			−1.24*	0.37
	C1. Stores drinking water			−2.21*	0.33
	C1. Own donkey			−1.59*	0.27
	C1. Own pit latrine			−2.09*	0.37
	C1. Own hand-dug well			−1.34*	0.32
Handpump use behaviors	C1. Drinking water source in dry season			−0.89*	0.30
	C1. Livestock watering source in dry season			−0.82*	0.29
	C1. Main drinking water source			0.60**	0.28
	C1. Main livestock watering source			−0.96**	0.44
	C1. Treat handpump water before drinking			0.99*	0.33
	C1. Household pays for water from handpump			0.65**	0.28
	C1. Household satisfied with handpump services			−2.05*	0.53
	C1. Handpump used for more than 5 years			1.69*	0.38
Household socio-economic status	C2. Respondent over 40 years old			0.98*	0.29
	C2. More than 5 people live in household			−1.80*	0.50
	C2. Top 20% of households by expenditure			−1.33*	0.35
	C2. Stores drinking water			−2.01*	0.31
	C2. Own donkey			−1.49*	0.26
	C2. Own pit latrine			−2.35*	0.36
	C2. Own hand-dug well			−1.56*	0.31
Handpump use behaviors	C2. Drinking water source in dry season			−0.91*	0.29
	C2. Livestock watering source in dry season			−0.86*	0.28
	C2. Main drinking water source			0.72*	0.27
	C2. Main livestock watering source			−1.22*	0.42
	C2. Treat handpump water before drinking			1.00*	0.32
	C2. Household pays for water from handpump			0.71**	0.28
	C2. Household satisfied with handpump services			−1.79*	0.52
	C2. Handpump used for more than 5 years			1.71*	0.37
	Observations	3,540			
	Log-likelihood	− 1,112.84		− 935.47	
	Chi-square	93.75*		407.98*	
	Pseudo-R^2	0.136		0.259	

*1% level; **5% level; ***10% level.

finding is the importance of alternative water supplies in predicting likely engagement or payment in improving existing water supplies (World Bank, 1993).

These findings coincide with two of the three significant, cross-country determinants of handpump sustainability in Africa: (a) paying for water and (b) age of handpump (Foster, 2013). We did not test distance to nearest district center (proxy for spare-part access). Other factors tested but found to be non-significant included: household health expenditure, owning a water filter, perceiving handpump water as safe to drink, and two or more handpump failures in the last year. There is a significant and positive preference for maintenance improvements from water users who 'treat' water before drinking.

Despite households using older handpumps responding positively to change, those households who encountered two or more failures in the last year provided no significant signal. What was not measured in this study was the nature and cost of handpump failures. More expensive failures may be related to older handpumps, all things being equal, but without data on actual handpump use each variable is a partial vector across interacting components of (a) age of handpump, (b) pumping activity, (c) quality of handpump (all models were Afridevs but from a variety of manufacturers), (d) quality of technical installation, including well construction and lining, and (e) natural environmental conditions. The latter refers to variation and potential component stress from deeper (40 m) to shallower (5 m) groundwater resources as well as the underlying hydrogeological conditions, which may vary with more aggressive groundwater (lower pH), higher salinity levels and other naturally occurring but spatially distributed elements. Without understanding the interaction of environmental, technical and social conditions it is speculative to attribute handpump functionality to one dimension without data on the other two. What is indicated here is that as handpumps age, users are more likely to value and pay for improved maintenance services.

Over two-thirds of households (71%) stated that they stored drinking water with an average household capacity of 2.7 days in the dry season and 6.6 days in the wet season. While this coincides well with a demand for a 3-day maintenance service, this relationship proved to be negative in supporting handpump maintenance changes. Two factors help to partly explain this outcome. First, although three in five households who use the handpump as their main drinking water source also store water, two in five households are not using the handpump as their main drinking water source. In effect, an equivalent aggregate number of households are using alternative water sources as their main drinking water supply as households who use and store water from the handpump. Second, older respondents were less likely (52%) to store water than the sample average, which may partly explain their preference for more secure water supplies.

A correlation matrix of socio-economic and handpump behavior data reveals how handpump use and wealth socially differentiate the sample (Table 2). The wealthy (top 20% by expenditure) are larger households who use the handpump as their main drinking water source pumping less per capita but are positively associated with paying for water. The poorer (bottom 20% by expenditure) are smaller households pumping more water with a negative but non-significant association with payment. Smaller households tend not to use the handpump as their main drinking water supply. If the handpump is the main drinking water source there is a higher satisfaction associated with lower health expenditure per capita. Finally, livestock owners (cattle or donkey) are negatively but not significantly associated with using the handpump as their main water supply; this contrasts with a strong positive association between households who use the handpump as both the main drinking and livestock water source. The poverty implications of these interactions suggest that poorer and smaller households rely heavily on handpumps (by higher pumping per capita) but struggle to pay for water, which contributes to using

Table 2. Correlation matrix of selected socio-economic and handpump use variables ($n = 118$).

	MDWS	MLWS	PCWP	Pay	Store	Treat	Satis	Well	Size	B20%	T20%	HH size	Health	Cattle	Donkey
Main drinking water source (MDWS)	1														
Main livestock water source (MLWS)	0.387**	1													
Per capita water pumped (PCWP)	0.135	0.074	1												
Pay for water (pay)	0.103	0.073	−0.070	1											
Store drinking water (store)	0.040	0.085	−0.120	0.112	1										
Treat water before drinking (treat)	0.010	−0.087	−0.047	0.065	0.213*	1									
Satisfied with handpump (satis)	0.327**	−0.019	0.043	0.127	−0.090	−0.082	1								
Own well (well)	−0.006	−0.040	−0.076	0.399**	0.059	0.251**	−0.139	1							
Household size (size)	0.175	0.047	−0.140	0.229*	0.067	−0.021	0.126	0.083	1						
Bottom 20% expenditure (B20%)	0.131	−0.100	0.302**	−0.107	0.067	−0.021	−0.001	−0.056	−0.229*	1					
Top 20% expenditure (T20%)	0.231*	0.146	−0.260**	0.106	0.029	−0.017	−0.009	0.042	0.417**	−0.316**	1				
Household size (size)	−0.201*	−0.135	−0.013	−0.061	0.210*	0.132	−0.113	−0.070	−0.158	0.234*	−0.058	1			
Top 20% health expenditure (health)	−0.336**	−0.015	−0.046	−0.068	−0.044	−0.006	0.055	0.105	−0.166	−0.052	−0.056	0.127	1		
Own indigenous cattle	−0.075	−0.016	0.170	0.021	−0.115	−0.215*	−0.036	0.027	−0.053	−0.008	0.001	−0.061	0.068	1	
Own donkey(s)	−0.097	−0.027	0.107	−0.131	0.007	−0.232*	−0.046	−0.077	−0.193*	0.011	0.090	0.021	0.155	0.417**	1

**Significant at the 1% level; *significant at the 5% level. Expenditure and household size adjusted by adult equivalent scale. All 'water' relates to handpump use.

alternative drinking water sources associated with higher health expenditure. Given the choice, modeling indicates resistance from wealthier households to new maintenance arrangements and this presents an important socio-political challenge in navigating the positive preferences for improved services but differentiated levels of support across livelihood groups within communities.

4. Discussion

These findings, though exploratory in nature and narrowly focused on a sample of handpumps in rural Kenya, reflect wider concerns and debates about the efficacy, acceptability and sustainability of community management of handpumps across Africa. Three policy implications emerge with respect to the global goal of accelerating progress toward universal drinking water security. First, community management of maintenance services is the least preferred option. Second, financial sustainability of rural water supply systems is contingent on major operational efficiency gains. Third, operational performance requires more advanced monitoring systems that reduce information asymmetries between donors, government and water users.

4.1. Do communities want community management?

Water user choices unambiguously identify community management of maintenance services as the least preferred option. The implication is not that community management is irrelevant but that risks and responsibilities in water service delivery could be more effectively allocated. Maintenance responsibility is commonly assigned to community water users. However, fixing handpumps depends on (a) having sufficient money for spare parts and a mechanic, (b) being able to access spare parts promptly, and (c) an available and competent mechanic. An external maintenance service provider with an agreed service level (3 days or less) based on prepaid contributions provides a mechanism for the water users to retain control by local specification of an agreed service level at an acceptable cost. In many ways, this enhances community management by giving them a clearer choice in service levels at an affordable cost.

4.2. Financial sustainability is contingent on operational improvements

The modeling results indicate that user payments are contingent on a vastly improved operational performance with an order of magnitude improvement from over 27 days down-time to 3 days or less. Kyuso respondents appear to be ‘rational’ economic agents in preferring lower to higher user fees. With median annual household expenditure of USD 313, a monthly fee of USD 1.2 would represent 4.6% of annual expenditure. Current payment behavior has just over half of all households (56%) paying some form of fee (per bucket, livestock, monthly, when handpump breaks). Over half (54%) pay on a monthly basis of whom over half (57%) pay USD 0.6 or less. This provides a provisional basis for user fees funding operational improvements though more empirical data are required to substantiate the case.

A key uncertainty of financial sustainability is implementing a payment modality that is acceptable to users with low transaction costs. Choice modeling results indicate that none of three tested alternatives were positively endorsed by users. This presents a significant barrier to financial sustainability as the ability to deliver a high quality, low-cost maintenance service will be geared to pooling risks at scale to reduce operational costs (Hope *et al*., 2012). While communities support a scalar model there is resistance to existing payment modes (per bucket, monthly fee) and emerging alternatives (mobile money). Despite the study sites being low-income and remote, 85% of households own at least one mobile phone with 73% using mobile money on at least one occasion. This suggests that mobile water payment has the potential to be a low-cost, inclusive and flexible payment mode though the evidence from the urban water sector suggests caution (Foster *et al*., 2012). Prepaid mobile water payments have been successfully introduced as part of the LIFELINK rural water delivery system in many parts of Kenya, which demonstrates user acceptability linked to guaranteed water services. Without resolving how rural water users can securely prepay, it is unlikely that any sustainable operational system will function without significant external support and subsidies.

4.3. Improved monitoring to reduce information asymmetries

If policy design and investments are to achieve sustainable development outcomes, the quality and frequency of measurements need to improve. Reliable water services require objective measurements of daily functionality of water services. Measuring the frequency and length of handpump down-time is critical to generate metrics of water service days per unit of investment. While respondent recall data are notoriously error-prone and subject to bias, the Kenya data provide some guidance in terms of the nature and scale of performance and measures to improve future design. Where measurements are flawed or absent, policy and donors may shift from measuring value to valuing measurements (Molle & Mollinga, 2003). This shift may be imperceptible and unintentional but lead to policy and investments evading deeper scrutiny against goals to improve water supply access for tens of millions of people without any commitment to guarantee water services over time (Moriarty *et al*., 2013).

The wider challenge in delivering sustainable maintenance services is an institutional design that avoids fragmentation and cannibalization from multiple competing models, initiatives and investments. A universal and reliable service delivery approach should be conceived of at scale so those more able to pay are not siphoned off by private sector models that make the case for helping the poor even less viable. Findings here illustrate that the poorest are more dependent on handpumps for water but less able to pay. Using handpumps is associated with lower health expenditure, which is a positive externality desired from public investments in water supply systems. The non-discriminatory nature of the human right to water established in Kenyan Water Law reinforces the need and opportunity to more energetically explore scalar models of maintenance service provision with clearer demarcation of risks and responsibilities. This study finds communities positively disposed for alternative institutional arrangements for maintenance service delivery where the community is able to choose a desired service delivery level at an acceptable cost. However, no acceptable payment mode is found from the alternatives tested. Without financial sustainability supported by community payments, no viable maintenance service model will emerge. The case for public support or donor underwriting to ensure financial risks are smoothed at scale is plausible given widespread use globally (Hope & Rouse, 2013). Kenya's Water Services Trust Fund is a funding mechanism designed explicitly for this purpose. Accountable monitoring of operational and financial performance is equally a necessary condition for institutional sustainability. Major advances in remote monitoring of rural handpumps have recently been made (Thomson *et al*., 2012; Thomas *et al*., 2013), which could be harmonized with mobile payment systems in building a new architecture of rural water service provision.

5. Conclusion

Accelerating progress to achieve universal drinking water security in rural Africa requires revised policy and investment approaches. The evidence illustrated here is that rural water users have a more expansive view of alternative maintenance systems than currently prescribed by governments and donors. Without financial sustainability through full or part cost recovery from rural water users, no institutional alternative will emerge or be sustained. Rural water users express a positive preference to pay for more rapid maintenance services though payment behaviors are not uniform within communities, nor is any current payment mode acceptable. Understanding and addressing the financial architecture of user payments from remote and poor rural water users are fundamental to progress from a community maintenance model clouded in rhetorical benefits and anecdotal impacts to objective and output-based alternatives. Monitoring systems that harness Africa's mobile network architecture provide new pathways to enhance accountability and measure performance in the design and delivery of rural water investments to lay lingering words of warning to rest (Falkenmark, 1982).

Acknowledgements

The research was financially supported by the UK Department for International Development (Smart Water Systems, R5737) and the Economic and Social Research Council (New Mobile Citizens and Waterpoint Sustainability in Africa, R23715). Rural Focus Ltd (Kenya) supported the data collection and Jacob Katuva created the map. Usual caveats apply.

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Received 26 August 2014; accepted in revised form 4 November 2014. Available online 22 December 2014